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SYLVAN HARRIS, EDITOR

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THE CARBON SITUATION AND COPPER CONSERVATION*

E. A. WILLIFORD**

The meeting of the Atlantic Coast Section of the Society on May 21st was devoted to the question of "Wartime Conservation in Theater Projection." The paper that formed the basis of the meeting has already been published, in last month's issue of the JOURNAL.

At the end of the presentation, the following discussion, on the carbon situation and the conservation of copper, was contributed by Mr. Williford.

I appreciate your request that I tell you something about the carbon situation. Fortunately, the basic materials for the manufacture of projector carbons are petroleum products, of which ample supplies are available. We do not see any possibility of there being any shortage of these materials.

For high-intensity type carbons, however, certain rare-earth minerals are used to produce the brilliant white source of light, and these rare-earth materials have been supplied principally from India.

Before America entered the war there was several years' supply of this material in the United States and, according to my latest information, there is still several years' supply here. More is coming in as shipping facilities are available. Brazil also contains large deposits of these minerals which could be used if the Indian source is cut off. There are even deposits of this material in the United States, although the costs of obtaining it would be quite high as compared with Indian costs, or even Brazilian costs. In any event, there does not appear, at this time, to be any prospective shortage of these rare-earth minerals.

For "Suprex" carbons, high-intensity negatives, and a few other types of projector carbons it has been necessary to curtail our use of copper in the copper plating. As you know, the war needs for copper are greatly in excess of any visible supply and it is up to every

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* Presented at the meeting of the Atlantic Coast Section at New York, N. Y., May 21, 1942.

** National Carbon Company, New York, N. Y.

one of us to do all we can to use as little copper as possible, and to salvage every bit that we can.

For some months now we have been using our advertising space to promote the idea of burning carbons at lower current, peeling the copper plating from any butt ends remaining, and saving the copper drippings from the lamp-houses. Many projectionists have been doing this and, in accordance with War Production Board instructions, have turned these peelings and drippings over to scrap dealers, even though the value might be so small that they receive no compensation in return.

In our own Research Laboratories intensive studies have been given to reducing the amount of the copper plating, and also eliminating it entirely, if possible. For the moment, we are producing thinner plated carbons, and as of today, our stocks of the 6.5-mm × 9-inch Orotip "C" negatives of the older standard plating thickness type have been exhausted. Within a few days all other types of carbons with the standard plating will, likewise, be out of stock and shipments thereafter will be of the new thinner plated variety which we have called Victory carbons.

The industry is extremely fortunate in that some of our research program over the past few years culminated very recently in the development of a new 8-mm diameter "Suprex" positive. Even with the Victory plating, these carbons will give the same light on the screen as the old carbons with 5 amperes less current and with approximately 20 per cent saving in carbon consumption. At 65 amperes, which is the maximum current for both the old and the new Victory carbons, the screen light is considerably greater and the carbon consumption also is considerably less.

In the case of the 7-mm positive—6-mm negative combination, it will be necessary to reduce the current on these carbons with resulting loss in screen light. The amount of this reduced illumination is only about 15 per cent, however. If the power source can be operated at 56 amperes and the new 8-mm—7-mm trim used, the same screen illumination can be obtained with a saving of about 30 per cent in carbon consumption, but at an increased power consumption of approximately 12 per cent.

These new carbons will be marked with white ink to distinguish them from the standard product which has been labelled with blue ink. The maximum permissible current will be printed on each carbon beside the trade-mark. The unit carton will have a special label indicating not only the maximum allowable current for the type of carbons contained in the package, but also showing the weight of copper drippings that can be recovered from the lamphouses, from a package of 50 such carbons. This weight has been carefully calculated, based on the minimum thickness of copper plating applied, and allowing for about 10 per cent loss through carelessness in handling. It represents what can be readily salvaged and unless or until the government advises you otherwise, we suggest that you save these drippings and any peelings from the butt ends of carbons until you have a quantity sufficient to give or sell to a scrap dealer. At the present time government regulations do not permit you to dispose of this copper scrap to any other person. The copper plating on the new Victory carbons is so thin that it is doubtful whether any plating remaining on the stubs can be salvaged. On the other hand, by the use of carbon savers, all carbons can be burned to stubs of not over 1 inch in length, in which case the amount of copper thus lost will be very small indeed.

We are glad to have been able to make this constructive change in the interests of copper conservation for the promotion of our national war effort and know that each of you will coöperate in this program of copper conservation, even though it may mean extra work and some inconvenience to you in your daily job.

EXPERIENCES IN ROAD-SHOWING WALT DISNEY'S FANTASIA*

WILLIAM E. GARITY** AND WATSON JONES†

***Summary.**—A discussion of the various problems encountered in the road-showing of "Fantasia" with the multiple-track Fantasound equipment. The experiences and conditions encountered are presented as a guide for the further development of this very important field. It is expected that this system will add greatly to the dramatic presentation of pictures and will, in some form, replace our sound-reproduction systems.*

Fantasia was the result of an idea that grew over a period of three years from a "standard" one-reel "short" to a multi-million dollar road show that required the largest outlay of sound equipment that has been used commercially in the theater to date. Many new methods and procedures were found necessary to achieve the results that were desired for the final product. These new methods and procedures applied not only to the sound technic but the pictorial aspect as well. In order to appreciate fully the amount of artistic and engineering work that was expended on Fantasia it is interesting to review some of the highlights of our experience over a period of about three years prior to the première of the picture in New York on November 13, 1940.

During the latter part of the year 1937 Walt Disney conceived the idea of making a cartoon "short" using as a basis some well known musical selection that lent itself to cartoon animation. A serious effort was made to interpret the composer's musical ideas pictorially as well as to record music that would blend into the picture and provide a combined, indivisible form of entertainment. The *Sorcerer's Apprentice* was chosen for the original, and was recorded in January, 1938, by 100 musicians conducted by Leopold Stokowski.

The *Sorcerer's Apprentice* was recorded at the Pathè Studio, Culver

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* Presented at the 1942 Spring Meeting at Hollywood, Calif.; received May 1, 1942.

** Walt Disney Studio, Burbank, Calif.

† RCA Manufacturing Co., Hollywood, Calif.

City, Calif., on a production stage that was altered acoustically for the occasion. Our theory was to make a multiple-channel recording that would have satisfactory separation between channels so that suitable material would be available from which to obtain any desired dynamic balance in re-recording the original material. In the effort to obtain satisfactory separation between channels, a semicircular orchestra shell was constructed in the stage. The shell was then divided into five sections by means of double plywood partitions. Two difficulties were encountered with such a set-up; one was poor low-frequency separation; the other was the inability of the musicians at the rear of the sections to hear the music from the other sections, to such an extent the tempo was impaired. This condition was improved, at a sacrifice in separation, by having the musicians move nearer the front of the shell sections. As work progressed on the animation and re-recording of the material, Walt Disney decided to add other musical selections and to present a full-length presentation that would be outstanding in its scope. It was at this time that discussions first took place regarding special equipment for the showing of the picture. The goal that we hoped to reach was the reproduction in the theater of a full symphony orchestra with its normal volume range and acoustic output as well as the illusion that would ordinarily be obtained with a real orchestra. Many ideas were investigated, equipment was designed, and tests made of various combinations of equipment that would give the ultimate in a sound and picture entertainment. For a further description of these investigations the reader is referred to a paper on "Fantasound" by Garity and Hawkins in the August, 1941, JOURNAL.

The best combination of music and recording conditions was desired for the additional selections, and it was decided therefore to abandon the *Sorcerers* set-up and to record the Philadelphia Orchestra in the Academy of Music in Philadelphia. This decision had two points in its favor; one being the fact that the acoustic properties of the Academy are excellent, and the second being that this orchestral group has been organized for many years and their musical talent is rated as one of the highest. At the time of the decision to do the recording at Philadelphia it was not known exactly what the music requirements would be in order to achieve the dynamic and musical balance necessary to the picture story being told. So that this requirement might be fulfilled in the re-recording of the original material, a multiple-channel recording was made and it was, of course,

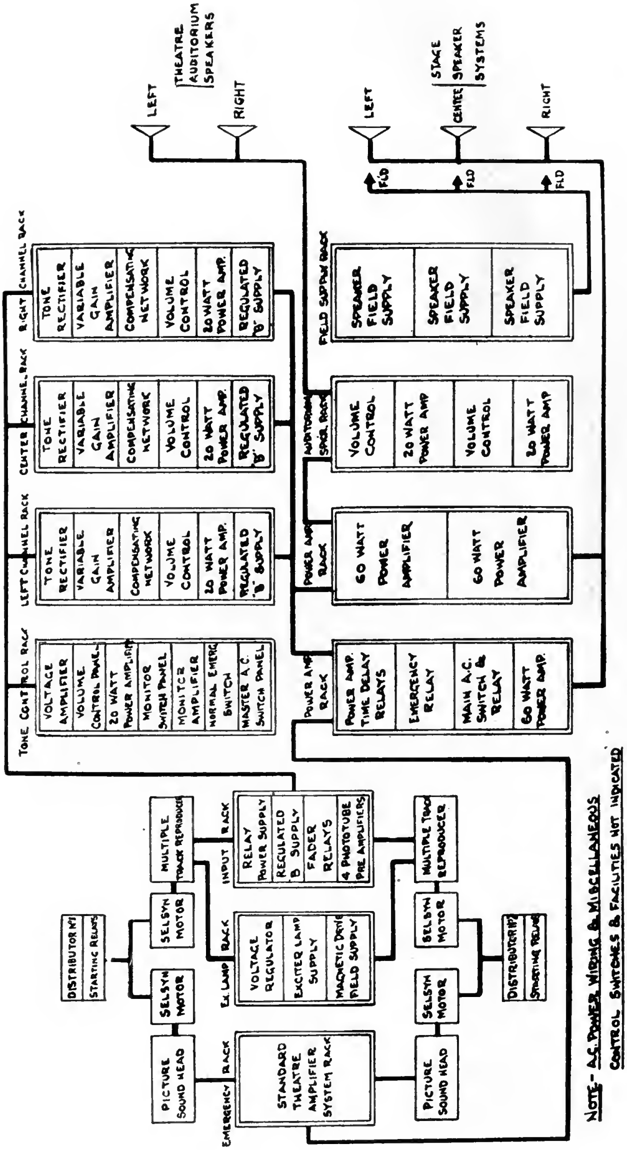

FIG. 1. Block diagram of Fantasound road-show unit.

necessary to install nine studio-type recording channels in the Academy.

The recording machines were located in the Academy basement, and since the inside of the building is constructed of wood, many safety measures had to be taken. No more than eighteen rolls of raw stock were allowed in the Academy at one time, and in order to insure a sufficient quantity of film for each recording session, a film-delivery truck was converted into a suitable loading room and was parked outside the building during recording sessions. All loading and unloading was done in this truck. The work of installation and recording was supervised by the authors, who spent the entire spring of 1939 in the Academy basement.

FIG. 2. Installation in the Carthay Circle Theater, Hollywood.

EQUIPMENT PROBLEMS

To appreciate fully some of the problems encountered in the design of the road-show units it is necessary first to see what constitutes a complete unit. Each Fantasound road-show equipment consisted of sound reproducers, amplifiers, and loud speakers so arranged as to reproduce sounds from a multiple sound-track film run in synchronism with the picture film. The level and distribution of sound to the various stage and auditorium loud speakers was automatically varied in a predetermined manner by means of the control-tone and program sound-tracks on the multiple sound-track film. Fig. 1 is a block diagram of the Fantasound equipment as used for the reproduction of *Fantasia.* This system consisted of three separate program amplifier and loud speaker channels, and a control-tone channel; two selsyn-operated multiple sound-track reproducers; two selsyn-operated sound-heads; two selsyn distributors; three two-way stage loud speaker systems; auxiliary theater auditorium loud speakers; and amplifiers and necessary operating facilities. Fig. 2 shows the equipment as installed in the Carthay Circle Theater, Hollywood.

Power Supply.—All equipment was furnished for 60-cycle power. The amplifiers and power-supply units required 110–125-volt single-phase current; the selsyn distributor 220 volts, three-phase. Where power fulfilling these requirements was not available, the necessary rotating equipment or transformers were supplied for the particular job. In order that the line-voltage variations would have the least effect upon the sound output level, the a-c input voltage to the exciter-lamp supply was regulated, and regulated supplies were employed to furnish plate power for the variable-gain amplifiers and tone rectifiers, and polarizing voltage for the phototubes.

Stage and Projection Room Space.—Due to the fact that each road show unit consisted of eleven 62-inch racks of amplifiers and power-supply units, in addition to the other items indicated in Fig. 1, there existed quite a problem in finding space in the average theater for the various items. The wiring and operating facilities of the equipment were so arranged that it was necessary to install a minimum of six racks in the projection room in addition to the two multiple sound-track reproducers. This was further complicated by the fact that many theaters available and suitable for road-show attractions generally did not have much of a projection room, if any. Power-switching facilities were contained in one of the racks installed in the projection room so that the additional five racks could be mounted outside the projection room if space was not available therein. The two selsyn distributors on which were mounted the necessary starting and remote-control devices were located outside the projection room where conditions permitted. The speaker-field supply rack was so arranged that it could be mounted on the stage proper, near the loud speakers, in order to conserve wire runs; however, in some theaters this was not advisable due to the differences in local rulings as to whose duty it was to turn on and off the power to the rack. Space behind the picture screen was generally available for the loud speaker systems. The screen had to be moved up or down stage in many theaters in order to get the best distribution of sound. The three loud speaker systems required an average width of 44 ft, and it was always necessary to change the masking draperies on either side of the screen in order to obtain satisfactory sound transmission from the side loud speakers.

Inter-Apparatus Connections.—The model road-show unit that was first manufactured made use of Cannon-type plugs and fittings for all inter-apparatus connections. Due to the large number of cable connections necessary, it was impossible to have a different type of plug for each circuit, and there was always the possibility and hazard of plugging a cable into the wrong position, with resulting damage to equipment. After a nation-wide survey of city inspectors concerning the use of rubber-covered cables and plugs on equipment located in projection rooms in a theater on a road-show basis, we found there existed many rulings, some definite and others rather vague. Some city inspectors would agree to the use of rubber-covered cables provided the show did not run longer than thirty days or so. Others would not agree to rubber-covered cables in the projection room on any condition. In one installation no exposed conduit was permitted, due, no doubt, to a safety measure as well as a "projection room beautification program." For the foregoing reasons all cables and plugs were eliminated and Greenfield or rigid conduit was used for all installation wiring.

Emergency Features.—Since this was a major project so far as the amount of sound equipment to be used was concerned, and it was to be a "two-a-day" show with road-show prices, some emergency feature was desired in case of failure of the Fantasound system. In case of failure of the control-tone variable-gain part of the system, switching facilities were provided whereby the control-tone section could be by-passed and the three program channels could operate with the volume range that existed on the program tracks themselves. This still involved the use of a large percentage of the equipment, and further simplification of the emergency feature was thought desirable. The sound-track on the picture film was a standard variable-area composite of the sound material that was located on the three program tracks of the multiple-track film. By means of one switch which actuated a relay system, the sound was transferred from the Fantasound set-up to the emergency channel, making use of the standard sound-track on the picture film, the emergency amplifier, and the center-stage loud speaker. Theater experience proved that the equipment was very reliable, and even though the number of component parts in the road-show unit was many times that of a standard theater set-up, the number of sound outages were no more than is experienced in a standard theater. The sound outages that did occur were caused in the majority of instances by operating failure rather than equipment failure. Such successful performance with the large quantity of equipment involved indicates the high degree of perfection that has been reached in present-day engineering and manufacture of theater sound equipment.

Audio Power Requirements.—The success of any high volume range reproduction depends greatly upon having equipment with sufficient undistorted power-handling capacity. The Fantasound equipment has three 60-watt amplifiers for the stage speakers. This proved satisfactory for the majority of installations; the New York unit used additional power. The full capacity of the system was usually reached on peak levels during the performance.

Equipment Testing and Program Level Adjustments.—The experimental work on the multiple-channel reproducing system indicated that slight differences in level between channels would give the effect of motion of the sound from one loud speaker to another. For this reason we found it necessary to provide facilities for readily checking the levels of the channels in order that the sound-perspective at the time of reproduction would be the same as intended during the rerecording of the picture. A portable-type bridging input amplified volume-indicator having a range of −50 to +40 db (6-mw reference level) was provided for making all measurements. Multiple-track test-films and film-loops were used for making such measurements as level balance, gain-change characteristics, push-pull balance of the sound-track, and frequency response. Bridging jacks only were used at points in the circuits where routine measurements were to be made. Switches were so connected that resistance loads could be substituted for purpose of measurement. Vacuum-tubes having any bearing on the characteristics of the control-tone variable-gain section of the system were aged, balanced, and matched. This simplified the work for the field personnel in the routine maintenance of the equipment.

Operating Features.—The routine show-operating details were kept as near to standard theater practice as possible; however, due to the use of a selsyn motor system and separate film reproducers, there did exist some difference in operating technic. There were three stations for the operating of the sound-control and motor systems. The motor controls for the selsyn system were operated by a sequence-switching arrangement that was quite foolproof. Suitable pilot-light indicating devices were employed for all control stations, and change-overs could be made from any station at any time. It was general operating practice to allow the selsyn motor on the picture machine and the multiple-track reproducer to remain "in lock" during the entire show, and because of this very little trouble was experienced from "out-of-sync" conditions. The power circuits were so designed that the entire system could be turned on by one switch, and during normal operating times such was the practice.

Manual switching was provided for monitoring the tone or program channels individually. This was fairly satisfactory with the exception that the volume range of the recording was too great for projection-room monitoring. With any reasonable adjustment for satisfactory high-level sounds it was impossible to hear the low-level sounds over the machine noise. Future equipment should be designed with a volume-compressor stage in the monitor amplifier and possible means for monitoring the combined channels.

Shipping Facilities.—All equipment was shipped from the factory in caravan packing units. Such packing facilities would no doubt have been satisfactory for the transfer of the equipment between installations. The weight of a complete Fantasound equipment was approximately 15,000 lbs; it was packed in forty-five cases and required one-half of a standard freight car space.

The following information was obtained from eight Fantasound installations, and indicates the general conditions that were encountered. Six of the installations required that a new or a larger capacity three-phase service be run to the projection room. The majority of the six were new services, as no old services were available. In some theaters adequate single-phase power was not available in the projection room. Such additional power-line runs to the projection rooms were always costly and time-consuming. In three of the theaters it was necessary to enlarge the projection room, as sufficient space was not available for all the equipment nor was there space nearby that could be used. This item made a large increase also in the installation cost. As a general rule the projection rooms encountered were poorly arranged and too small for a first-class installation of the entire equipment. It must be remembered, however, that these theaters were not usually first-run motion picture houses, but were theaters that could be engaged for such a road-show project.

In some of the earlier installations the right and left stage speakers were placed as far out to either side as conditions would permit. Preliminary tests indicated that this was undesirable, as there was an objectionable sudden movement of the sound when shifted from one loud speaker to another. The condition was corrected by moving the side speakers nearer the center by such an amount that a smooth transition occurred when the sound was shifted from one speaker to another. The correct separation of the theater stage speakers for obtaining a sound illusion similar to that obtained at the time of re-recording depends to a certain extent upon the general acoustic properties of the re-recording monitoring room and the location and spacing between the monitor speakers. Due to the fact that the Disney re-recording monitoring room is a 600-seat theater of average theater acoustic properties, it was more or less an easy matter to anticipate the final results.

The normal undistorted audio-power output of the equipment was 220 watts, which proved satisfactory for most theaters. In the Broadway Theater (New York) the power was increased to 400 watts and three additional loud speaker systems were added to the stage complement to handle the additional power.

The music and the control-tone tracks for *Fantasia* were re-recorded with the idea that a certain volume-range could be used in the theater showing the picture. This volume-range as chosen, which consisted of a 40-db control-tone range and a 30-db range on the music tracks, was found to be greater than could be tolerated in the theater. It was general practice to use the high-level section of the music as the point at which the gain-controls were set for the correct level. If the low-level portions of the music were below the theater noise-level, the volume-range was reduced by changing the ratio of the control-tone level to the variable-gain amplifier output. The music was re-recorded with a one-to-one ratio; however, in some theaters it was necessary to use a ratio of eight to five. This means of controlling the volume-range of sounds that have already been recorded was found to be very useful and necessary for the successful presentation of the picture. The best audience reaction to the high-level musical passages occurred when the level was at a certain value, which varied from theater to theater and was determined by trial and error. A decrease of 2 db in this level resulted in a decided "let-down" of audience reaction as the "thrill," or "punch" was lacking.

Conclusions.—The outstanding success of *Fantasia* in its limited number of runs with Fantasound has demonstrated the value of this means of increasing the dramatic value of a picture.

There were three primary reasons for the discontinuance of the use of Fantasound:

(*1*) The amount of equipment required and the time necessary to make the installation.

(*2*) Because of the time element attractive theaters were not available to us, as the first-class houses in the various communities had established policies and the installation of the equipment would generally require darkening the house for a few days.

(*3*) The advent of wartime conditions precluded the possibility of developing mobile units that would have lessened installation time and costs.

(*4*) The variation in the regulations throughout the country, both as to operating personnel and local ordinances, materially affected the operating and installation costs.

(*5*) Space factors of the projection room in particular were problems of major importance.

We are convinced that, with greater simplification of equipment in keeping with the available space in the theater, the elimination of the separate selsyn sound-track reproducer, and the combining of the multiple-track on the composite print, future sound reproduction will employ multiple-track reproduction with automatic volume control, and, something that was not used in Fantasound, the automatic change of frequency-response with volume. We can only express our own opinions and the opinions of those who worked with this equipment; *viz.*, having used the multiple-track system, no matter in what form, the ordinary sound-track reproduction is flat and dull by comparison. We can not say what the problems of original recording would be for the live-action producer. We can assume they will be many and various, but we are sure that with study and ingenuity they can be overcome, and the final results will be worth while.

THE FUTURE OF FANTASOUND*

EDWARD H. PLUMB**

Summary.—*A non-technical discussion of Fantasound from the musician's point of view. The use of Fantasound is reviewed as a basis for discussing ways in which it can be used in the future.*

Fantasound has been demonstrated to the public only in Walt Disney's *Fantasia*, but to accept or reject Fantasound on the basis of its use in that picture would be unjust. *Fantasia* is a remarkable showcase for an experiment in sound engineering because it uses music as a vital function of the picture. However, the dramatic effectiveness of Fantasound was limited by three conditions peculiar to this production.

(*1*) During its actual picture footage *Fantasia* uses only music on the sound-track. This eliminates the possibility of placing and moving dialog or sound-effects in the multiple speaker system that Fantasound includes. Dialog and sound-effects are the "real" sounds of the movies with which the audience is thoroughly familiar. Because of this familiarity it is quite possible that the location of these sounds in the theater could be more easily registered than the placement of musical sounds.

(*2*) The music that *Fantasia* interprets was conceived long before sound-film was available for use. The compositions were designed for concert performance and were so well designed for that medium that any orchestral changes made to improve reproduction greatly affected their basic character.

(*3*) The original recording of the entire orchestral performance of *Fantasia* had been completed before it was known what dimensional effects would be available in the theater. It was thus impossible to guess what method of recording would be most efficient for reproduction in Fantasound.

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* Presented at the 1942 Spring Meeting at Hollywood, Calif.; received May 1, 1942.

** Music Department, Walt Disney Studio, Burbank, Calif.

This is in no sense to be interpreted as an apology for *Fantasia* or the methods used in it. It is merely a description of certain obstacles that would not be confronted in the usual feature.

The future of Fantasound depends upon the efficiency with which the original sound material can be transferred to film and upon the dramatic effectiveness of the total result. These related factors dictate the future of Fantasound because they represent, respectively, the expenditure necessary and the expenditure warranted by box-office returns.

Before suggesting a method of recording an orchestra that might be practicable for future productions in Fantasound it seems advisable to describe briefly the method employed in *Fantasia*. During the original performance, each of six sound cameras recorded the close pick-up of a particular section of the orchestra. A seventh camera recorded a blend of these six close pick-ups, and an eighth recorded a distant pick-up of the entire orchestra.

In preparing the final re-recorded track from this original material several weaknesses became apparent. Because of acoustical pick-up the separation between the six sections of the orchestra was merely relative. In the material on the woodwind channel, for instance, the woodwinds usually predominated, but material from other sections of the orchestra was definitely present. Many times, because of differences in performance level, the material from adjacent sections would be as loud as, or louder than, the woodwinds directly picked up. This lack of complete separation was not an insurmountable obstacle in creating an artistic balance for ordinary reproduction, but it greatly limited the dramatic use of orchestral colors in Fantasound. If we wished, for dramatic reasons, to have a horn call emanate from a point to the right of the screen, our purpose would be confused by hearing the same call, at a lower volume, on every other speaker in the theater. Greater separation in the original recording could have been achieved only by greater segregation of the sections or by moving the microphones closer to the individual instruments. To go any further than we had gone toward segregation of sections or close pick-up would have impaired quality of performance in one case and recorded tone quality in the other. On the point of efficiency of the *Fantasia* recordings we must observe that only one-third of the material recorded on chosen performances was used in the final dubbing. The unused film contained sound that was too repetitious of other channels, too poor in quality, or, during long sections, too unimportant in the design of the composition to help the total result.

Since the completion of *Fantasia* we have recorded orchestral performances of five compositions for possible use in Fantasound. It is not likely that these can appear as productions for a long while, but the method that was used may provide a possible approach to future Fantasound projects. The recordings were much less expensive and, there is every reason to believe, can be much more effective dramatically than the *Fantasia* recordings. We concentrated upon the achievement of two qualities of Fantasound that seem to us to be important—the illusion of "size," possible to attain by proper use of a multiple-speaker system, and recognizable placement of orchestral colors important to the dramatic presentation of the picture.

For the illusion of "size" or "spread," we used a three-channel recording set-up. Channel *A* was fed by a directional microphone far enough from the instrumentalists to cover the entire left half of the orchestra. Channel *B* recorded the right half of the orchestra. Channel *C* recorded a distant pick-up of the entire orchestra. This three-channel system recorded the "basic" tracks of the composition. It is important to note that in planning the material for these "basic" tracks any orchestral color or passage for which we might have special dramatic use was omitted from the performance. The recording of this special material will be described later.

In reproduction over the Fantasound system this method of recording the basic tracks has great flexibility. To regain the natural spread of the orchestra, the *A* channel (left half of the orchestra) appears on the left stage speaker, the *B* channel (right half of the orchestra) appears on the right stage speaker, and the *C* channel (distant pick-up) appears on the center speaker. The distant pick-up appearing in the center adds an illusion of depth which is beneficial and also provides a more practical "cushion" for the solo instruments or other special material that would normally appear in the center. The "panpot" (described by Garity and Hawkins in the August, 1941, JOURNAL) can execute practically any variation of this reproduction plan that could be demanded. Each track can appear on any one stage speaker, any two stage speakers in whatever balance desired, or on all three stage speakers in any balance. The house speakers can be added to the left and right stage speakers in whatever set balances desired, or they can replace the left and right stage speakers so that sound comes only from left and right house and center stage (as in "Ave Maria" in *Fantasia*).

In the recording of what I have termed special material—material whose location it is important to register—we employed the only method that assures absolute separation. The section of the basic track with which the special material is to synchronize is used as a playback on earphones available to conductor and instrumentalists. The physical difficulties of this method can be minimized by careful planning of the orchestration. It is usually possible to avoid the occurrence of the same melodic passage or rhythmic pattern in both the special and basic material. This makes synchronization less critical and also allows more freedom in performance of the special material. As advantages, the playback method offers complete control of the volume relationship between special and basic material; complete freedom in locating or moving the special material; and freedom to choose the pick-up, in recording the special material, that produces the finest quality in reproduction.

As an example of the use of the playback method, in *The Swan of Tuonela*, by Sibelius, there is an English horn solo that is vitally important in the design of the composition. We knew that this English horn should be a principal actor in dramatizing the score. We had recorded the composition played by the complete string orchestra omitting, among other instruments, the English horn. We then recorded the English horn alone, using the performance by the strings for the playback. A relatively distant pick-up was used, which gave the tone of the English horn brilliance, but also lent a feeling of mystery in character with the subject. Because of the complete separation achieved it is possible to submerge the solo in the rest of the orchestra or to make the solo stand out in a clear relief physically impossible to attain in concert performance. The solo can locate as its source one of the three stage speakers or, by balancing its volume between two speakers, can seem to locate a definite point between them. The solo can come from the left or right unit of house speakers without the stage speakers or, if power or diffusion are desired, can come from every speaker in the theater. The solo can move in such a way that it seems to follow the pattern of a pictorial effect; it can change from offstage to onstage; or it can change its source, by a smooth, irregular movement of the panpot dial, so that it seems to float through the theater. I have mentioned a single composition and only a few of the effects possible. However, it is clear that the restrictions offered by this tentative method are infinitely less than those offered by the method used for *Fantasia*. (The *Fantasia* score contained only one example of complete separation—the solo voice and chorus of "Ave Maria" were recorded by the playback method to an orchestral accompaniment recorded a year and a half before. The vocal performance of "Ave Maria" was the last material to be recorded for *Fantasia*, and we were able to use everything Fantasound had to offer. It is interesting to note that for many of those in the audiences—at least in New York and Los Angeles—Fantasound was "turned on" only for "Ave Maria.")

The advantages of volume range are probably more obvious than the advantages of other features of Fantasound. To be able to use the upper volume range without distortion and the lower range without submerging the tone in ground-noise has been the dream of every dramatically minded sound-director since the advent of sound reproduction. Experience shows us, however, that this greatly extended volume range still has important natural limits. If sound is reproduced so low that it is unintelligible or so high that it causes physical discomfort, there must be adequate dramatic reason. Either extreme is likely to irritate.

Dialog and sound-effects, as material for use in Fantasound, have one decided advantage over music. They do not have to be recorded differently from the customary recording of ordinary sound. Their placement, movement, and extended volume range are all accomplished after they are normally put on the film.

Dialog is the only sound medium in whose reception the audience has been well rehearsed. The average member of the audience has heard the sounds that the screen sound-effects imitate, but he does not ordinarily analyze their character or location with any great care. He has listened to music but, perhaps wisely, he does not bother himself with the details of its complex pattern. In the reception of speech, however, he has trained himself to register, in great detail, character, pitch, volume, and location. Location of sound-source is an unconscious function of his daily group conversation, group work, and group play. It is reasonable to expect, then, that when dialog placement has dramatic meaning it will be efficiently received by the audience—at least, more efficiently received than the placement of sound-effects or music. Because of the visual limitations of the screen, dialog, in Fantasound as in ordinary reproduction, comes normally from the center of the stage. For this purpose the center stage speaker is adequate. Because the ear is critical of voice placement, however, it is not far-fetched to attempt the location of characters by changing the speaker source. If an actor appears in the area at the extreme left of the projected frame, or if the implied location is slightly to the left of the projected frame, placement of the voice on the left stage speaker supports the illusion. Such use of the three stage speakers creates the possibility of dialog between extreme left and extreme right or between center and either side without greater sacrifice of intelligibility than would exist in dramatic productions on the stage. Obviously the device could be over-used to the point of annoyance, and should be limited to dramatic situations that are definitely improved by the illusion. In the treatment of off-stage voices the house speakers could be used to advantage. When a voice, or a group of voices, comes from the left or right unit of house speakers, an effect of reverberation is added to the original recording. The loss in intelligibility and in point-source definition could have dramatic value because they imitate these same losses in the reception of real sounds from a distance.

Fantasound is able to make its greatest contribution in combining dialog, music, and sound-effects. In ordinary reproduction one of these three mediums must, with rare exceptions, be dominant while the other two are sacrificed. In Fantasound it is possible to follow the continuity of the dialog clearly and still receive the full emotional impact of the music, or the dramatic realism of atmospheric sound-effects. As a possible use in the theater, consider that the center stage speaker would be saved exclusively for on-stage sound—dialog, music performed on the screen, or realistic sound-effects. The house speakers and, at a lower level, the side stage speakers would project music or general sound-effects at a level natural for them. As long as the music or effects are pertinent to the story being portrayed they will not distract and would not cause the dialog to become unintelligible. This physical separation of sound-tracks also reduces to a minimum the unpleasant phenomenon produced when a well-modulated track is "pinched."

If these comments seem to wander it may be because Fantasound is at the wandering stage of its development. We have the tools and we have not decided what we intend to build with them. These tools may not be available in the theater "for the duration," but this might be an excellent period during which to develop a practicable, effective plan for using them. It is within the power of Fantasound, as an idea, to revitalize the industry. This power, however, can not be fully developed until script, direction, music, and recording are planned with Fantasound as an organic function.

MOBILE TELEVISION EQUIPMENT*

R. L. CAMPBELL, R. E. KESSLER, R. E. RUTHERFORD, AND
K. V. LANDSBERG**

Summary.—*While portability is a necessary requirement for outside pick-up equipment, several advantages result when portability is carried into the studio. To equip a studio of adequate size with fixed equipment for operation of several cameras involves considerable time and expenditure. However, with portable studio equipment, the entire equipment installation can be located to suit studio needs, as well as moved to different studios or outside locations.*

The dolly type equipment is described in some detail and systems for program control are discussed. Some of the design features discussed are portable and flexible synchronizing equipment; electronic view finders; oscilloscope monitors; and other operating facilities.

In the course of the development of television equipment, many of the improvements and simplifications resulting in better apparatus from the standpoint of performance and convenience of use are really the applications of ideas developed in allied fields that have been transferred to meet television design requirements. It may also be said that television equipment design must follow, to some extent, the established precedents and engineering practices (*e. g.*, radio broadcasting equipment). When the precedent is followed too closely, however, difficulties are likely to appear in operation and maintenance because of the inherent complexity of the television system. In sound broadcasting there is only one electrical signal comprising the intelligence to be transmitted. In television there are five separate electrical waves (sometimes more depending upon the system employed) which are combined and transmitted simultaneously to be used at the receiver in order to reproduce the picture. To make up this composite television signal wave, several electrical wave-forms not appearing in the final signal must be generated in order to obtain the television system operation as we know it today. From this it can be seen that the operation of a television camera is by no means as

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

** Allen B. DuMont Laboratories, Passaic, N. J.

simple an operation as setting up and operating a microphone for sound work.

With the above in mind, the purpose of this paper is to describe a type of television camera equipment designed both for studio and outdoor use with respect to its function in a television operating plant. Particular components of the system to be described are (*1*) mobile camera control dolly; (*2*) electronic view-finding system; (*3*) flexible synchronizing equipment; (*4*) sweep-driven control apparatus; (*5*) interchangeability of units; (*6*) cross-control of camera dollies; and other operating features. Particular reference will be made to mechanical considerations as well as some novel electrical features used in the equipment.

One application of this equipment would be for broadcast studio operation. The economic factors involved in equipping a studio solely for television operation are likely to be out of proportion to the anticipated return on the investment in the case of most broadcasting stations or other operating enterprises. Using the studio-type portable equipment, television programs can be presented with a minimum of installation difficulties. The cameras and camera-control equipment are merely rolled into the studio (together with adequate portable lighting fixtures) and the show is on. In the case of remote work, special events, *etc.*, the same equipment can be wheeled into a small truck, and unloaded and quickly set up for operation into a video line or relay channel.

A familiar and important requirement of portable equipment is weight. Considering the number of complex circuits involved in a television system, it can be seen that this problem is much more severe than in the case of equipment for remote sound work. Considerably more apparatus is involved, and the question that immediately arises is, "Shall we have a few heavy units or shall we have several small, light-weight units?" In this equipment the latter was chosen for the following reasons:

(*1*) The most logical electrical arrangement was to split the system into several units according to their functions.

(*2*) Standard mechanical chassis arrangements could be adopted for ease of manufacture.

(*3*) Servicing of all units was to be as convenient as possible.

(*4*) No unit should be a two-man job to carry.

(*5*) Future improvements can be added by replacing a unit at a time if desirable.

(*6*) Television cameras using different types of pick-up tubes may be used on the same equipment chains.

The camera and corresponding control equipment are arranged to operate in single or dual chains. In the case of a single chain, this equipment is divided into units as follows:

(*1*) Synchronizing generator
(*2*) Blanking sweep and power unit
(*3*) Camera
(*4*) Camera power supply
(*5*) Electronic view-finder
(*6*) View-finder supply
(*7*) Camera control
(*8*) Shading generator*
(*9*) Camera monitor
(*10*) Camera monitor power supply
(*11*) Camera control power supply
(*12*) Line amplifier
(*13*) Line amplifier power supply
(*14*) Line monitor
(*15*) Line monitor supply

For a dual chain, the equipment required is:

(*1*)	Synchronizing generator	1
(*2*)	Blanking sweep and power unit	1
(*3*)	Camera	2
(*4*)	Camera power supply	2
(*5*)	Electronic view-finder	2
(*6*)	View-finder supply	2
(*7*)	Camera control	2
(*8*)	Shading generator**	2
(*9*)	Camera monitor	2
(*10*)	Camera monitor supply	2
(*11*)	Camera control power supply	1
(*12*)	Line amplifier	1
(*13*)	Line amplifier power supply	1
(*14*)	Line monitor	1
(*15*)	Line monitor supply	1

In Fig. 1 is shown the apparatus outlined above arranged for dual chain operation. On the camera-control dolly are the synchronizing generator, power units, camera-control units, monitors, and line equipment. With each camera connected to the main equipment dolly is the auxiliary camera power-unit and the view-finding apparatus. This assembly is then connected back to the camera-control dolly by means of the camera cable, interlocked a-c power cable, and view-finder video cable.

For studio use the camera equipment proper is sometimes mounted on a studio platform dolly having a pedestal arranged to take the Akeley gyro tripod head shown in the figure. The camera dolly platform supports the camera equipment and the cameraman, and it can be moved about the studio for camera "dolly" action shots.

Synchronizing Generator.—The synchronizing generator used in this equipment is of the flexible fully electronic type and generates the DuMont synchronous wave (Fig. 4). The generator can be operated

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* For use in conjunction with iconoscope cameras.

** For use in conjunction with iconoscope cameras.

on any of the standards listed below, and can be easily converted to other standards that may be desirable without affecting the standard chosen for regular operation.

Lines/frame	Fields/second	Interlace
441**	60	2:1
525*	60	2:1
625**	30	2:1
343†	120	2:1
441†	120	2:1

The synchronizing system may be switched to any one of the above standards by means of a single wave switch and a few simple adjustments.

FIG. 1. Dual camera chain equipment.

The complete generator is housed in two units, *viz.*, the synchronizing generator unit and the blanking sweep and power unit. Fig. 2 shows the front panel of the synchronizing generator unit with the cover removed. At the top of the unit is a monitor CRO (cathode-ray oscillograph) which is connected to all circuits provided with front panel adjustments. This CRO is of the "automatic" type; that is, the timing axis is automatically synchronized to the signal selected by the monitoring selector switch by means of an additional

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* F. C. C. (49851) "Television Report," May 3, 1941; also Donald G. Fink, National Television System Committee, Doc. No. *505L-200M1*.

** Experimental Standards.

† Color Standards.

deck on the selector switch. Because of the many complex circuits involved in a synchronizing generator, and because it is desirable during operation to check the performance of the entire instrument without shutting down or throwing it out of adjustment, this monitor CRO is considered essential.

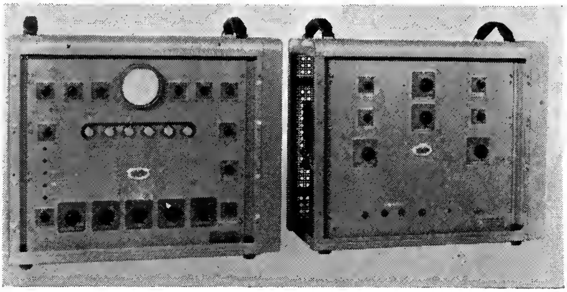

FIG. 2. Synchronizing generator with front cover removed.

Fig. 3 is a block diagram of the synchronizing system employed in the equipment. The synchronizing generator can be divided into units according to the function of the various circuits.

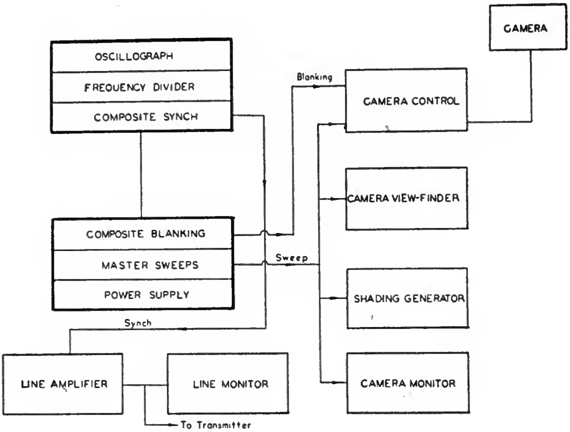

FIG. 3. Diagram of scanning and synchronizing system.

Unit No. 1 (*1*) Monitor CRO
(*2*) Frequency divider circuit

Unit No. 2
- (*3*) Composite synch wave generator
- (*4*) Composite blanking
- (*5*) Master sweep generator
- (*6*) Power supply

The monitor CRO has been explained above. The frequency divider unit consists of transformer-coupled relaxation oscillators arranged to divide in accordance with the line and frame scanning standards selected. The switch to different standards is accomplished by means of a multiple deck wave switch, connected to the oscillator and associated circuits, whereby the optimal circuit constants are selected for operation on the scanning standard chosen.

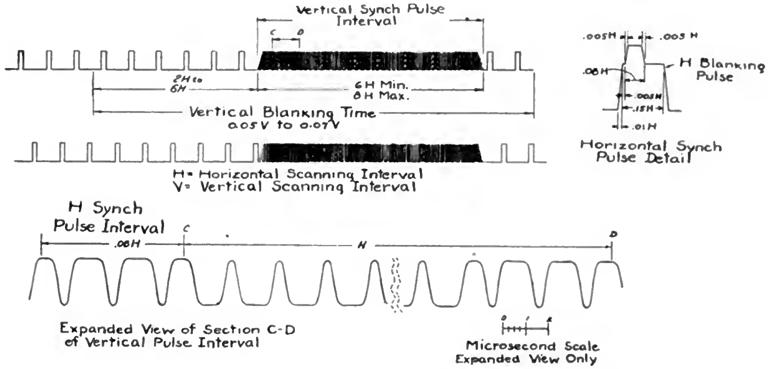

FIG. 4. DuMont synchronizing signal.

The composite synchronizing signal generator circuit develops the synchronizing wave as shown in Fig. 4. Use of this type of signal makes it possible to minimize operating difficulties in the field so far as synchronizing generator performance is concerned. This is principally due to the fact that the composite synch signal consists of two signals that are relatively simple to generate. Furthermore, improved vertical synchronizing performance is attained at the receiver.* In the composite synch signal generator is the shaping circuit for horizontal pulses, the high-frequency carrier pulse generator for the field pulses, and the mixing and output circuits.

The blanking, sweep, and power unit contains the circuits indicated in its name. Power for all circuits in the generator is supplied

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* National Television System Committee, Doc. No. *325R-200D31*.

from this unit by means of a well filtered, regulated supply. From the generator unit, driving pulses are fed to the sweep generators which control the scanning circuits on the cameras, monitors, and shading generators.

Horizontal and vertical blanking voltages are derived from the respective sweep signal generators and shaped in the blanking generator circuit. They are next mixed to form a composite blanking wave which is fed to the camera-control unit.

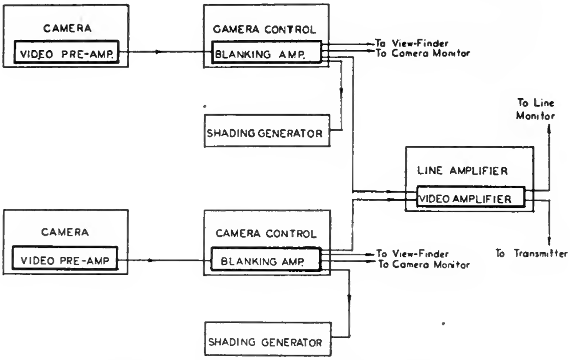

Fig. 5. Diagram of video system.

Low-impedance outputs are provided in the synchronizing generator unit to feed a single or dual camera chain with the following signals:

(*1*) Horizontal sweep
(*2*) Vertical sweep
(*3*) Composite blanking
(*4*) Composite synch

By means of the synch distribution unit, several camera chains may be controlled from one generator if desired. For normal operation on dual chain, and with reasonable cable lengths, the synch distribution unit can be eliminated.

Video System.—Fig. 5 shows the video system employed in a dual chain. The video signal generated in the iconoscope output resistor is fed to the preamplifier in the camera, where correction for capacitance of the iconoscope output circuit is accomplished by means of a peaking stage in this amplifier. A cathode follower output stage on the preamplifier feeds through the main cable to the camera-control amplifier, which will be described later.

Camera.—Fig. 6 shows the camera equipment. In the camera are the video preamplifier (Fig. 7), camera sweep circuits, a type *1850* iconoscope, camera blanking circuits, and protective circuits. Power for these circuits is fed from a separate cable from the camera power unit. The amount of power dissipated in the camera itself is such that the heat generated by the tubes would be excessive, especially when used in a "hot" studio or out in the sun. Therefore, it has been found desirable to isolate those tubes generating most of the heat and place them upon a deck on the exterior of the camera. The lens mechanism is operated by means of a handle at the side, and provisions are made for interchanging lenses in the approximate range of $6^1/_2$ inches $f/2.5$ to 16 inches $f/3.5$.

Camera Control.—In the camera control unit are the following circuits:

(*a*) Video blanking amplifier
(*b*) Camera horizontal sweep control and keystoning circuit
(*c*) Camera vertical sweep control circuit
(*d*) Pedestal control
(*e*) Iconoscope beam control
(*f*) Iconoscope rim light control
(*g*) Monitor and view-finder video supply circuits.

The camera cable terminates in the rear of this unit, and all signals feeding the camera pass through the camera control unit. (Note: The video signal to the view-finder is fed over a separate small co-axial cable.) A test-circuit for checking the plate currents of amplifier tubes in the camera control is connected by means of a switch to a meter on the front panel. The camera video amplifier comprises five stages and two blanking clippers.

FIG. 6. Camera equipment (Iconoscope).

Of interest in the camera control unit are the blanking circuit and the pedestal control circuit. The former utilizes a low-impedance diode limiter for clipping the blanking pedestal after mixing, and beyond this point in the amplifier is the pedestal control which is a similar diode circuit, but has a variable d-c bias control for adjusting the amplitude of the pedestal in accordance with lighting conditions.

The video output circuit of the camera control consists of a high-level cathode loaded stage which feeds the line amplifier and a low-level cathode loaded stage for feeding the monitor, view-finder, and shading generator CRO. Fig. 8 is an interior view of the camera control on the wiring side. Power for the camera-control unit is obtained from a separate, regulated supply to which the camera power and view-finder power units are interlocked.

View-Finder.—In motion picture production, probably the most important technician is the cameraman. His successes or failures are very probably due to his ability, before the shot is taken, to visualize how the particular scene will appear when projected on the screen. By means of the electronic view-finder, the television cameraman has an instantaneously developed picture before him at all times. View-finding by means of matched lenses is an alternate method by which the cameraman can monitor his work. This method is expensive, however, and does not lend itself readily to quick interchangeability of lenses, sometimes required during programs. For these reasons the electronic method of view-finding was chosen. Besides being able to determine the pictorial value of the scene before the camera, the electronic view-finder is used as the focusing monitor. Thus, the cameraman can adjust the optical focusing instantaneously, and since he is in control of the camera, he can anticipate to some ex-

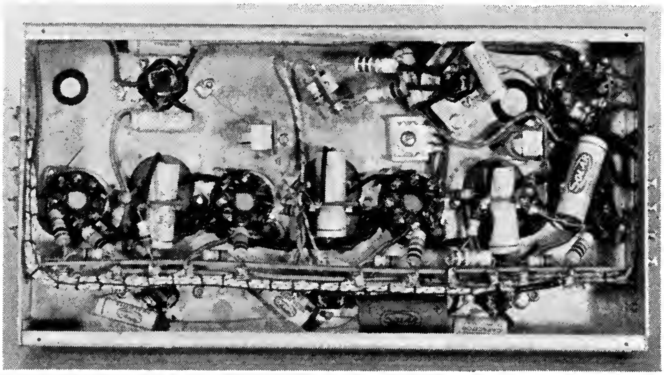

FIG. 7. Camera preamplifier.

tent the position of the focusing handle and thus maintain the optical focus at all times. As an auxiliary to the electronic view-finder, a framing device of some variety or other, or a Mitchell finder, is sometimes attached to the camera for the purpose of providing finding facilities outside the field taken in by the camera.

The electrical arrangement of the view-finder is as follows: A high-intensity 5-inch electrostatic-type cathode-ray tube is sweep-driven from signals to the camera. The sweep voltages are applied to plates of the cathode-ray tube by means of amplifiers located within the view-finder unit. The video signals fed to this unit are tapped off a monitor line in the camera control and fed to a video amplifier in the view-finder unit. Power and control circuits located in the view-finder supply-unit are fed to the view-finder by means of an interconnecting cable. (Controls are provided on the view-finder unit for maintaining the adjustments of brightness, contrast, and electrical focus, similar to those employed in television receivers.) Figs. 9 and 10 show the internal arrangements of the view-finder and view-finder supply-units, respectively.

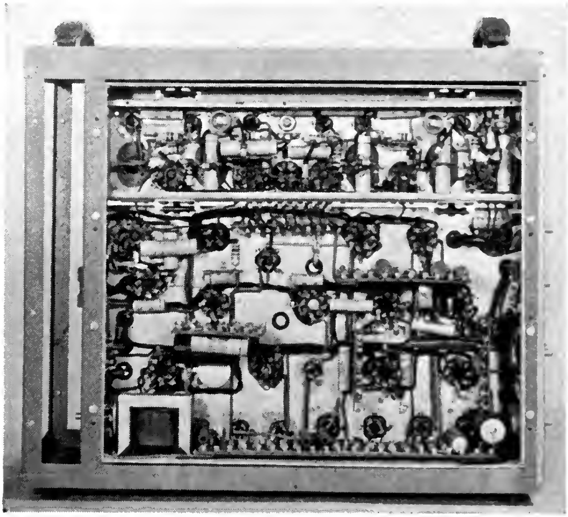

FIG. 8. Camera control unit, wiring side.

Shading Generator.—The shading control generator is a separate unit in the equipment and is used only in conjunction with iconoscope cameras. The shading signals are derived from the horizontal and vertical master sweep signals from the synchronizing generator.

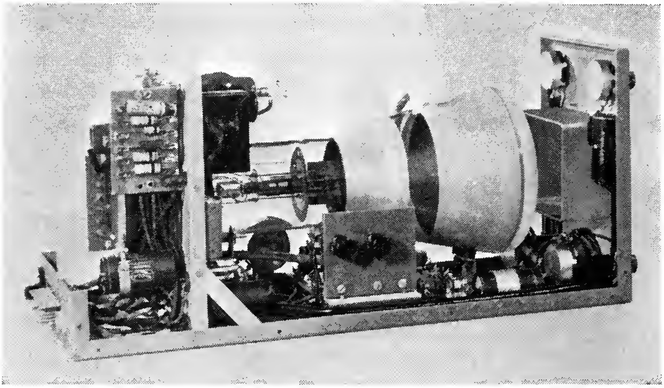

FIG. 9. View-finder interior view.

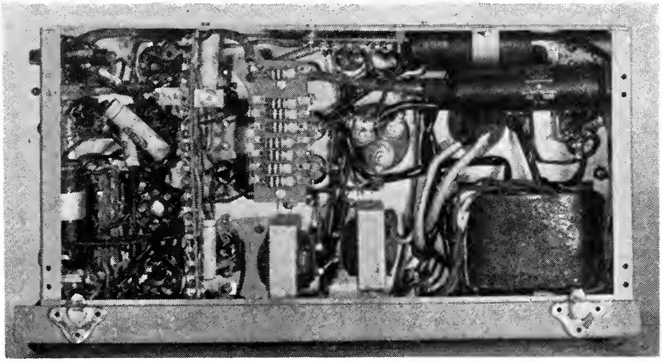

FIG. 10. View-finder supply, interior view.

From these sweep signals the following shading voltages are generated in this unit:

(*a*) Horizontal saw-tooth
(*b*) Horizontal parabola
(*c*) Horizontal sine
(*d*) Vertical saw-tooth
(*e*) Vertical parabola
(*f*) Vertical sine

These signals can be controlled both in amplitude and phase so that many varieties of composite shading voltage can be obtained. These signals are mixed in a common amplifier whose output is fed into the iconoscope output circuit by means of a line in the camera cable. In the shading generator are the following circuits.

(*a*) Shading generation, mixing, and output circuits
(*b*) Shading CRO
(*c*) Internal power unit

Video from the corresponding camera control is fed to the shading generator CRO in order to monitor the shading signals. The time axis on this CRO is driven from either the horizontal or vertical sweep depending upon the setting of a switch on the front panel. Thus, the operator selects the line-frequency sweep for checking horizontal shading, and the field-frequency sweep for checking vertical shading. A regulated supply is used to power all the units in this circuit. Fig. 11 shows the shading generator.

FIG. 11. Shading generator.

Camera Monitor.—On each camera chain is a monitor unit connected by cable to the camera control corresponding to the camera being operated. This monitor is usually placed directly on top of the camera control or shading generator for the convenience of the operator. The camera monitor is powered from the camera monitor supply by means of an interconnecting cable. Since electrically the camera monitor is identical with the view-finder, it need not be described further here. Fig. 12 shows a camera monitor unit and Fig. 13 the monitoring system in general.

Line Amplifier.—Normally, the camera-control units generate video signals at sufficient level for feeding monitor lines and controlling a camera chain as outlined above. However, the signals from the two cameras must be selected or mixed, as the case may be, and then mixed with the synchronizing signal to form the composite television signal. This is accomplished in the line amplifier, which contains the following circuits:

(*a*) Video switching unit
(*b*) Synch mixing amplifier
(*c*) Main output stage
(*d*) Four auxiliary output stages
(*e*) Monitor CRO

Push-button switching of cameras is accomplished in the switching unit by selecting one or the other of camera-control video signals. The composite synch signal from the synchronizing generator is fed to the line amplifier, as well as the two video signals. Just before the output stage, a mixing circuit is provided to introduce the synch signal with the video. A synch gain control is provided for maintaining the proper percentage of synch signal to video. In the event that separate synch transmission is used, this signal is cut at this point and fed directly from the generator to the transmitter or relay apparatus. Fig. 13 shows the line amplifier unit.

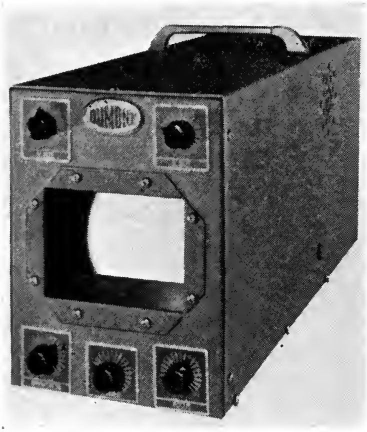

FIG. 12. Camera monitor unit.

The main output stage of the line amplifier is a heavy-duty cathode follower stage which normally feeds a 75-ohm line at an approximate level of 6 volts. In addition to this stage, three low-level stages are provided for 75-ohm monitor lines, such as program directors, auxiliaries, and local monitor. The monitor CRO is for the purpose of monitoring the signal out on the various lines. The video signal applied to the CRO is normally connected to the main output line. However, by means of a plug-in arrangement at the back, this CRO can be used to check all input and output terminals on the unit. Power for the line-amplifier unit (excepting CRO power, which is a built-in unit) is obtained from a separate supply which is identical to that used for powering the camera-control unity. Fig. 14 shows the tube side of the line amplifier.

Line Monitor.—The line monitor unit is used for checking the signal selected by the switching unit (Fig. 13). In addition to monitoring the video signal fed out on the line, this unit serves also to monitor the synchronizing performance of the entire system. The viewing unit of the monitor is identical with the camera monitor previously mentioned, with the exception of the driven sweeps, and is powered from a supply unit also identical with the camera monitor supply. In addition to this supply, however, is a synchronizing wave from the composite scanning unit for separating the synchronizing wave from the composite signal and applying it to the horizontal and vertical sweep oscillators of this monitor in the same manner as in typical home television receivers. This line monitor, while intended primarily for operation with the DuMont synchronizing signal, is arranged to operate on synchronizing signals having rectangular field pulses as well as those of the radio-frequency type.

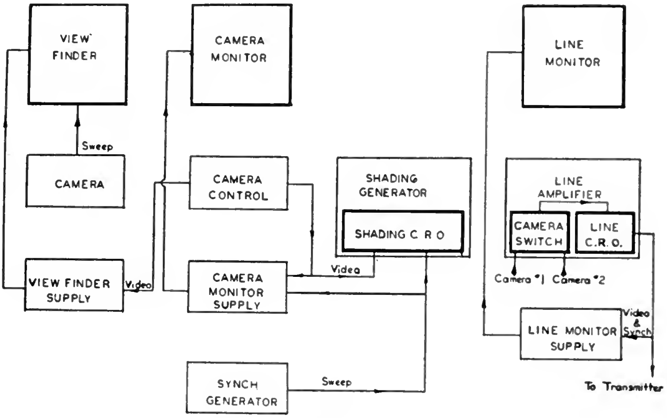

FIG. 13. Diagram of monitoring system.

Control Dolly and Operation.—The camera-control dolly is a lightweight frame on 10-inch pneumatic wheels occupying a floor space of 64 × $28^1/_2$ inches for a dual chain. The height of the control desk is 30 inches, and the operating desk slides into the unit when not in use. Single or dual equipment is controlled from the camera-control dolly by the camera-control operator. He has control over the electrical performance of the video system, including the synchronizing generator. Each camera is operated by a cameraman who, with the aid of the electric view-finder, follows the action, maintains the focus, and is in general control of the pictorial value of the subject matter being picked up by his camera. There are provisions for interphone connections by which this operator is in communication with the two cameramen and also with the terminal point to which the video signal is being supplied. A sound program control-unit is sometimes mounted on the camera-control dolly. When sound facilities are controlled here, some of the duties of the video control operator can be taken over by the sound man.

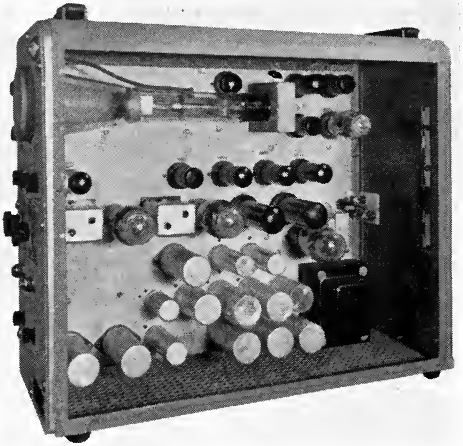

FIG. 14. Line amplifier, tube side.

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THE APPLICATION OF POTENTIOMETRIC METHODS TO DEVELOPER ANALYSIS*

JOHN G. STOTT**

Summary.—*Potentiometric titration methods are applied to routine developer analyses in order to simplify and speed up the operation and to minimize the human error arising from judgment of color change end points, etc. A brief theoretical treatment of potentiometric titrations is included, and new tests for elon, hydroquinone, and carbonate are outlined. Previously published methods for bromide and sulfite are also included. Detailed procedure outlines are included along with a discussion of the problem of pH vs. the alkali content of a developer. A glossary showing stepwise procedure operations required to accomplish the analyses has been compiled along with a complete equipment and chemical reagent list. The precision of the methods is evaluated by a table showing analysis data on carefully mixed known developers.*

In recent years the literature of photographic technology has yielded many schemes and procedures relative to the quantitative chemical analysis of photographic solutions. Many of these suggestions have dealt with but one or two of the common constituents of photographic solutions, particularly in the studies on developers, whereas a complete quantitative chemical analysis giving accurate data on all of the important constituents is essential in order to evaluate the actual photographic function of the developer. While all these contributions have been of value, it has been difficult for the motion picture laboratory chemist to segregate this maze of data and to arrive at a working procedure that will lead to rapid and consistently accurate results in the routine analysis of photographic developers.

The first complete working procedure for *MQ* developer analysis was published by Evans and Hanson[1] in 1939. The need for further clarification and extension to more general types of solutions was realized by R. B. Atkinson and V. C. Shaner, co-authors of "Chemical Analysis of Photographic Developers and Fixing Baths"[2] published in 1940 and based upon a careful study of the literature as

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* Presented at the 1942 Spring Meeting at Hollywood, Calif.; received April 15, 1942.

** Eastman Kodak Company, New York, N. Y.

well as on their own work. The working procedures outlined call for a minimum of equipment and technical skill and give accurate and rapid results.

With this information at his disposal, it is possible for the motion picture laboratory chemist to run complete chemical analyses on photographic developers with sufficient speed that the data obtained can be of immense value in production processing.

It is the purpose of this report to construct a procedure of analysis such that all the more important constituents of an *MQ* developer may be determined by the application of one primary method of end point evaluation, the only variations from this standard procedure being in pretreatment of the developer solutions and in titrating reagents used. This is accomplished by the application of potentiometric methods to end point determinations. Thus the entire "heart" of these analysis methods is some type of sensitive potential measuring device; without this instrument these methods are useless. All the work of this paper has been done using a Beckman *p*H Meter, Laboratory Model *G*, which is so constructed that it can be instantly converted from a *p*H-measuring device to a potential-measuring device with a range of -1300 to $+1300$ millivolts.

THEORETICAL TREATMENT

Since these analysis methods depend entirely upon potentiometric methods, it will be desirable to outline briefly the theory behind the phenomenon in order to understand more clearly what is happening during the course of a potentiometric titration.

When a metal is placed in a solution of its ions, such as a silver electrode in a solution of silver nitrate, an equilibrium is set up between the metal and its ions in the solution that can best be represented by the following equation:

$$\underset{\text{silver metal}}{Ag^{\circ}} \rightleftarrows \underset{\text{silver ion}}{Ag^{+}} + \underset{\text{electrode transfer}}{ie}$$

A potential difference exists between this silver electrode and the solution of silver ions, the magnitude of the potential difference depending upon the concentration of silver ions. This silver electrode potential can be measured if a reference electrode is placed in the solution and connected to the silver electrode through a potentiometer set-up. The reference electrode must be one that has a known potential and does not affect the reaction at the silver electrode. Such a standard electrode is the saturated calomel electrode which maintains a constant potential in respect to the solution regardless of the other electrode in the solution or the ions in the solution itself.

Suppose that we are interested in determining the bromide concentration of a solution. A silver electrode and a saturated calomel electrode are placed in the pretreated solution, and the leads from the electrodes are connected to the potential measuring device. The potential of the silver electrode is then measured during titration with a standard silver nitrate, plotting a curve of the measured potential *vs.* the units of silver nitrate added.

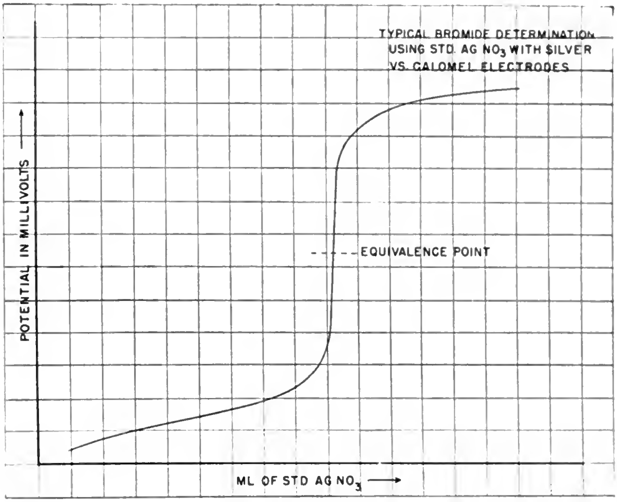

FIG. 1. Typical bromide determination.

Upon addition of the first portion of silver nitrate to the solution containing bromide, nearly all the silver is removed from the solution as solid silver bromide. A small amount of silver ion remaining in solution in equilibrium with the silver bromide determines the potential of the silver electrode. A second addition of silver nitrate results in a further precipitation of silver bromide; and since bromide ions are still present in excess, the amount of silver ion in solution is still the small amount in equilibrium with silver bromide, increased slightly due to the decreased bromide concentration. Since the change in silver ion concentration is very small, the potential change is also small. However, when the bromide concentration becomes small, that is, when we approach the end point of the titration, the addition of the same increment of silver nitrate causes a much greater change in the silver ion concentration and the potential changes are greater, until at the end point we obtain the maximum slope in the plot of potential *vs.* silver nitrate. Such a curve is shown in Fig. 1. The end point of the titration is the point of maximum slope or the midpoint of the straight-line portion of the vertical part of the curve. The last portion of the curve represents the change in potential as the silver ion is increased, but since each addition increases the concentration by a lesser increment than the preceding one the slope becomes less.

This type of reaction involving the precipitation of the constituent to be determined is but one of the types of reactions that may be studied by this method. Oxidation-reduction reactions may also be studied by measuring the change in the concentration ratio of the oxidized and reduced form of a substance using an inert electrode. Such a reaction is illustrated by the titration of an oxidation agent, such as iodine, with a reducing agent such as hydroquinone. In this titration the reaction of the oxidant may be expressed as follows:

$$\underset{\text{iodine}}{I_2^\circ} \quad \rightleftarrows \quad \underset{\substack{\text{iodide}\\\text{ions}}}{2I^-} \quad - \quad \underset{\substack{\text{electron}\\\text{transfer}}}{2e}$$

The potential changes in the solution are due to the changing ratio of free iodine to iodide ions, and the rate of change of potential with added hydroquinone will follow a course similar to that in the silver nitrate–bromide system.

Before a given substance can be determined by the method outlined above it must be certain that interfering substances have been removed. This pretreatment of solutions prior to titration will be described in detail in the procedure outlines for the analysis of each constituent.

This treatment of the theory underlying potentiometric titrations is merely an outline, and the reader is referred to texts on the subject for a more complete treatment of the subject.[3]

PROCEDURES

These procedure outlines will deal with the actual operations required in pretreatment of solutions prior to titration, along with a brief explanation as to the reason for carrying out these operations.

All the titrations will be carried out in a similar manner by determining the potential of the unknown solution after each addition of a unit volume of reagent, and by plotting the potential in millivolts *vs.* the volume of reagent added. When the final titration curve has been drawn, the equivalence point of the titration is located as previously described, and a simple mathematical calculation will give the final analytical result. When further experience has been obtained in conducting potentiometric titrations, the need for plotting the titration curves in all the determinations will be eliminated since violent fluctuations of the potentiometer needle begin to occur near the equivalence point. Then the actual location of the equivalence point amounts to determining the maximum potential change obtained upon the addition of small volumes of reagent. This method of equivalence point evaluation has proved sufficiently accurate in this laboratory to be within slide-rule accuracy. Since the bromide and chloride determinations are made on the same solution by means of locating two equivalence points on a titration curve having two breaks, it will always be necessary to plot a titration curve for this analysis. However, in routine analysis where a rough estimate of the bromide content is possible, the titration may be carried out without plotting up to the beginning of the first break in the curve, after which point the plot must be made for most accurate results. The carbonate determination also requires a plot since the inflection points of the curves must be carefully followed in order to get accurate values. However, a scheme similar to the bromide-chloride determination may be employed in this determination in order to save time and tedium.

Vigorous stirring of the solution during titration is essential. This has been accomplished in this laboratory by employing a small non-sparking motor equipped with a glass stirring-rod which operates throughout a titration. The actual set-up used in this laboratory is pictured in Fig. 2. Many refinements and variations of this set-up are possible, but this simple arrangement has proved most satisfactory.

Schematic condensations of instructions are always valuable in this type of work, and thus a stepwise procedure for each analysis will be listed in the glossary at the end of this paper. A complete list of the equipment and reagents needed to conduct this analysis work will also be included in the glossary as an aid to installation of proper laboratory facilities.

Hydroquinone.—The method of separating the hydroquinone from the rest of the developer solution by extraction from the acidified developer with ethyl acetate has been previously worked out.[4,5] The time-consuming and difficult operation has always been the determination of the hydroquinone in the organic solvent after extraction. This present method makes use of the fact that ethyl acetate is somewhat soluble in water. A 25-ml sample of developer is placed in a 150-ml extraction funnel and a few drops of 0.04 per cent thymol blue solution are added. The solution is then acidified with 1 : 1 sulfuric acid until the solution turns red, and then 1 ml of acid is added in excess to assure complete extraction of the hydroquinone. Exactly 50 ml of ethyl acetate are added to the extraction funnel and the solution is shaken thoroughly for a few moments. The water layer is then drawn off into a second 150-ml extraction funnel and the operation is repeated using another 50-ml portion of ethyl acetate. One extraction removes only 92 per cent of the hydroquinone, and thus two extractions are necessary in order to obtain maximum accuracy. The water layer is drawn off again and saved for the elon determination. The two 50-ml portions of ethyl acetate are then mixed together in one of the extraction funnels, and 25 ml of SO_2 wash

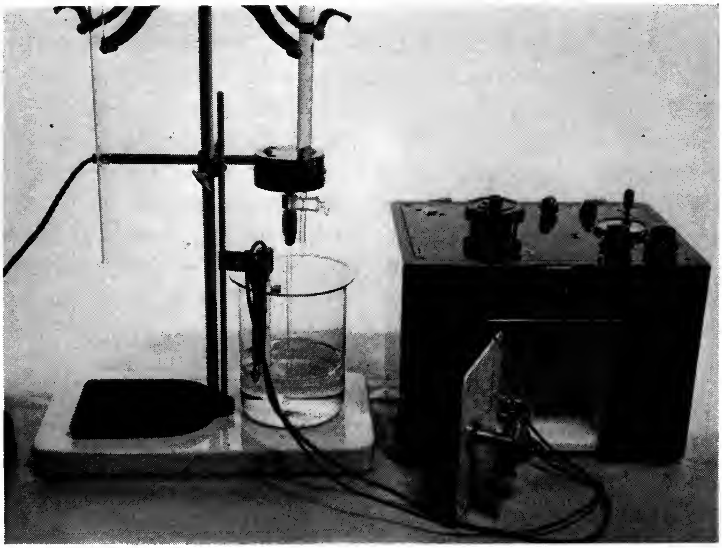

FIG. 2. Typical apparatus set-up.

solution are added (100 gm sodium sulfite, 10 gm boric acid, and 1.0 gm of potassium hydroxide[1]). This wash solution removes all the sulfur dioxide formed by decomposition of the sulfite in the developer upon acidification and extracted by the ethyl acetate. This mixture is shaken thoroughly and the water layer is drawn off and discarded. Ten mls of the ethyl acetate extract are then pipetted slowly into 200 ml of water acidified with 2.0 ml of 1 : 1 sulfuric acid while the solution is being vigorously stirred. When all the ethyl acetate has gone into solution, platinum and calomel electrodes are immersed in the solution, the leads are connected to the potentiometer, and the instrument is balanced. The solution is then titrated with 0.01 *N* ceric sulfate, and the equivalence point is located as previously outlined. With the volumes of developer and ethyl acetate, and the concentration of ceric sulfate used in this outline, the following calculation gives the hydroquinone concentration of the developer:

(ml of ceric sulfate to equivalence point) $\times$ 0.22 = gm of hydroquinine per liter

In cases where the hydroquinone concentration of the developer is unusually low or unusually high, the volumes of developer and ethyl acetate used may be varied to give increased accuracy or to save titrating time. If the ratio between the developer volume and the extract fraction is changed, then the volumetric factor must be changed accordingly to give correct results.

Ceric sulfate is used in this titration because of its high oxidation potential giving a large potential change at the equivalence point, and because of the fact that ceric ions will not add or substitute on the hydroquinone molecule and thus introduce extraneous reactions having a considerable temperature *vs.* potential coefficient. Precise temperature control is not essential in this titration since an *absolute* potential is not required but rather the *rate of change* of potential on addition of unit volumes of reagent.

Elon.—The water layer resulting from the two ethyl acetate extractions in the hydroquinone determination is used for the elon determination since almost all the hydroquinone has been removed by the acid extraction. This hydroquinone-free water layer is again placed in a 150-ml extraction funnel and several drops of a 0.04 per cent thymol solution are added. The *p*H of this solution is then adjusted by adding 2.0 *N* sodium hydroxide until the color of the solution turns blue. At this *p*H the elon will be extracted from the solution by ethyl acetate. Exactly 25 ml of ethyl acetate are then added to the funnel, and the mixture is shaken for a few moments. The water layer is then drawn off into a second 150-ml separatory funnel to be re-extracted, and the above extraction is repeated twice more with 15 ml of ethyl acetate and then 10 ml of ethyl acetate. The extraction is done three times to extract a maximum of elon from the solution since only about 80 per cent is extracted at each operation. Three extractions will remove about 99.2 per cent of all the elon, and thus the error from this source is minimized. The three portions of ethyl acetate are then thoroughly mixed together and placed in a 50-ml burette. The tip of the burette is then immersed in 400 ml of water acidified with 4.0 ml of 1 : 1 sulfuric acid, and 25 ml of the ethyl acetate are added slowly to the solution while it is being vigorously stirred. When the ethyl acetate has gone into solution completely, the titration is run using 0.01 *N* ceric sulfate in precisely the same manner as described for the hydroquinone determination. With the volumes and concentrations used in this outline, the elon content of the developer may be calculated by the following relationship:

$$(\text{ml of ceric sulfate to equivalence point}) \times 0.0688 = \text{gm of elon per liter}$$

Once again the volume ratios may be altered to conform to the desired accuracy of the determination.

Sulfite.—The quantitative determination of sulfite in a developer is accomplished in a manner previously described.[2] The determination is based upon the following reaction:

$$Na_2SO_3 + H_2O + I_2 \rightarrow 2HI + Na_2SO_4$$

A portion of the developer is placed in a 50-ml burette. Ten milliliters of 1.0 *N* iodine are placed in a 600-ml Erlenmeyer flask and diluted with 100 ml of water which has been acidified with 5.0 ml of concentrated hydrochloric acid. This solution is then titrated with the developer until the brown color of the solution bleaches out. This end point may be determined potentiometrically, but in this laboratory experience has indicated that this is entirely unnecessary. In fact no starch indicator is needed since the titration is accurate to within one drop of developer by observing the color change from the characteristic brown color of the iodine to a colorless solution. Using the volumes and concentrations herein mentioned, the sulfite content of the developer can be calculated from the following relationship:

$$\frac{630}{\text{ml of developer required}} = \text{gm of } Na_2SO_3 \text{ per liter}$$

Bromide and Chloride.—It has been pointed out by Evans, Hanson, and Glasoe[1] that "The photographic influence of the presence of chloride in the two developers used was investigated over the range of concentrations from 0 to 8 gm per liter and it was found to have no effect. However, the sensitivity to bromide was such that if the *bromide analysis included the chloride so that the chloride was replaced by an equivalent amount of bromide, an appreciable error would arise.*" Former methods of determining the halide content of a developer[2] have employed the absorption indicator technic which makes no distinction between the bromide and chloride in the developer. It has been the experience in this laboratory that if the total halide content of the developer is used for precise control work regardless of whether only part of that halide has an actual photographic effect, the actual function of the halide can not be accurately predicted. In working developers it has been found that the ratio between the bromide content and the chloride content does not remain the same over *ranges of total halide concentration*, and thus it would seem that a determination distinguishing between the two halides is necessary for precise laboratory control.

A method for determining bromide and chloride in a developer by a potentiometric titration had been worked out in this laboratory. However, the method proposed by Evans, Hanson, and Glasoe[1] proved to be more accurate since their treatment of the solution prior to titration proved more effective and complete, and thus interfering substances were better eliminated. Therefore this basic method is to be outlined herein.

A 100-ml sample of developer is boiled to complete the reduction of any silver held in solution by the sulfite and then treated with 40 ml of 1 : 1 sulfuric acid to decompose all the sulfite. The acidified solution is then boiled to drive off all the dissolved sulfur dioxide and the solution is allowed to cool. Eighty cubic centimeters of a solution of sodium acetate, 150 gm to a liter of water, are added, and silver and calomel electrodes are immersed in the solution and connected to the potentiometer. The solution is then titrated with a standard silver nitrate solution (14.27 gm per liter), and a plot is made of potential *vs.* volume of silver nitrate added. The first break in the curve will come at the bromide equivalence point, and a continuation of the titration will reveal the chloride equivalence point. Since only the bromide is of importance, as has been pointed out, the titration may be halted at the bromide equivalence point. The concentration of the silver nitrate is so adjusted that by dividing by 10 the number of milliliters of silver nitrate consumed in reaching the bromide equivalence point, the grams per liter of potassium bromide are immediately computed.

$$\frac{\text{ml of std. AgNO}_3\text{ (14.27 gm/liter)}}{10} = \text{gm of KBr per liter}$$

An illustration of the resulting plot when both the bromide and the chloride are titrated is given in Fig. 3.

Sodium Carbonate.—The majority of methods proposed for the chemical analysis of sodium carbonate in a developer have made use of a gas evolution technic. In this type of analysis the developer solution is treated with some reagent that ties down the sulfite in the solution either by converting it to sulfate or by forming some complex salt so that no sulfur dioxide will be formed upon acidification. The sample of developer is then acidified in some closed vessel so that the evolved carbon dioxide can be collected and measured. Such a method of analysis was worked out in this laboratory involving the collection of all the gas in a gas burette with a leveling tube attached, and the measurement of the total gas volume. This total quantity of gas was then transferred to a Hempel absorption pipette filled with a solution of potassium hydroxide, and the carbon dioxide was selec-

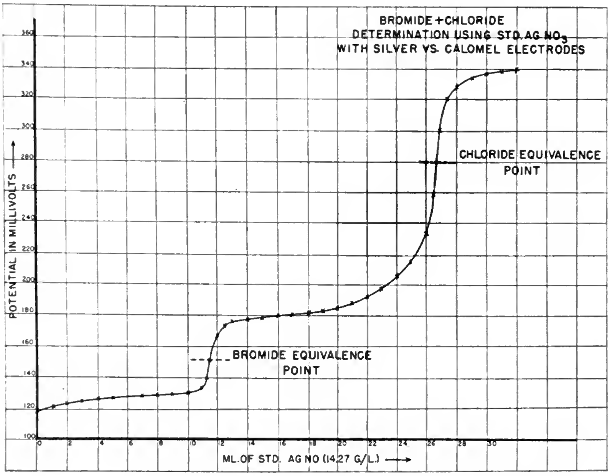

FIG. 3. Typical bromide plus chloride determination.

tively absorbed. The resulting gas volume was re-measured and the difference between original and final volumes gave the volume of carbon dioxide evolved from the developer upon acidification. A simple calculation then gave the sodium carbonate content of the developer.

This method, because of its basic gas evolution technic, has several serious limitations, and experience in this laboratory has indicated that this analysis is not always trustworthy. One case arose in this laboratory where calcium carbonate peeling off the sides of developer tanks coated with hard-water scale caused an error in the final calculated result of about 35 per cent of the actual sodium carbonate concentration of the developer.

It has been found in this laboratory that a titration of carbonate developers with standard acid leads to an end point that is independent of calcium carbonate sludge, and can be used as a method for determining carbonate. Such a titration is based upon a measure of the *p*H of a solution after each addition of acid, and has an end point similar to the previous potentiometric end points. The point at which the alkali is all used up or converted to a less alkaline salt gives the greatest changes in *p*H with small additions of acid. Such *p*H measurements are usually made with a glass electrode but in the case of the usual photographic developers the course of the titration may be followed more easily by means of potential measurements made with a platinum electrode. Evans and Hanson[6] have shown that a stable potential could be measured in an *MQ* developer, and that this potential changed rapidly with *p*H. The true chemical nature of this potential is controversial but for the purpose of a carbonate titration this is of no importance, since the end point is determined by the point of maximum change of potential and not by any consideration of the actual value of the potential itself. However, it has been found by Cameron[7] that potentials measured in developer solutions are affected by the amount of air or oxygen present so that vigorous and fairly constant agitation should be used during the carbonate titration.

A 10-ml sample of developer is pipetted into 200 ml of distilled water. Either a platinum or a glass electrode is used for this titration with the calomel electrode as the standard once again. The solution is titrated with 0.10 *N* hydrochloric acid and a titration curve of potential or *p*H *vs.* volume of acid added is made. The first break in this curve represents the conversion of all the sodium carbonate to sodium bicarbonate. The curve form will appear as illustrated in

Fig. 4, and the equivalence point is located as is illustrated by finding the exact midpoint of the straight-line portion of the curve. The following calculation with the volumes and concentrations used will give the actual sodium carbonate concentration of the developer.

$$(\text{ml of } 0.10\ N \text{ HCl to equivalence point}) \times 1.06 = \text{gm of } Na_2CO_3 \text{ per liter}$$

In cases where other alkalis stronger than carbonate are present in the developer, this acid titration type of analysis will give a quantitative measure of their concentrations. If the above calculation is used even if other alkalis, such as sodium hydroxide, are present, the total alkali content of the developer will be computed in terms of sodium carbonate. This will give a measure of the active alkali in the developer computed as if sodium carbonate were the only alkali present. This would not necessarily correlate with the photographic activity that would result if carbonate were the only alkali present.

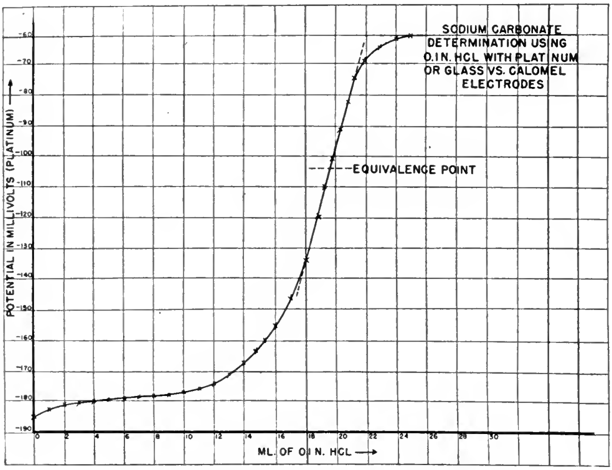

FIG. 4. Typical sodium carbonate determination.

*p*H.—In line with the determination of the sodium carbonate in a photographic developer is the controversial question of the correlation between the *p*H of a developer and its photographic activity.

It has been impossible in the work conducted in this laboratory to associate photographic changes with *p*H measurements while all other constituents of the working developer in question remained constant. A working developer in continuous production was studied while the sodium carbonate concentration of the developer was progressively decreased. The *p*H of the developer was periodically checked with both a common glass electrode and one of the newer-type glass electrodes having no sodium ion correction, and complete chemical analyses also were made at the same time. The control strips processed at the time of developer sampling indicated that little or no correlation between *p*H and photographic results could be found. However, a determination of its carbonate concentration gave a close measure of its photographic activity and a direct correlation between these two variables could be established (Table I).

TABLE I

Gamma vs. pH vs. Carbonate Concentration—Eastman Fine-Grain Positive Type 1302

*p*H (Glass Electrode with No Na† Error)	Gamma	Carbonate Values, Gm per Liter
10.38	2.86	68.0
10.14	2.82	38.7
10.12	2.77	37.0
10.11	2.75	35.8
10.10	2.72	22.4
10.08	2.70	18.0
10.10	2.70	18.0
10.08	2.69	19.1
10.09	2.70	18.5

This difficulty has been noticed particularly in the case of positive-type developers of the carbonate type having high *p*H values. The impossibility of predicting the alkali concentration from *p*H measurements on a positive-type developer is further substantiated by the data in Table II.

Thus it is felt that a careful chemical analysis of the active alkali in a positive-type developer using an acid titration technic is essential in order to predict the activity of the developer Formerly, the emphasis has been placed upon *p*H measurements with the chemical analysis data functioning as supplementary information.

However, in the case of negative-type developers having lower *p*H values, more correlation between the *p*H of the developer and its activity can be established. Moreover, since a chemical determination of the borax concentration of a developer is time-consuming and of low accuracy, this method of analysis is omitted in favor of a measurement of the *p*H of the developer. Although it is not felt

TABLE II

Table Showing Analysis Data vs. Developer Formula

Positive Developers

	Analyzed Data, Gm per Liter	Mixed Formula, Gm per Liter	Per Cent Error
Developer P-1			
Elon	2.80	3.00	−6.7
Sodium sulfite	78.9	80.0	−1.4
Hydroquinone	14.5	15.0	−3.3
Potassium bromide	4.05	4.0	+1.25
Sodium carbonate (anhydrous)	38.0	40.0	−5.0
*p*H 10.00			
Developer P-2			
Elon	1.40	1.50	−6.7
Sodium sulfite	39.3	40.0	−1.75
Hydroquinone	7.22	7.50	−3.7
Potassium bromide	1.99	2.00	−0.5
Sodium carbonate (anhydrous)	19.4	20.0	−3.1
*p*H 10.06			
Developer P-3			
Elon	0.69	0.75	−8.0
Sodium sulfite	19.8	20.0	−1.0
Hydroquinone	3.63	3.75	−3.2
Potassium bromide	1.03	1.00	+3.0
Sodium carbonate (anhydrous)	10.30	10.00	+3.0
*p*H 10.22			
Developer P-4			
Elon	0.25	0.25	±0.0
Sodium sulfite	29.2	30.0	−2.6
Hydroquinone	4.72	5.00	−5.6
Potassium bromide	0.78	0.75	+4.0
Sodium carbonate (anhydrous)	23.1	23.0	+0.43
*p*H 10.30			

that this is the ultimate in proper control of borax-type developers, too little practical experience and data have been obtained in this laboratory to warrant a more positive commitment.

DISCUSSION

It is felt that the aforementioned procedures outline a standardized technic for the chemical analysis of photographic developers. The analyses are simple and require a minimum of equipment and technical skill, and yet incorporate factors that tend to eliminate the so-called "human error." It must be kept in mind, however, that to date little data have been published regarding the actual function of each constituent of a developer or the magnitude of the photographic change introduced by a given change of one or more constituents. No universal equation can be formulated for this probem, unfortunately, since the equation would hold for only one type of film being processed in one developing machine functioning under one set of conditions. Thus chemical analysis of developers as an instrument of processing control is invaluable, but in studying photographic changes in terms of developer analysis, the data must be tempered with considerable experience and knowledge of processing conditions until further technology in this field is introduced.

The author wishes to express his sincere appreciation to D. E. Hyndman and H. E. White for their unfailing encouragement and many helpful suggestions. Likewise, the many suggestions and constructive criticisms of R. M. Evans of the Kodak Research Laboratories, and Mr. George Kelch and Dr. Harold Frediani of the Fischer Scientific Company have proved invaluable in the completion of this work.

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GLOSSARY

Schematic Condensation of Analysis Procedures

Hydroquinone—Platinum and calomel electrodes

(*1*) Pipette 25 ml of developer into 150-ml extraction funnel.
(*2*) Add few drops of 0.04 per cent thymol blue solution.

(*3*) Add 1 : 1 sulfuric acid until the solution is red, then 1 ml in excess.
(*4*) Add 50 ml of ethyl acetate and shake for one minute.
(*5*) Remove water layer to second extraction funnel and repeat No. *4*.
(*6*) Remove water layer and save for elon determination.
(*7*) Mix two ethyl acetate portions and add 25 ml of SO_2 wash solution.
(*8*) Shake for a few moments and remove and discard water layer.
(*9*) Pipette with vigorous stirring 10 ml of ethyl acetate extract into 200 ml of water and 2.0 ml of 1 : 1 sulfuric acid in a 1000-ml beaker.
(*10*) Titrate to equivalence point with 0.01 N $Ce(SO_4)_2$ and record volume

Calculation:

$$(\text{ml of } 0.01\ N\ Ce(SO_4)_2) \times 0.22 = \text{gm of hydroquinone per liter}$$

Elon—Platinum and calomel electrodes

(*1*) Place sample from *Hydroquinone* No. *6* in 150-ml extraction funnel.
(*2*) Add few drops of 0.04 per cent thymol blue solution.
(*3*) Add 2.0 N NaOH until solution turns blue.
(*4*) Add 25 ml of ethyl acetate and shake for one minute.
(*5*) Remove water layer to another 150-ml extraction funnel and repeat No. *4* using 15 ml of ethyl acetate.
(*6*) Remove water layer to extraction funnel and repeat No. *4* using 10 ml of ethyl acetate.
(*7*) Discard water layer and mix three portions of ethyl acetate extract.
(*8*) Place 50 ml of ethyl acetate in burette and add 25 ml with vigorous stirring to 400 ml of water and 4.0 ml of 1 : 1 sulfuric acid in a 1000-ml beaker while tip of burette is below surface of water.
(*9*) Titrate with 0.01 N $Ce(SO_4)_2$ to equivalence point and record volume.

Calculation:

$$(\text{ml of } 0.01\ N\ Ce(SO_4)_2) \times 0.0688 = \text{gm of elon per liter}$$

Sulfite

(*1*) Place portion of developer in 50-ml burette.
(*2*) Pipette 10.0 ml of 1.0 N iodine into 600-ml flask with 100 ml of water and 5.0 ml of conc. HCl.
(*3*) Titrate iodine solution with developer until brown color disappears and record volume.

Calculation:

$$\frac{630}{\text{ml of developer to end point}} = \text{gm of } Na_2SO_3 \text{ per liter}$$

Bromide and Chloride—Silver and calomel electrodes

(*1*) Boil 100 ml of developer in 1000-ml beaker for several minutes.
(*2*) Add 40 ml of 1 : 1 sulfuric acid and boil for few minutes more.
(*3*) Allow to cool and add 80 ml of sodium acetate solution and 100 ml of distilled water.
(*4*) Titrate with std. $AgNO_3$ solution (14.27 gm per liter) to equivalence point of bromide and to chloride if desired. Record volume.

Calculation:

$$\frac{\text{ml of AgNO}_3\text{ to bromide equivalence point}}{10} = \text{gm of KBr per liter}$$

Sodium Carbonate—Glass or platinum *vs.* calomel electrodes

(*1*) Pipette 10 ml of developer into 200 ml of water in 1000-ml beaker.
(*2*) Titrate through carbonate-bicarbonate equivalence point with 0.10 *N* HCl, plotting acid volume *vs.* potential curve. Determine equivalence point from curve.

Calculation:

$$(\text{ml of } 0.10\ N\ \text{HCl}) \times 1.06 = \text{gm of Na}_2\text{CO}_3\text{ per liter}$$

EQUIPMENT

(*This list will include a small overstock in order to accommodate breakage without hindering continuation of work.*)

Quantity	Type of Equipment
1	Beckman *p*H Meter, or similar device for potential measurements
1	5-inch platinum electrode with 30-inch shielded leads
1	5-inch glass electrode with 30-inch shielded leads (optional)
1	5-inch silver electrode with 30-inch shielded leads
1	5-inch calomel electrode with 30-inch shielded leads
1	Electrode holder
1	Small non-sparking electric motor complete with stirrer
1	8-inch hot plate
1	Wash-bottle, complete
3	150-ml extraction funnels with ground-glass stop-cock and ground-glass stopper
2	Burette stands with porcelain base
2	Fisher double burette holders
1	1000-ml volumetric flask with ground-glass stopper
2	250-ml volumetric flasks with ground-glass stopper
2	100-ml volumetric flasks with ground-glass stopper
4	50-ml burettes
1	2000-ml beaker
4	1000-ml beakers
4	600-ml beakers
4	250-ml beakers
4	100-ml beakers
4	600-ml Erlenmeyer flasks
1	1000-ml graduated cylinder
1	250-ml graduated cylinder
4	100-ml graduated cylinders
2	50-ml graduated cylinders
2	10-ml graduated cylinders
2	25-ml pipettes
2	10-ml pipettes

2	5-ml pipettes
2	2-ml pipettes
2	1-ml pipettes
1	Ring stand
2	$2^1/_2$-inch iron rings for extraction funnels
8	500-ml reagent bottles (brown glass with ground-glass stoppers)
	Assorted cork stoppers and rubber stoppers
	Assorted glass stirring rods
	Assorted glass tubing
	Assorted rubber tubing
4	90-degree ring stand clamps
4	Pinch-clamps

CHEMICAL REAGENTS

(*Stock should always contain listed quantities.*)

Raw Chemicals

Quantity	Chemical
2 lb	Boric acid (C. P.)
5 gal	Distilled water
5 lb	Ethyl acetate (C. P.)
2 lb	Hydrochloric acid (concentrated)
1 lb	Potassium hydroxide sticks
2 lb	Sodium acetate
2 lb	Sodium hydroxide
2 lb	Sodium sulfite
5 lb	Sulfuric acid (conc.)

Standard Reagents and Solutions

Quantity	Solution
500 ml	pH = 10.0 buffer solution
500 ml	0.10 N ceric sulfate ($Ce(SO_4)_2$) (stock solution)
500 ml*	0.01 N ceric sulfate ($Ce(SO_4)_2$) (working solution)
500 ml	1.0 N hydrochloric acid solution (stock solution)
500 ml	0.10 N hydrochloric acid solution (working solution)
500 ml	1.0 N iodine solution
500 ml	Std. silver nitrate solution (142.70 gm per liter) (stock solution)
500 ml	Std. silver nitrate solution (14.27 gm per liter) (working solution)
500 ml	Sodium acetate solution (150 gm per liter)
500 ml	2.0 N sodium hydroxide solution
500 ml	0.04 per cent thymol blue solution
500 ml	Wash solution (SO_2)—100 gm sodium sulfite, 10 gm boric acid, 1.0 gm potassium hydroxide

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* In mixing 0.01 N $Ce(SO_4)_2$ solution from the 0.10 N $Ce(SO_4)_2$ stock solution, care should be taken to add 5 ml of 1:1 sulfuric acid to each 100 ml of 0.01 N solution to be made. Ceric sulfate is insoluble in pure distilled water, and the acid must be added to prevent precipitation of ceric sulfate upon dilution of the 0.10 N stock solution.

CONTINUOUS REPLENISHMENT AND CHEMICAL CONTROL OF MOTION PICTURE DEVELOPING SOLUTIONS*

H. L. BAUMBACH**

Summary.—*The chemical reactions that take place in a photographic developer are discussed in detail. It is pointed out that, following the determination of a chemical formula that produces optimal photographic results, the concentration of every important ingredient of this solution may be held constant by the use of continuous replenishment and chemical control. After a discussion of the theoretical considerations involved, details are given for the establishment of picture negative, variable-density sound negative, and positive systems in use at the Paramount West Coast Laboratory.*

INTRODUCTION

The ultimate that the user of photographic materials can ask of his developing solutions is that they remain absolutely constant, day after day and month after month, at exactly the values necessary to obtain optimal results. In order that the developer may produce consistent results, it is essential that the concentration of each important ingredient remain constant. One method of obtaining this condition involves the use of a replenishing solution that is added in an amount directly proportional to the use of the chemicals within the developer and is compounded in such a manner that the concentration of every ingredient of the developer remains exactly the same, at the constant value desired.[1] This method is called one of continuous replenishment, because replenishing solution is added as the developer is used, and at any subsequent time the developer is in exactly the same condition that it was at the start. The life of the solution is thus indefinite, and the amount of film that has been processed with it is not significant.

When a solution of this type is used to develop a photographic image, a chemical reaction takes place whereby the developing agents, *i. e.*, hydroquinone and metol, sodium sulfite and silver halide,

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* Presented at the 1942 Spring Meeting at Hollywood, Calif.; received April 14, 1942.

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

react to form hydroquinone and metol monosulfonates, metallic silver, and hydrobromic acid. The continued development of photographic film in a developer thus causes a decrease in the concentrations of hydroquinone, metol, and sodium sulfite, and the formation of additional hydroquinone and metol monosulfonates and hydrobromic acid. The decrease of concentrations of the developing agents and sodium sulfite results in a decrease in the rates of reaction of these substances with silver halide and hence extends the time necessary to produce a given density or gamma on a photographic film.

All the substances involved in the reduction of the latent image are quantitatively exhausted from the developing solution, but it does not follow that all the products of the reducing reaction remain in the developer. The quantities of products retained depend upon the extent of diffusion of the ions from the gelatin layer back into the developing solution, the rate of which may be influenced by many factors, such as the amount of developer or film agitation, the developing time, the condition of the gelatin layer, the temperature, *etc.* One would expect, for example, that a more nearly equivalent quantity of bromide ion would be liberated within a negative developer where the developing action is quite slow, than would be liberated in a positive developer with its high rate of development.

The products of the development reaction may all influence subsequent action of the developing solution. The developing-agent monosulfonates are themselves developing agents of somewhat less reducing power than the parent substances; their developing action is of concern only in a developer of high *p*H value. The bromide ion has a pronounced effect upon the developed image; an increase in concentration of potassium bromide of 0.1 gram per liter may reduce the density of a developed image by as much as 0.20 but for other types of film this same increase will have a negligible effect upon density. The hydrogen ion liberated by the developing action slows the rate of development by reducing the ionization of the developing agents; the extent of this effect is primarily dependent upon the buffering salts present, for large amounts of salts of weak acids will absorb hydrogen ions to form the weak acid so that there is little change in the *p*H of the solution.

Every item involved in the reaction of development of a photographic image results in the reduction of the activity of the solution toward continued development action. A decrease in the concentration of hydroquinone, a decrease in the concentration of metol, a decrease in the concentration of sodium sulfite, an increase in acidity, and an increase in the concentration of bromide ion act to cause a lengthening of the developing time required to produce given density and gamma values for an emulsion.

In addition to the action of silver halide upon a developing solution, there is the reaction involving the oxygen of the air; while this reaction is much the same as the previous one, there are important differences. The reaction involves hydroquinone, metol, sodium sulfite, and oxygen that has dissolved, to form the familiar developing agent monosulfonates, practically inert sodium sulfate, and sodium hydroxide. Concentrations of hydroquinone, metol, and sodium sulfite are reduced, thus causing less developer activity, but the liberation of sodium hydroxide increases developer activity by raising the *p*H and hence increases the extent of ionization of the developing agents. The effect of the increase in *p*H may more than counteract the loss in developing-agent concentration, as is illustrated by the action of a developer of the class of *D-76*, which gains in activity as it is subjected to air oxidation.

It is evident that any developing solution that is being used in a developing machine involves factors and reactions that are related in a very complex manner. Every reaction involving hydroquinone and metol reduces the concentrations of these agents, but does so at a rate that depends upon the amount of film developed in a given time, the density of the developed image, the extent of developer oxidation, the amount of dissolved oxygen, the *p*H, the concentration of sodium sulfite, the temperature, and doubtless other factors. With use, the concentration of sodium sulfite also decreases, but the *p*H may either increase, decrease, or remain the same. Sensitometric or visual measurements of a particular film give few clews concerning the actual condition of the developer after it has been subjected to use.

It is necessary to use adequate methods of chemical analysis that permit a careful study of the behavior of each developer ingredient under each condition of use. The type of developing machine used, the kind of film being processed, the exposure of the film, the method of circulation, the values of gamma and density selected, the rates of travel of the film through the machines are factors that compel a critical analysis to be made of each situation, in order that an accurately operating, continuously replenished system may be designed.

The usual method of developer maintenance is based upon the addition of enough additional metol to counteract the density-depressing effect of increasing amounts of bromide ion, until a condition is reached for which the loss of emulsion speed can not be compensated. Here the useful life of the developer ceases, and it is normally discarded and a new batch is prepared. A continuously replenished system is based upon the addition of a bromide-free solution to the developing solution at a rate sufficient to dilute the bromide liberated and hold it at a constant concentration. In addition to diluting the bromide as it is formed within the developer, the ingredients that are used up in the reaction are to be replaced by the replenishing solution at exactly the precise rate necessary to maintain their concentrations at a constant value.

While it is true that continuously replenished systems lead to considerable economy of operation, the prime reason for their use lies in the uniformity of the resulting photographic quality. Under the batch system of replenishment, it is not usually possible to cause a developing solution to change in the concentrations of all its ingredients in precisely the manner that maintains uniform values of density and gamma or a uniform picture or sound quality, whereas it is evident that the exact maintenance of every developer ingredient at the concentration that produces good film quality must result in much closer adherence to standards than is possible with the batch system.

THEORY OF CONTINUOUS REPLENISHMENT

With an absolutely constant developing solution as a goal, it is first necessary to determine the important factors that influence the rate of development for a given emulsion. Painstaking research made in this laboratory, and doubtless duplicated elsewhere, shows that the following factors pertaining to the processing of film require consideration in order that the processing may be stabilized; factors not included pertain chiefly to film manufacturing and handling variations.

(*1*) Strength of the developing solution.
(*2*) Degree of developer agitation.
(*3*) Temperature of the developer.
(*4*) *p*H of the "short-stop" or fixing solution.
(*5*) Temperature during film drying.
(*6*) Humidity during film drying.

Of these variables, only the first presents any real control problem. Numbers *2*, *3*, *5*, and *6* are mechanical problems for which engineering equipment is available. Number *4* is a chemical problem moderately easy to control. The important chemical variables that influence the photographic strength of the developer are:

(*A*) Concentration of hydroquinone.
(*B*) Concentration of metol.
(*C*) Concentration of sodium sulfite.
(*D*) Concentration of bromide ion.
(*E*) *p*H.

Other factors, such as concentrations of other halides, alkalinities, and developing agent monosulfonates, have some effect, and these effects are important when used developers are to be synthesized, as Evans, Hanson, and Glasoe have shown,[2] but they need not be considered in a stabilized system of continuous replenishment, because such variables are of second-order magnitude. To explain the manner in which a continuously replenished system is derived, let us use a typical positive developer of the following formula as an illustration:

Hydroquinone	4.00 gm per liter
Metol	1.00
Sodium sulfite	40.0
Potassium bromide	2.50
*p*H	10.10

If these concentrations are required in order to produce good film quality, the attempt to maintain every ingredient constant requires a certain specific procedure. The only item over which the chemist has no direct control is the rate of release of bromide ion from the film. Since bromide ion can not easily be removed from the developer, it can only be diluted. This rate of release is primarily proportional to the rate of film travel through the machine and to the integrated density of the silver deposit. It is evident that, for the sample case above, it will be necessary to add one liter of bromide-free solution to the developer for every 2.50 grams of bromide liberated by the film, if the concentration is to remain constant at 2.50 grams per liter; hence a release of 3.4 ounces of bromide ion, expressed as potassium bromide, by 10,000 feet of exposed film in one hour requires dilution at the rate of 10 gallons per hour. The total quantity of developing solution that is present is of no concern. Whatever quantities of other ingredients that are used up in developing this 10,000 feet of film must be added to the replenisher in addition to the concentrations of these substances already present in the developer.

The rate of release of bromide ion thus becomes the determining factor for the rate of replenishment, and when only one certain concentration of bromide ion is permissible, the replenishment rate becomes fixed at the figure that satisfies the condition of equilibrium.

Since the rates of exhaustion of the developing agents and the sulfite are in proportion to the rate of release of bromide ion, it is possible to replace these substances by using the same solutions that are necessary to dilute the bromide, even though it is ideally necessary to use two different replenishing solutions to maintain a developing solution, where each would correct for the specific type of oxidation that the developer undergoes. For the halide oxidation, one solution would dilute the bromide, correct for the acid liberated, and replace the hydroquinone, metol, and sulfite used; for the air oxidation, the other solution would correct for the alkali, and replace the hydroquinone, metol, and sulfite in different proportion without diluting the bromide. The latter replenisher would contain the same concentration of bromide that was present in the developer. In actual practice, the errors introduced by combining these two replenishers are quite small, because there is little of one type of oxidation without the other.

Chemical analysis must be used to show the necessary amounts of hydroquinone, metol, and sulfite that are to be added to a replenisher to replace these items within the developer. The *p*H of the replenisher must be adjusted to the value that produces the desired *p*H within the developer; this value may be higher, lower, or the same, as conditions indicate.

From the above discussion, the general statement may be made that the replenisher must be stronger in hydroquinone, metol, and sulfite and weaker in bromide than the developer that is being maintained. The rate of addition of replenisher for a given type of film development is determined by the rate of release of bromide and by the bromide concentration that is being maintained.

DERIVATION OF A CONTINUOUSLY REPLENISHED PICTURE NEGATIVE DEVELOPER

Before any continuously replenished system can be considered, it is necessary to make a complete chemical study of the reactions that take place in the developer as it is used.[3]

Fig. 1 is a record of various chemical analyses for batches of picture negative developers, where the concentrations of hydroquinone, metol, and bromide are plotted against film footage. This developer was being replenished by the addition of a relatively concentrated solution of metol at a rate indicated by sensitometric tests. With use, the developer increased in bromide concentration because the replenishment rate was not sufficient to obtain proper dilution. No effort was made to replace hydroquinone since it was necessary to utilize the decrease in ratio of hydroquinone to metol to compensate for the influence of the increasing bromide upon emulsion speed. When the concentration of hydroquinone became low, most of the developer activity was carried by the metol, and there was no further opportunity to compensate for bromide; at this stage the developer needed to be discarded. Near the end of the useful life of the developer, but before the occurrence of any serious emulsion speed loss, the concentrations were as follows:

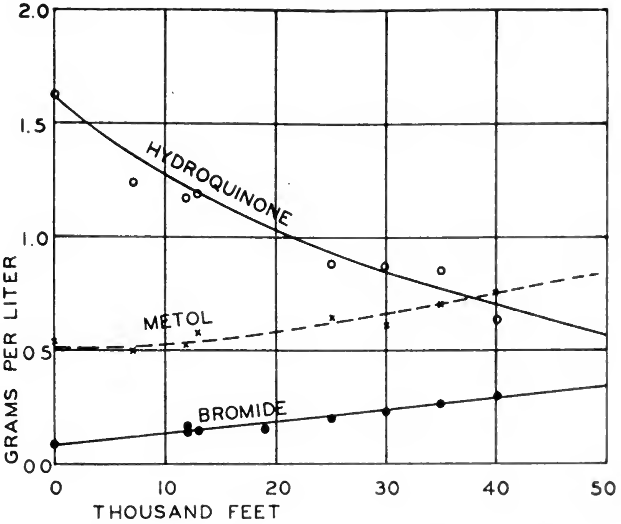

FIG. 1. Analyses of picture negative developer batches for various film footages.

Hydroquinone	0.50 gm per liter
Metol	0.80
Sodium sulfite	50.0
Potassium bromide	0.300

The average of many tests showed that 3000 feet of developed film released 1.0 ounce of bromide into this developer. Since the total amount of bromide present in the 450 gallons of developer was 18 ounces and since each strand of the developing machine handles 3000 feet of film per hour, in each hour it is necessary to add 25 gallons of bromide-free replenisher for each strand if the bromide concentration is to remain constant. Further tests showed that during this hour there were used up 4 ounces of hydroquinone, 1.5 ounces of metol, and 2 pounds of sodium sulfite. Therefore, in the 25 gallons of bromide-free solution that must be added per hour, per strand, these amounts of chemicals are needed in excess of the concentrations present in the developer at equilibrium. While chemical analyses have furnished the information necessary to determine replenishment needs, it is important that the rate of replenishment be made proportional to the rate of film travel through the machine. Charts have been prepared that indicate the correct rate of replenishment for any combination of development times, and since the system of replenishment is based entirely upon film footage, any errors that are the result of unusual film exposures are self-correcting and not accumulative.

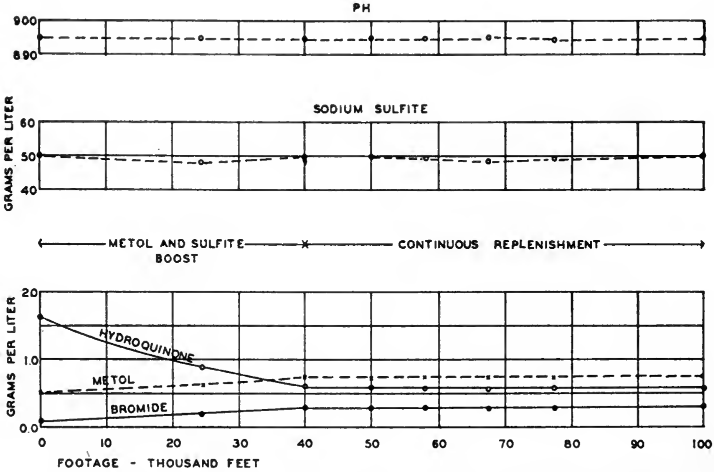

FIG. 2. Analyses of picture negative developer during establishment of continuously replenished system.

Fig. 2 shows the analyzed concentrations of the picture negative developer during the installation of this system. The developer was handled as a batch and replenished as such until 40,000 feet of film had been processed, after which it was replenished continuously. This developer might have been prepared synthetically at the desired equilibrium concentrations with identical results.[2]

A CONTINUOUSLY REPLENISHED SOUND-TRACK NEGATIVE DEVELOPER

The principles that were outlined for the derivation of a picture negative developer apply equally well to the formulation of a similar system for sound-track negative. The chief difference lies in the character of the negative film; the sound-track area is much smaller than that of the picture; and the density and gamma values are somewhat different. Hence for each foot of film developed, the sound-track uses considerably less of the developing agents and releases considerably less bromide than does the picture. This difference would make it possible to replenish the sound-track negative developer at a much lower rate, but instead, advantage is taken to operate the developer at a lower bromide concentration in order to obtain maximum emulsion speed.

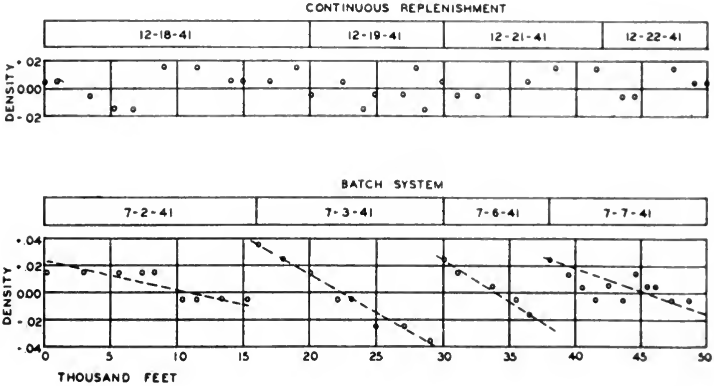

FIG. 3. Calculated densities at constant gamma for sound-track negative under continuous replenishment and under the batch system.

For a development rate of 4000 feet per hour this developer requires dilution at 35 gallons per hour in order to maintain a potassium bromide concentration of 0.160 gram per liter. Because so little chemical action takes place in this developer, the replenisher formula is very little stronger in developing agents than is the developer. So little metol is used that only an additional ounce in 300 gallons is necessary in the replenisher. Air oxidation is the dominant oxidation in this developer; consequently the *p*H of the replenisher is made considerably less than that of the developer so that the developer *p*H remains constant.

Continuous replenishment has been of great advantage in this developer, especially with the use of fine-grain negative films. Tests have shown that these films are three times as sensitive to a bromide concentration change as the conventional type; consequently careful chemical control is very important.

Fig. 3 compares, for four consecutive days in each case, calculated values of density for a given gamma as plotted against film footage, for the two types of developer systems.

It is evident that continuous replenishment has improved the accuracy of development and eliminated differences between beginnings and ends of runs.

A CONTINUOUSLY REPLENISHED POSITIVE DEVELOPER

Because positive emulsions can be made to give good quality when the bromide concentration is high in a developer, and because it is not important to maintain a high emulsion speed of film used for this purpose, positive emulsions can be processed with much greater economy than can negative emulsions. A continuous system of replenishment yields from 100 to 150 feet of developed film for each gallon of replenisher used in a negative system, whereas there are 1200 feet of film processed for each gallon of positive replenisher used.

As was the case with the negative systems discussed previously, it is necessary to select the desired bromide concentration for this system, but since almost any reasonable figure can be tolerated, it is convenient to use a figure that results from another factor. If no squeegee is used to return the volume of developer carried off by the film as it leaves the developing unit, an amount of developer is removed that is primarily a function of the film footage and only secondarily a function of the speed of the film through the machine. Therefore, replacement of the volume of developer lost, as film is processed, by an equal volume of replenisher will maintain the total volume of developing solution at a constant figure and result in an equilibrium concentration of bromide. As our particular system is designed, the bromide comes to equilibrium at a concentration of 3.50 grams per liter. The system of continuous replenishment for the positive developer thus is greatly simplified; it operates solely upon the basis of maintaining the total volume of developer constant and the adjustment of the rate of replenishment to values necessary to satisfy this condition.

The greatest amount of development, of all three systems, occurs in the positive system; and this fact, coupled with the small amount of replenisher used per foot of film developed, causes the positive system to have the greatest differential in ingredient concentrations between replenisher and developer. For example, in order to maintain the hydroquinone concentration at 2.0 grams per liter in the developer, it is necessary to adjust this concentration to about 6.0 grams per liter in the replenisher. Consequently the positive developer requires the most frequent chemical analyses of all the systems in order that it may be controlled.

ERRORS AND CHEMICAL CONTROL METHOD

In the systems of continuous replenishment that have been discussed, the proper replenishment rate has been determined, either directly or indirectly, as a function of film footage passing through the machine; the actual exposure that the film has received and the amounts of silver actually developed have not been considered. It would be expected that differences in integrated developed film density would require modification of the replenishing solutions, and such is actually the case. However, the large volumes of developer solutions that are used contrast with the small degree of chemical action that takes place, and over moderately short periods of time the developing solution concentrations will show no change. To make the system of continuous replenishment practicable for use in a production laboratory, it is necessary to adjust the replenishment for an average processing condition and then, by periodic chemical analysis, to make correction of the developer to its "standard" formula. If the chemical analyses are frequent enough and correction is made immediately, the developer ingredients are held very close to constant values. It is impracticable to make corrections in the replenisher formula to correct for errors in the developer formula unless these errors are consistently in one direction.

Experience has taught us that the number of analyses that are needed for efficient control of the developers is not excessive. For the picture negative developer, *p*H determinations are made every two hours of use, bromide determinations are made every day, and analyses for hydroquinone, metol, and sulfite are performed twice a week. The entire system is so close to equilibrium that the greatest error that could be attributed to chemical inaccuracies is ±0.01 in density units. The sound-negative developer is controlled in similar fashion, with the one exception that the hydroquinone, metol, and sulfite analyses are performed weekly instead of twice every week.

Here the replenisher is so nearly like the developer, because of the small chemical action involved, that the system is extremely stable. The positive developer requires analyses for *p*H and for bromide every four hours, and daily analyses for hydroquinone, metol, and sodium sulfite. Under these conditions this developer is easily controlled to ±0.02 density unit.

Chemical analyses are made upon developers for *p*H by the use of the Beckman Laboratory Model *p*H Meter fitted with a Type *E* glass electrode. Determinations of *p*H upon fixing baths are made with the Beckman Industrial Model *p*H Meter, equipped with the conventional type glass electrode. Analyses for hydroquinone and for metol are made by the extraction of the developing agents with ethyl ether and titration with standard iodine solution.[4] Analyses for sodium sulfite are obtained by the titration of a known quantity of iodine with the developer.[5] Analyses are made for bromide by the potentiometric titration of the acidified developer with silver nitrate, using a silver electrode and a calomel electrode.[6]

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THE PRACTICAL ASPECT OF EDGE-NUMBERING 16-MM FILM*

H. A. WITT**

Summary.—*The use of the edge-number and how it is generally applied in the industry, and the advantages of edge-numbering at 16 frames as a standard for 16-mm film are discussed.*

It has been long-accepted practice to edge-number 16-mm film in relation to 35-mm frames. Such practice has proved advantageous in complex films, such as one constructed of some 16-mm film combined with 35-mm to complete a final subject in finished form on 16-mm, still maintaining all the advantages gained in the past practice by the use of 35-mm.

It has long been essential in all branches of the industry to edge-number 35-mm film. Without the benefit of edge-numbering, many hours of additional work would be necessary in handling the multitude of details in the assembling of a motion picture production. Edge-numbering is found to be of practical value in the laboratory as designations of the raw-stock in relation to the sensitometric strips; as indications to the laboratory for the printing of rushes or designated portions of takes to be printed in some abnormal manner; for indicating trick effects; and for cataloguing and identifying prints in vaults. It has proved invaluable in the final assembling of any negative where a selection is made in terms of feet of film.

Although none of these would seem to indicate any necessity for a definite standard, the 16-frame interval between edge-numbers has become accepted practice and the majority of those involved in such detail work have become accustomed to such designations.

If we are to adopt the newly recommended practice of edge-numbering 16-mm film at intervals of 40 frames, we should have a new designation bearing no relation to the 35-mm edge-numbering with reference to frame count.

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* Presented at the meeting of the Mid-West Section, Feb. 24, 1942; and at the 1942 Spring Meeting of the Society at Hollywood, Calif.

** Wilding Picture Productions, Inc., Chicago, Ill.

As to the relative merits of edge-numbering at 40-frame intervals or by any other method, let us take a practical case of a simple picture and follow it through its various steps.

To the cameraman, any scheme of edge-numbering would be acceptable, inasmuch as he uses it mainly for the designation of trick effects or printer light corrections. The laboratory requires no special method of edge-numbering inasmuch as its use is mostly for reference and selection.

The film editor, however, has a very definite use for the edge-number. It is used for the designation and selection of material, storage, and an indication of synchronism of sound and picture when edited as separate track and picture. A film editor could have for final assembly into a picture the following combination:

a 16-mm picture,
a 35-mm sound-track, to be edited into a picture interspersed with standard library stock footage (35-mm).

The 35-mm track and picture are edge-numbered at intervals of 16 frames and the 16-mm picture at 40 frames. In synchonizing picture action with the voice track, the editor has two different designations and as he progresses to the layout of his optical work for normal dissolves or fades from his 35-mm stock picture library material to his 16-mm picture, his procedure becomes highly involved. The possibility of error is greatly increased because of the usual practice of specifying for such trick effects a fine-grain duplicating master positive or dupe negative and of ordering such material through the laboratory according to edge-number.

If we are to revert to the practice of numbering the working print, we should have a problem which is unresolvable under the newly recommended practice, because we now have a 35-mm sound-track that should bear some designation comparable to that of the 16-mm film being run in combination with it.

In the final assembly of the negative the edge-number is used primarily as a reference in selecting material, but the actual assembly becomes somewhat complex due to the material that is being matched. In the final assembling of the 16-mm negative track and 16-mm negative picture, the following are to be checked and matched:

16-mm re-recorded sound-track (negative),
16-mm original picture (negative),
16-mm dupe picture (negative),
35-mm sound-track print,

16-mm picture print,
35-mm library picture print.

It is obvious that with these various types of film sizes and edge-number designations, a considerable loss of time and great likelihood of error on the part of the editor will result.

In the steps necessary to the final completion of this picture, the edge-number designations are frequently of prime importance in either selection or layout. We need comparable designations for both 35-mm and 16-mm film. The suggestion has been made that 16-mm film be numbered at intervals of 16 frames, or 32 frames. A 16-frame interval would be too small to be of any real value, but by using a 32-frame interval and omitting the even numbers and using a star or other identifying mark at the 16th frame, the system would become comparable to the 35-mm.

A NEW ELECTROSTATIC AIR-CLEANER AND ITS APPLICATION TO THE MOTION PICTURE INDUSTRY*

HENRY GITTERMAN**

Summary.—*A brief description of the principles and early development of electrostatic precipitation, and a brief description of a new air-cleaner using the electrostatic principle that generates practically no ozone. Reference is made to recent applications of the new precipitator.*

The theory of electrostatic precipitation is not new. In 1824 Hohlfield described the action of an electrical discharge upon smoke. However, no practical significance was attached to his discovery. In 1884 Sir Oliver Lodge made the first practical use of the principle of electrostatic precipitation in the removal of fumes from a lead smelter.

Around 1906 Dr. Cottrell was successful in making use of this principle in the removal of fumes in zinc and lead smelters. Dr. Cottrell was able to patent his method, turning the patent over to the Research Corporation. This corporation has been successful ever since in collecting troublesome fumes in any number of industries. Nearly all of us are familiar with the Cottrell precipitators which this corporation has installed in the smokestacks of many of our public utilities. The Cottrell system uses extremely high voltages and high currents, which in turn cause the generation of huge amounts of ozone, for which reason the system has never been practicable in cleaning atmospheric air for breathing purposes, or where the action of ozone could be detrimental to product or equipment.

Principle.—It was not until 1931 that Mr. G. W. Penney, manager of the Electrophysics Division of the Westinghouse Research Laboratories, was able to announce an air cleaner using the principle of electrostatic precipitation that generated practically no ozone. The functions of charging and collecting the solid particles in the air were

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* Presented at the 1941 Fall Meeting at New York, N. Y.; received February 2, 1942.

** Westinghouse Electric & Manufacturing Co.; New York, N. Y.

separated and the necessary operating voltages reduced to 13,000 volts maximum. This was accomplished through the use of a collecter cell, consisting of cylindrical rods alternating with fine tungsten wires. Thirteen thousand volts is applied between the wire and the rod, creating a strong electrostatic field. As the particles in the air-stream pass through this field, all the particles receive a positive charge. Immediately following this electrostatic field in the line of air-flow are placed parallel plates $^5/_{16}$ inch apart. These plates are charged with 6000 volts d-c. The positively charged particles are attracted to the negative plates, grounded and deposited. Fig. 1 illustrates this principle.

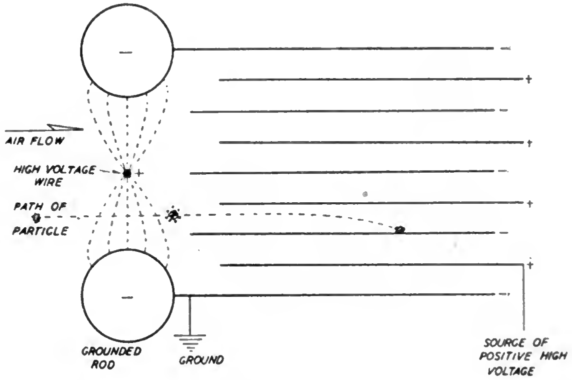

FIG. 1. Operation of electrostatic air-cleaner.

Uncleaned Air | Mechanically Cleaned Air | Electrostatically Cleaned Air

FIG. 2. Relative efficiency of air-cleaning methods (10,000 cu-ft of air through each sample).

An outstanding improvement due to this development is the fact that for the first time electrostatically cleaned air can be breathed.

A power-pack is used to supply the direct current needed for the operation of the ionizer section and the collector section. This power-pack consists essentially of transformers to increase ordinary 110–120-volt single-phase, 60-cycle current to the voltages required. This current is then rectified by means of rectifier tubes. A pulsating direct current results, which is smoothed out into a pure direct current by means of capacitors. Extremely small currents are needed. For example, 40,000 cubic feet of air per minute can be cleaned with an expenditure of only 400 watts.

FIG. 3. Standard collector cell.

Efficiency.—All our experimental work to gain an idea of comparative efficiency has been based upon a particle-count system of testing. On this basis we find that the best of air-filters can remove only about 32 per cent of the particles in the air-stream. On the other hand, electrostatic precipitation removes as much as 97 per cent of the particles. The average commercial air-filter removes in the neighborhood of 10 per cent of the particles. It is safe to say that electrostatic precipitation is the most efficient method of air-cleaning ever developed.

Fig. 2 illustrates the comparative efficiency of an ordinary air-filter with electrostatic precipitation. This method of testing is known as "the blackness test." The actual test consists in drawing air through a standard laboratory cloth for a given length of time on the dirty-air side of the air-cleaner. The same procedure is followed on the clean-air side until a spot of equal discoloration is arrived at. The ratio of the time needed to accomplish this is then evaluated and a percentage of efficiency is obtained. As an example, suppose that it would take one minute to get a certain blackness on the dirty-air side and ten minutes to get equal blackness on the clean-air side. We would then have a ratio in time of 1:10 or 90 per cent efficiency.

Fig. 3 shows a standard collector cell. It is 8 inches wide, 36 inches high, and 24 inches deep. This cell is capable of handling 600 cubic feet of air per minute. The velocity of the air is 300 feet per minute.

In Fig. 4 we see illustrated the method of placing the cells in an ordinary air-distributing duct. It is obvious that this method admits of great flexibility in fitting the cells into the duct. The cells have a foundation consisting of a bedplate that inclines the cells at an 8-degree angle from the vertical. Water is used to wash the cells and remove the precipitate. The inclination of the cells permits easy drainage in the cleaning operation.

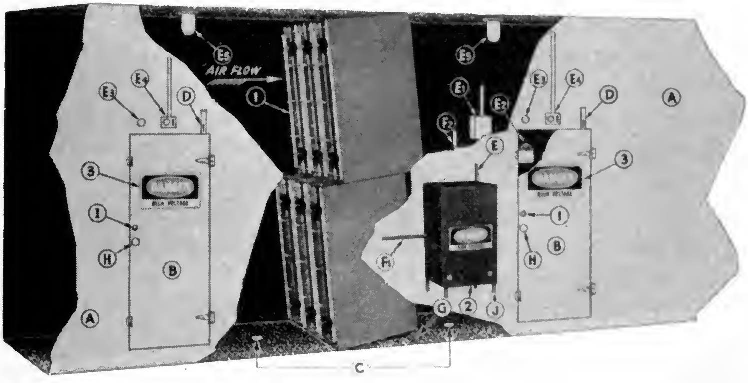

FIG. 4. Method of placing cells in ordinary air-distributing duct

Self-contained units with one to three cells are available for small installations. It is only necessary to attach them to a source of air and the proper duct work, combined with a blower system.

Application.—For a number of years after Dr. Penney's original development of this equipment, various trial applications were made in the field. Refinements in design were made and finally in 1938 the apparatus was officially announced as a commercial product.

Since then hundreds of installations have been made. For instance Precipitron-cleaned air is supplied to huge steel mill motors and generators for cooling purposes. It has been found that the old methods of air-cleaning allowed many particles to enter the motors and generators, causing damage to the insulation. In addition, periodic shut-downs were necessary in order to blow out the dirt that had accumulated. Through the use of Precipitron air-cleaning, these troubles have been eliminated.

In commercial applications—offices, restaurants, stores—it has also been found that Precipitron air-cleaning preserves interior decoration by removing the small particles that discolor and disintegrate furnishings. Lighting efficiency can be maintained at a maximum since dust does not accumulate on lighting fixtures, walls, or ceilings.

Certain particles in the air-stream are organic in composition, and when these particles get into air-conditioning and ventilation ducts they putrify and generate obnoxious odors. Electrostatic precipitation removes these particles from the air-stream and permits more pleasant breathing air. As a result the amount of fresh air brought into ventilating and air-conditioning systems can be reduced and great savings in cooling and heating energy effected.

The optical and film industries also have been benefited greatly by this method of air-cleaning. These industries need the cleanest air possible in their manufacturing and processing divisions. All the major film-manufacturing concerns use this method of air-cleaning. Many of the optical instrument manufacturers have found it indispensable in their process work.

Little if any work has been done in electrostatic air-cleaning connected with the air-conditioning of modern theaters. It is obvious that great economies and improvements can be made through the use of this equipment for such applications. We hope to be able to announce successful applications in the near future. Applications for Precipitron air-cleaning exist in nearly every industry, since dust is a universal problem.

CURRENT LITERATURE OF INTEREST TO THE MOTION PICTURE ENGINEER

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

American Cinematographer

23 (June, 1942), No. 6

Visual Suggestion Can Enhance "Rationed" Sets (pp. 246–247)	J. W. Howe
Technical Progress of Russia's Film Industry (pp. 248–249, 285)	G. L. Irsky
Animated Cartoon Production Today (pp. 250–251, 282–285), Pt. III—Animation	C. Fallberg
Training Films in the U. S. Navy (pp. 252–253, 281–282)	W. Exton, Jr.
Choosing Film Materials for Professional 16-Mm Production (pp. 254, 278)	J. A. Larsen, Jr.
A.S.C. and Academy to Train Camera Men for Army Service (pp. 255, 278)	
Debunking Filtering (pp. 262, 274, 276)	A. J. Stout
Making Composition Work for You (pp. 263, 272, 274)	P. Tannura

British Kinematograph Society, Journal

5 (Jan., 1942), No. 1

Film Editing (pp. 2–9)	S. Cole
Future Trends in Laboratory Practice (pp. 10–19)	I. D. Wratten
Difficulties in Producing Imbibition Prints from a Tri-Pack Original (pp. 20–26)	M. V. Hoare

Educational Screen

21 (May, 1942), No. 5

Motion Pictures—Not for Theaters (pp. 180–182), Pt. 37	A. E. Krows

International Projectionist

17 (Mar., 1942), No. 3

Projection Room Uses of Tube Data (pp. 7–9, 20)	L. Chadbourne
Color of Light on the Projection Screen (pp. 10–12)	M. R. Null, W. W. Lozier, and D. B. Joy

Optical Illusions Producing Three-Dimensional Effects (pp. 16–18)	T. M. EDISON
Conserving Critical Materials in the Projection Room (pp. 19, 23)	

17 (Apr., 1942), No. 4

Reducing Trouble-Shooting to Systematized Procedure (pp. 7–8, 22)	L. CHADBOURNE
New 13.6-Mm Carbons for Increased Screen Light 9–10)	M. T. JONES, W. W. LOZIER, AND D. B. JOY
Theater Equipment Goes to War (p. 11)	
Review of Projection Fundamentals (pp. 12–14), Pt. I. Kinds of Electric Current	
Underwriters Code as It Affects Projection Rooms (pp. 16–19)	

Motion Picture Herald

147 (May 16, 1942), No. 7

New Screen Aids Television for Theaters (p. 93)

147 (May 30, 1942), No. 9

Wartime Conservation in Theater Projection (pp. 23–26, 31)	
Determining the Efficiency of Your Reflector-Lens System (pp. 27–28)	C. E. SHULTZ

Optical Society of America, Journal

32 (May, 1942), No. 5

Visual Sensitivities to Color Differences in Daylight (pp. 247–274)	D. L. MACADAM
The Photographic Reciprocity-Law Failure and the Ionic Conductivity of the Silver Halides (pp. 299–303)	J. H. WEBB

SOCIETY ANNOUNCEMENTS

1942 FALL CONVENTION

HOTEL PENNSYLVANIA, NEW YORK, N. Y.
OCT. 27TH-29TH, INCLUSIVE

After a very successful convention at Hollywood last May, the Society has decided to continue holding its meetings twice a year, at least so long as the holding of conventions does not interfere with the war effort. In fact, it is felt that the continuance of technical activities in societies such as our own is important in an age such as the present when both peacetime and wartime activities are so highly technologic.

The Fall Convention will be held at the Hotel Pennsylvania, New York, October 27th to 29th, inclusive. These dates have been chosen in view of the fact that the Acoustical Society of America will hold its convention at the same place on October 30th and 31st. Those who are interested in the activities of both organizations may thus take in both conventions in one trip. Details of the Fall Convention will be published in the next issue of the JOURNAL. Those contemplating presenting papers should communicate with the Office of the Society at the earliest possible date. (*See inside front cover.*)

ADMISSIONS COMMITTEE

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

BRIGGS, ALLEN
3117 Calhoun Blvd.,
Minneapolis, Minn.
CHERRY, HERBERT
5310 Magnolia St.,
Philadelphia, Pa.
FERREL, G. F.
Box 191,
Belton, Mo.
FLECK, H. R.
Vaporate Co. Inc.,
130 West 46th St.,
New York, N. Y.
GOEHNER, W. R.
262 Glenwood Ave.,
East Orange, N. J.
GOLDBLOOM, LEROY
3509 Ingleside Ave.,
Baltimore, Md.
HEYER, JOHN
52 Fordholm Road,
Hawthorn, E. 2,
Victoria, Australia
HUGHSON, M. R.
141 Brantwood Road,
Snyder, N. Y.

LAYFIELD, F. E.
323 South Xanthus,
Tulsa, Okla.

PAGES, M. H.
Jose P. Varela 4571,
Bella Vista, B. A.

REISS, MEYER
811 Quincy St., N. W.,
Washington, D. C.

SCHLOEMER, GENE
605 Park St.,
Rolla, Mo.

SMITH, D. G.
Technicolor Motion Picture Corp.,
30 Rockefeller Plaza,
New York, N. Y.

THOMPSON, R. L.
1005 East Mulberry St.,
Evansville, Ind.

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

WEISSER, F. E.
Commack Road,
Islip, L. I., N. Y.

JOURNAL OF THE SOCIETY OF MOTION PICTURE ENGINEERS

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JOURNAL OF THE SOCIETY OF MOTION PICTURE ENGINEERS

SYLVAN HARRIS, EDITOR

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CINEMATOGRAPHY IN THE HOLLYWOOD STUDIES (1942)

Summary.—*Current practices in cinematography as followed in the Hollywood studios are described. Some of the subjects covered are camera equipment, set lighting, operation of camera crews, exteriors and use of booster lights, exteriors taken indoors, make-up, diffusion, coated lenses, use of light-meters, color contrast of sets, set and production designs, value of hard light for exteriors and interiors, stand-ins, air photography, matching stock shots, Technicolor and bipack, Kodachrome, and monopack.*

Black and White Cinematography

JOHN W. BOYLE**

We have come a long way from the time, some twenty years ago, when one was able to recognize the cameraman by the fact that he wore his cap backward, just as one could tell the director by his puttees. No longer does the producer say, "A rock is a rock; shoot it in Griffith Park." Most of the pictures today are made in the studios or on the back lot, and it is the job of the director of photography to set the mood of the story by lighting the scenes in the proper key and using what photographic effects he can conceive and execute on short notice. Although much time is devoted to the preparation of the story and dialog of a picture, only on rare occasions is sufficient preparation allowed for the technical problems involved in set and location planning. Successful pictures result from the teamwork of the various technical staffs involved, with the purpose of achieving the finest artistic and commercial photographic results on every picture produced, be it a simple "short" or a feature.

On some of the more pretentious productions "production designers" have contributed much to further the artistic photographing of

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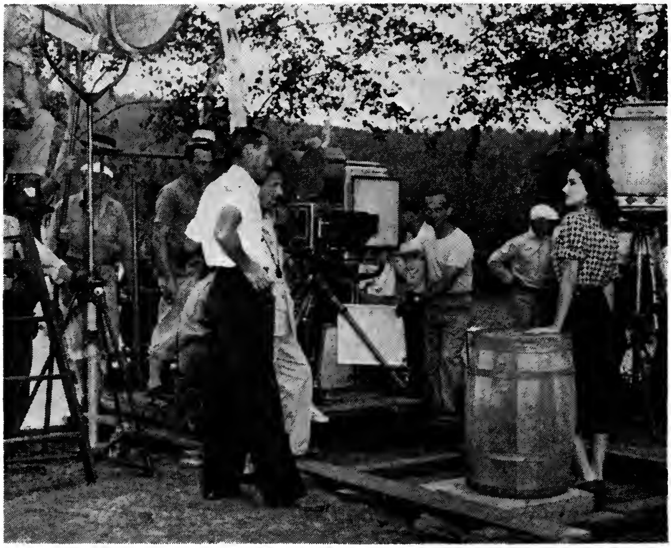
* Presented at the 1942 Spring Meeting at Hollywood, Calif.

** Universal Studios, Universal City, Calif.

the picture. These production designers are skilled artists, and are called in well in advance of the actual production. They become familiar with the script, cast, and the amount of money that may be spent on the production, and are able to furnish to the director and cameraman a series of sketches showing what the actual scenes should look like. It is hoped that this kind of preparation will come into general use for all types of pictures.

On this subject, Jack Okey, art director for Alexander Korda's *Jungle Book*, has written the following:



Scene from *Captains of the Clouds* showing use of booster lights for technicolor exterior shot. (*Warner Bros.-First National.*)

"The present-day motion picture is without question the most complex medium of expression ever devised by man. It is certainly not the brain-child of any one person but rather the sum of many individual contributions. All creative talents are called upon to contribute their efforts, the maker of pictures among them. Nothing can paint a picture of a picture as well as a picture.

"In reality a motion picture is a series of pictures. The man most fitted to create pictures is an artist, with his highly specialized training and talent. A man having the power of visualizing an idea and drawing a picture of it that all may see, certainly has a place in the making of motion pictures.

"If the producer would call upon the artist at the same time he called upon his writer, and would have him prepare preliminary drawings or paintings of the subject in mind, there is little doubt that the sketches would help both the producer and the writer to decide many matters; in fact, the director and the chief cameraman should be included in these early conferences. Often a simple sketch will be of assistance to the writer in showing plainly what might take thousands of words to explain. By predetermining questions in this early stage, many costly delays and disappointments can be avoided. Decisions can be made from the sketches as to the desirable lighting effects, wardrobe, characterization, location, sets, and even the very

Effect of water reflections, produced by moving broken glass reflecting light from shots.

spirit or mood of the whole production. During the preparation period, the artist can make a series of sketches to act as future reminders of the many discussions taking place at the time. As the script develops, a series of sketches, known as continuity sketches, can be made of the various scenes. They provide advance information, and make it possible for the departments to predetermine their work in an intelligent and artistic manner.

"Often on the set, a man under the excitement and stress of the many responsibilities resting upon him may not be able to recall readily what he had previously decided to do with a certain situation. A quick glance at the sketches will recall the entire scheme to him. The sketches can be referred to in the same way in which the written script is used. Sketches that break up the written scene into long, medium, and close shots can stimulate the creative ability of both director and cameraman. They can be guides to strong, beautiful, dramatic patterns or compositions.

Dolly shot on location, with booster lights. Dolly tracks alongside rails permit trucking shot of incoming train. (*Paramount Pictures.*)

"The arrangement of the characters on the screen in good composition can do much to heighten the story. As one simple, well known example, in a "close-up" of an aggressor the head should be well forward on the picture plane, leaving more space behind the head than in front of it; whereas the close-up of the defendant should show more space in front of the head than behind it. Sketches can convey such things as reminders to all concerned throughout the whole production period.

"The word 'composition' has appeared here several times. It is a word almost impossible to define. There are a few elementary rules to govern the building of a picture, such as rhythm without repetition, the bearing of one thing upon another, the relative influence of lights and darks, but these are so self-evident that the painter does not think of them while he is at work. He attacks his subject with his inherent good taste or talent, composing the drama of the subject and injecting into it as much beauty as he can conceive.

An example of overhead lighting.

"I do not mean to infer that there have not been many beautiful pictures recorded in the past, because there most certainly have. What I mean to point out is an easier and surer way, a method of suggestion and help, a wiser procedure."

The short time allotted in practice to the cinematographer to read the script and prepare for production should be emphasized. It is a common occurrence to finish one picture on a Saturday night and be handed a script for a new picture to start the following Monday morning. The cinematographer must then spend Sunday in acquainting himself with the final version of the script; arriving on the set early Monday morning he finds the painters still painting and the set dressers still at work. However, none of these activities have deterred the "gaffer" or chief electrician from roughing in the lighting and in placing the overhead units on scaffolds above the set.

With screen stories today overloaded with dialog, it is important that the picture be kept moving. This calls for much camera movement and the shifting of the cast from one position to another throughout the set. Such camera movements involve much study in lighting and composition, and here again it is only by the complete coördination of all departments concerned that the smooth, finished results one sees on the screen are possible. The "operative" cameraman must know his cue to "pan"; the sound technicians must have their cues and must know when and where to move the microphone without causing shadows; the mixer must know when to change the fader setting; the "grip" must know when and at what speed to "dolly" the camera; the assistant cameraman must be constantly alert and must anticipate each actor's move and keep the lens focused always at the proper distance (most scenes, especially those showing two or more actors in the scene, are shot at "split focus," and since the actors do not always keep to their marks on the floor, the assistant must use his judgment). Other members of the staff must also know their cues; the electricians, for instance, must known when to dim or brighten certain lighting units, by the aid of dimmers. A good dimmer operator will often compensate for errors of the actors in missing their marks by brightening the light if the actors do not come far enough forward or by dimming the light if they come too close. It is such coördination of all departments that makes for success; sometimes a scene that is perfect from the dialog or action standpoint is spoiled because someone did not "hit his marks" correctly. Constant attention and expert handling of the various gadgets by these technicians behind the camera have saved many a production hour for the company.

While modern camera equipment has somewhat simplified these tasks, it is not possible for every unit, even in the major studios, to be equipped with the latest model camera; hence a compromise must often be effected under certain conditions. For example, it is common practice to start a scene with a "big head" close-up or insert, and then dolly back to a medium or long shot. This calls for variable diffusion, and only on the most modern cameras is variable diffusion practicable. A compromise adopted in such cases is the use of a slight amount of diffusion, which softens the extreme close-up somewhat and yet is not objectionable in the long shot. With the new Fox camera and the latest Mitchell camera, the diffusion is adjustable from as soft an effect as may be desired for the big close-up to absolute clearness or no diffusion in the medium or long shot. Since variable diffusion is usually necessary in making dolly shots, an additional assistant is required to manipulate the device, which leads to crowding on the dolly or rotambulator. Metro-Goldwyn-Mayer Studios have overcome the difficulty by designing a remote-control device for operating both the follow focus and the variable diffusion.

The "set" procedure is as follows: The set is prepared and dressed, and the night crew or "swing gang" rigs the overhead lighting units, deliberately placing on the scaffolds more units than may be necessary, as it is more economical to have the units already in place than to take time to place them once operations on the set have begun. The cameraman and chief electrician having learned whether the scene is to be a night or day sequence, the electrical crew proceeds to rough in the lighting and wire the necessary fixtures. If the first sequence happens to be an interior shot with the sun shining brightly outside, preparations are made to light the set in a rather high, or day, key. The required, or desired, position of the sun is determined, and high-intensity arc lamps are placed so as to project a stream of light through a door or window, or both, and cast shadows in the proper direction. If both night and day sequences are to be photographed on the same set, then a decided contrast in lighting must be achieved by keeping the day scenes in a high key and the night scenes in a low key.

The director and cinematographer next confer as to the best way in which to play the action called for by the script, and the cast is called in and is rehearsed by the director. The cinematographer watches the action through a finder which he carries about the set; behind him follows an assistant, who marks the floor with small pieces of adhesive tape indicating points at which the actors stop in their motions, while the grip marks the various camera positions so that he may lay the track along which the dolly rolls, since a good percentage of shots are made from dollies these days. In the meantime other members of the cast and the crew watch the rehearsal. After the first rehearsal the "second team," or "stand-ins," are brought in, and the cameraman and gaffer proceed to light them in their various positions. The camera dolly is put into place on its tracks and a mechanical rehearsal follows, the stand-ins walking through the action and stopping at the various positions indicated by the tapes on the floor, for the benefit of the electricians, camera crew, and sound men. The grips, besides timing their dolly moves and seeing that the dolly operates with absolute quiet, search in the meantime for stray light-rays that might strike the lens or the diffusion mediums in front of the lens. After all lights have been "goboed" and dolly movements corrected, the lights are adjusted as may have been found necessary, and the "first team" is called in for a dress rehearsal. This final dress rehearsal with the actors themselves allows the director and cinematographer to make final corrections in lighting and movement. It is not unusual during such dress rehearsals to alter or delete certain lines of dialog; such changes in turn necessitate changes in the camera movement and dolly timing. After such corrections have been made, microphone shadows eliminated from the camera field, and dolly movements smoothed out, the crew and cast are ready for a "take." Rarely is the first take satisfactory unless the scene is a very simple one. Additional takes, or retakes, are made until a satisfactory one is obtained, with such lighting corrections being made as might be necessary.

Because of the variability of the weather, the unwanted noises of the outdoors, and other difficulties, more and more exterior scenes are being photographed inside the studios. These artificial exteriors are more convincing today than they used to be because of many technical improvements and advances. The speed of emulsions has been increased, enabling the cameraman to "stop down" the lens while using only slightly additional light. The "special effects" men can assist the illusion by hanging leafy tree branches in such positions as to cast pleasing shadow patterns on walls and buildings; slight motion of the leaves creates a convincing illusion of outdoors. The use of water and glass surfaces, with the proper reflection and agitation, leads to many realistic marine effects in both night and day shots.

Make-up in motion pictures compares to retouching of "still pictures"; in other words the artists must be "retouched" before they are photographed. Naturally there are some whose complexions require hardly any make-up, but in most cases make-up is necessary to cover slight skin blemishes and smooth out the skin textures. Arthur

Miller reports that in the production *How Green Was My Valley* none of the cast wore make-up except the mother and daughter. The men were coal miners, and looked the part; however, these same actors in a modern story with a drawing room setting would no doubt have been made up. Most of the studios are well organized with good make-up departments, and their coöperation with the cameramen has been most helpful.

While there is no question that the new high-speed fine-grain panchromatic emulsions and the improved American-made lenses lead to clean-cut photography, the modern electrical equipment is also a very important contributing factor. The lighting units have been brought well under control; the light can be directed by "barn doors" to the spots desired; and numerous other gadgets may be used for screening and softening the light in certain areas. Dimmers and their operators play very important parts in almost every scene. Often the camera and operators are so close to an actor that their shadows appear in the scene; by dimming the lamp causing these shadows the objection is eliminated, and the lamp is brought up to its proper brightness after the camera is out of range. Small units are helpful when working in congested areas, and much credit should be given to the studio electricians for their ingenuity in handling the small units so that they deliver the necessary light without being seen by the camera.

The use of artificial light outdoors is common practice nowadays for the simple reason that it has been found to be an economy. Lamps on location allow quicker set-ups. The units are more flexible and can be placed where desired and, unlike reflectors, need not be placed where the sun is shining. While both reflectors and lamps are used on location, the lamps are much better for close-ups and intimate action; they can be easily controlled and are not so hard on the artists' eyes. For lighting wooded sets and sets in congested areas, lamps are indispensible. It is not unusual to finish a day's work on location after all the sunlight has gone, in some cases after darkness has set in. Matching the artificial light with daylight is an art that most of the men have mastered. Likewise, it is sometimes necessary to shoot night scenes in the daytime; if the locations are picked with discretion and the correct filters and booster lights are used, such night exteriors can be handled economically. When production costs rise for one reason or another, the studios economize, especially on the lower-budget pictures, by using standing sets and cloth backings, and by taking other short-cuts. The cameraman is expected to use his art and imagination in manipulating the lights and the camera so as to cover up such deficiencies.

Practical cinematography has led to many improvements in the art. As newer and better films became available they were rapidly adopted, for which reason the art of the cameraman is constantly changing. Recommendations and suggestions of the cameramen played a part in the development and application of the photoelectric exposure meter; in most studios the meter is used to establish the key lighting, and, with the increasing use of these precision instruments, pictures are now being printed very uniformly, despite the widely varying types of lighting and effects employed.

The method of calibrating lenses by measuring the transmitted light with a photoelectric meter, as developed by the Camera Department of Twentieth Century-Fox under Dan Clark, has eliminated practially all errors of exposure. A recent test of 150 lenses so calibrated, regardless of focal length, make of lens, *etc.*, and used under identical conditions, gave exact exposure at a given stop. It has also made possible the effective use of coated lenses, giving greater contrast and better definition as compared with uncoated ones.

Putting Clouds into Exterior Scenes

CHARLES G. CLARKE*

A landscape that includes a cloud-flecked sky is far more attractive than the same scene without the clouds, particularly in photographic landscapes, where, without the benefit of color, the cloudless sky area is rendered as an uninteresting expanse of monotone. It has long been a major problem of the studios to be assured of obtaining attractive exterior scenes, for a great deal of equipment and personnel are involved when moving a unit out of the studio. It is not possible to decide suddenly to move out to an exterior location; exterior scenes must be planned well and at least twenty-four hours in advance. During the long California summer, weeks on end follow without clouds of any description, and the cameraman is often faced with the

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* Twentieth Century-Fox Film Corp., Beverly Hills, Calif.

problem of having to photograph scenes with little or no pictorial embellishment. Heretofore, in the major productions, it has often been necessary to "dupe" in clouds after the scenes have been made, and sometimes locations at a distance have been chosen where conditions indicated that chances of obtaining real clouds were reasonably favorable. The budget for the average production does not permit the great expense of either of these alternatives, so a process had to be developed by means of which clouds could be produced with dependability and economy.

The process to be described uses appropriate photographic transparencies of real clouds set before the camera, and operates on the principle that the barren sky acts as a printing light. The transparency reduces the light passing to the film in proportion to the density gradations of the transparency. On the finished positive the whitest "cloud" is of the brightness of the unfiltered sky. As photographic emulsions are especially sensitive to blue light, plain sky areas are rendered very bright. This characteristic provides a means of producing bright, fluffy "clouds." Obviously sky-correcting filters are not used, for if the sky is darkened by filters, the brilliancy of the "cloud" is destroyed. An appropriate negative of a sky-scape that has been exposed with good filter correction is chosen. The view should have a perspective and cloud arrangement that will later form a pleasing composition when a transparency made from the negative is combined with an actual foreground setting. When making the positive transparency, the lower portion is "dodged" off so that the foreground setting may be photographed through this portion which is perfectly clear and transparent.

The transparency is set up before the lens of the camera and is adjusted so that the horizon of the transparency is in proper relation to the horizon of the actual scene. A wide-angle lens is employed and the smallest lens-stop possible is used so that the transparency and the actual scene may be in the same relative focus. In bright sunlight, stops from *f*/14 to *f*/22 are usually desirable. As wide-angle lenses at small stops have great depth of field, the focus may be set considerably forward of the actual objects in the scene, so that the transparency and the most distant parts of the actual scene may be in equally sharp focus. Coated lenses are of decided benefit to the system because of the better definition, crisper images, and the lack of the "hot spot," often encountered when wide-angle lenses are stopped down greatly.

The process is used principally on location where transportation is an important factor, for which reason the relatively small size of 11 × 14 inches has been chosen for the transparencies. For stationary scenes the transparencies are placed about 18 inches from the lens. For panoramic scenes a device is employed that accommodates films 16 × 40 inches in size. Films are used because they may be curved to the radius of the panning camera and thus be at a uniform distance from the lens. To overcome displacement or "slippage" the camera is so mounted that the nodal point of the lens is at the axis of the vertical tilt and panoram. For the stationary set-up the transparency is attached to the usual matte-box supports, while for the panoramic attachment an auxiliary plate is introduced between the tripod and the panoramic head. To this plate is attached the holder for the curved plates, for obviously they must remain stationary while the camera is panned across the transparency.

This invention has been in use since late in 1939, and many of the productions of this studio have been released with cloud scenes made by this process. Among them may be mentioned *Brigham Young*, *Hudson's Bay Company*, *Romance of the Rio Grande*, *The Cowboy and the Lady*, most of the *Cisco Kid* series, and many others. In many cases these artificial cloud scenes are edited in with real-cloud scenes, and even the cameraman who photographed them both is afterward often at a loss to tell which is which.

Besides the great advantage of being able to create pictorially beautiful scenes under unfavorable circumstances, the economic importance of the method is very great. In a production such as the *Romance of the Rio Grande*, for example, some forty of the scenes were made in this manner. If the clouds had been put in by the matte-shot method the cost would have run into many thousands of dollars. The complete outfit that was used cost less than $100. The set-up is quite simple and is accomplished almost as rapidly as an ordinary set-up. The camerman has the visual effect before him on his ground-glass. After adjusting the transparency to fit the setting, he is ready to make the scene. No further tests or experimentation is necessary. No alteration of the negative is necessary, and it is processed in the usual way.

In addition to simplicity and economy, the method has the advantage over the matte-shot method of being able to place action over the sky area. In the matte-shot and duping methods, it is necessary to keep all action below the horizon, lest such action run over into the division line when the sky portions are later exposed in. The cloud portions of the transparencies are ordinarily perfectly clear, only the areas between clouds having any density. As long as the action stays within the "cloud" it may be placed anywhere in the sky. Buildings, steeples, moving trees, and the like may extend over the horizon. When it is known that close-ups are to follow extreme long-shots in the same sequence, a suitable cloud plate is chosen so that the action may be properly composed in both. Dark objects or silhouettes may extend through the sky portions with no "ghosting" whatever, for they are but obstructions to the printing light of the sky.

As the intensity of the skylight varies greatly, from a direct front-light to an extreme back-light, a great number of transparencies of different densities would be required to suit all such conditions if some means of control were not possible. Such a control is provided by a graduated neutral-density filter. For front-lighted and side-lighted subjects the light is relatively uniform and control is seldom necessary. For back-lighted subjects the sky, hence the printing light, varies considerably from sunrise to noon and on to sundown. For such shots we carry two densities of the same plate. Adjustments between these densities are provided by the graduated neutral-density wedges. If the sky is extremely brilliant and the transparency is rendered too light in relation to the foreground, the neutral-density filter is adjusted so as to retard the sky area only. When the transparency is rendered too dense in relation to the foreground, the filter is inverted so as to retard the foreground area, allowing the sky area to "print up." Location kits contain about twenty different transparencies including examples of front-lighted, side-lighted, and back-lighted clouds. In some the composition is arranged so that buildings, trees, *etc.*, may extend over the horizon on one or both sides. As the plates may be reversed left to right to suit the composition or lighting conditions, the number of plates required is thereby reduced. From time to time new transparencies are made, and before being put into production their densities are tested photographically. Those that meet approval are put into the location kits. Needless to say this system has the hearty approval of the cameramen. No longer do they dread having to photograph exterior scenes on cloudless days. The directors likewise, realizing the importance of pictorial beauty in the productions, have been most coöperative in arranging action within the limits of the method.

This system is not intended to replace real clouds. It does, however, offer a fine substitute when nature has not been generous. Even when there are real clouds in the sky, the scenes may have to be photographed at angles that do not include the clouds. Edited together, scenes with and without clouds are inconsistent. This method fills in the gaps. Dramatic moods may be created by choosing suitable cloud formations regardless of the actual sky conditions at the time. Hazy skies, which are so difficult to control with color-correcting filters, make no difference to the transparency, which requires only a printing light whether it be hazy or otherwise. By using suitably toned or dye-toned transparencies the method may be applied to color-photography.

Rear-projection plates may be made at any time after or before the regular production long-shots have been made. Using the same transparency for both purposes guarantees that the identical cloud effects will prevail in each when the final scenes are edited in sequence. It is impossible to discuss here all the adaptations of this method. The method is constantly used in this studio, and extensions and improvements in the technic of using are occurring constantly.

Technicolor Cinematography

WINTON HOCH*

This essay does not in any way pretend to be a comprehensive coverage of the equipment, methods, and problems of the Technicolor cameraman at the present time, but is intended rather to present some of the items that might be of general interest. Inasmuch as the general technics of motion picture photography are well known and have been frequently discussed in the literature, there will here be presented some of those aspects that are peculiar to, or receive emphasis from, the fact that the camera is photographing in color.

These aspects arise in very large part before photography, and of all the preparation activities that take place before the actual start of photography, two that are very important to the Technicolor cameraman are color design of the sets and costume color selection. The

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* Technicolor Motion Picture Corp., Hollywood, Calif.

importance of proper color design and costume color selection can not be overemphasized. The set colors should be chosen with care for hue, chroma, and value, and with a knowledge of the costumes to be used, the relative importance of the set, its cutting and physical relationship to the other sets, and the orientation of these factors with the script. While it is true that the cameraman can control the set effect to a large extent by his lighting of it, this color control work must be carefully handled or the screen result will not be optimum. Obviously the more adverse conditions the cameraman meets, the more the production is likely to suffer either in screen result or lost production time to correct those adverse conditions, or both. These two factors of set and costume color probably go farther than any other group of factors in representing the difference between a black-and-white production and a color production. The net result might be termed the "color score" of the picture. It might be compared to a musical score sometimes flashing and brilliant and at other times subdued. It follows that if the problem is ignored, discords usually occur.

Obviously, without sets and costumes in color, the only colors left are flesh tones. A very interesting color emphasis effect was demonstrated in the RKO picture, *Irene*, where an entire set was designed in neutral tones and the star wore the only color.

To handle this very important set and costume color contact, the Technicolor Motion Picture Corporation has available the services of a color control department to advise on the color design of the sets, the evaluation of costume colors, and allied problems. This department has a background of experience from all productions, and its experience and highly developed judgment are available, through the normal functioning of the department, to each new production as it comes along. This department is the spearhead of the Technicolor photographic activity.

The make-up problem is handled, as in black-and-white pictures, by the studio make-up departments, although the color cameraman does have the responsibility of requesting the "touching up" of the make-up as it may be necessary, and he very often has special problems that require close collaboration with the make-up man. For instance, on exteriors with the actors working in sunshine, they usually begin to sunburn, and make-up changes must be made in many cases to handle these gradually tanning complexions. Frequently this means a new make-up problem in order to keep the camera appearance of the flesh tones the same. It can readily be seen that this can become a difficult job. The reverse is also true. As the troupe begins stage work after returning from the exteriors, their tanned skins will slowly fade and the problem of compensating by make-up continues. Occasionally we have had difficulty due to physical exertion on the part of the principals, causing faces to flush beneath the make-up, which effects the camera appearance.

The color camera is very discerning of flesh quality, and we find it necessary to include in the make-up area the neck and throat, and the hands and arms if they show. On rare occasions no make-up at all is used, and it is frequently omitted when photographing babies, as their clear smooth skin generally needs no correction.

It should be kept in mind that, generally speaking, the primary function of make-up is to correct extremes in colors, cover blemishes, and generally reduce the tone range observed in any average group of persons. If one will note the varying complexions of people, he will readily appreciate that if three or four persons were lined up side by side to be photographed, it would be highly desirable and probably very necessary to correct the flesh tones and greatly reduce the tone spread. This must not be interpreted as meaning that all flesh tones should appear alike. Variations of tone are very desirable. It is the extremes that are undesirable. Obviously a white man with a heavy tan who photographs like an Indian is not a very convincing white man. The most critical care is given to the close-ups, especially of the principals. The care and attention given to the problem are, of course, directly proportional to the screen importance of the skin tones.

A great deal of time and money has been spent in solving the make-up problem, and literally thousands of feet of film have been exposed and printed on various make-up tests to discover the best make-up materials and technics for the color camera. A proper make-up requires highly skilled artistry in its application.

Other important items to the cameraman are his lights. Here, color photography again introduces an important factor of which the cameraman must be cognizant, and which must be watched very closely on certain types of work. That factor is color-temperature. Our present three-strip Technicolor cameras are balanced to an average daylight color-temperature. For true color rendition, especially in the pastel shades and neutral grays, this temperature should not vary on the set by more than about ±250°.

There has been in the past some misconception regarding the status of incandescent lamps (designated in the studios as "inkies") with respect to Technicolor photography. Some people have understood that the Technicolor cameras are changed over by filters and prisms to accept an unfiltered incandescent-lamp color-temperature. Others have indicated that they thought that the camera automatically corrected any unfiltered inky light that might be added to an arc-lighted set. These conceptions are wrong.

The filters, prisms, and film of our present three-strip Technicolor camera are all balanced to daylight and this balance is used both for exteriors and interiors. This simplifies the production problem a great deal. First of all, there is manufactured and used only one set of film emulsions. This means that manufacturing, ordering, shipping, storing, exposing, and developing are all standardized for one system, with all the obvious attendant advantages, not the least of which is a lower negative cost.

This single standard also simplifies set-lighting problems, both interior and exterior. All regular Technicolor lighting units have been balanced to this daylight color-temperature by actual and repeated tests with the Technicolor camera. Therefore, they may all be used interchangeably as far as color-temperature is concerned. The only other factors governing their use are the very direct functional ones such as size of unit, light output of unit, operational characteristics of the unit, the type of light that it gives (that is, whether a "hard" light or "soft" light), and the unit efficiencies with respect to light output *vs.* current input, and with respect to light output *vs.* the throw required of the unit for the particular job in hand.

The more common units used for general production are (HI = high intensity):

The 150-ampere HI arc
The 120-ampere HI arc
The white-flame Twin Broad arc
Inky Sr. spotlight
Inky Jr. spotlight
Inky Baby spotlight

Among others less frequently used but in many cases no less important should be mentioned many special converted lamps, a 65-ampere HI arc spot, and a 10-kw corrected inky lamp.

The light-sources used for photography might be classed in four general groups as follows:

- Daylight
- High-intensity arc light
- White-flame arc light
- Incandescent light

The daylight, of course, is our standard for color-temperature. The HI arc lights are all corrected for normal work with a *Y-1* gelatin filter placed in front of the arc light. This filter was especially made for Technicolor, using a special non-fading yellow dye supplied by us. The exact filter strength is determined by camera test. The white-flame arcs were balanced to a daylight color-temperature by the National Carbon Company, and therefore require no filter of any kind. The incandescent lighting units must fulfill two requirements to meet the daylight color-temperature standard. They must first be equipped with incandescent bulbs burning at a color-temperature of 3380°K, and second, they must be fitted with a tested Macbeth glass filter. All General Electric bulbs marked *C.P.* will burn with a color-temperature of 3380°K when operated at their rated voltage. It should be emphasized that the rated voltage must be supplied, and in the case of the arcs, the proper amperages and proper gap lengths and positions must also be maintained.

Daylight as a source probably presents fewer troubles, although very early in the morning and very late in the afternoon trouble is frequently encountered. An interesting difficulty occurred early one afternoon when the smoke from a forest fire filtered the sunshine to such a brownish orange hue that it was necessary to abandon the location for that day.

The conditions just outlined do not have to be met at all times, but they should be adhered to if a pure white light is necessary and desirable for the work in hand. Certainly there is no limit to the effects obtainable with colored lights. For instance, frequently straight unfiltered flickering inky lights are used to produce a warm glow on the costumes and faces to simulate firelight. Artistic sense and experience must dictate the extent to which colored lights are used. The colored-light possibilities have been frequently used, perhaps most recently and extensively in the colored shadow and live action sequences in *Fantasia*. Its first featured use in three-color pictures was in the first three-color production, *La Cucaracha*.

The rigging and lighting of a color set is similar in many respects to that of a black-and-white set, with the exception that lighting units balanced for Technicolor are the units used, unless effects are in order. Most Technicolor sets rely upon arc-light units for the bulk of the lighting. The large sets especially use the larger arc units. Some of the very small sets are from time to time lighted entirely by corrected inky light. Inky units are valuable also on big sets as auxiliary lighting units. They must be watched for age and cleanliness, as an aged bulb and a dirty reflector, filter, and lens can substantially reduce the lamp output. Needless to say, cleanliness is also an asset with arc-light lenses, and proper maintenance and servicing of all lighting units are important.

Exterior sets and set-ups are also handled in a very similar manner to black-and-white set-ups. Scrims, nets, reflectors, and booster light all play their part. It should be noted that the so-called gold reflector is not acceptable in color work (unless for effect) for obvious reasons.

The color-temperature factor is once more introduced when reflectors are extensively worked. The term *daylight* has been advisedly used. By definition daylight is the light from the entire sky, including direct sunlight if the sky is clear. Sunshine has a color-temperature of about 5,500°K, while blue sky has a color-temperature varying from 10,000° to 20,000°K. When reflectors are used as lighting aids they select only the sun, which is reflected into the scene, and introduce a filler light that is warmer in tone than daylight. In addition, it must be remembered that the so-called silvered suface, which is usually aluminum or tin, reflects slightly less blue than it does red and green. This factor also adds slightly to the effect of a lower color-temperature. For these reasons reflectors are not considered as desirable as booster light for some purposes. This is especially true of close-ups where flesh quality is of critical importance.

Process photography in Technicolor is now largely a matter of routine. The scenes selected for process work are, of course, subject to the usual limitations for that type of work, but astonishing results have been obtained. Progress in this field can be largely attributed to two factors: improvement in plate quality, and improvements in background projector equipment. As Technicolor production film is processed day by day the technical crews improve in skill and the research groups add their contributions, to the end that the process plates now furnished to the studios are specially printed for the optimum contrast, color-quality, and density required for this type of work. The equipment combinations of each studio have been photographically tested for color-balance, and this color-balance is also taken into account when the plates are printed.

It has been found that background projectors vary appreciably in the color-quality of the projected light. Generally speaking, the projectors using reflectors have a little more blue in the light than the condenser projectors, although this color-quality varies appreciably depending upon the condition of the reflector and the nature of its surface, or upon the glass used in the particular condenser set-up in use. Some condenser lenses have a very pronounced yellowish cast that is not very desirable for color work.

There has been appreciable pressure in the last few years aimed at increasing the background projector outputs. The present high outputs have resulted from improvements in carbons, objective lenses, projector optics behind the objective lens, and lamp house, and in the successful combination of several projectors for throwing superimposed, matched, and synchronized images onto the process screen. Astonishing progress has been made toward increased output, and fortunately these developments reached the point where they were incorporated into production equipment before the present war appreciably curtailed progress in this line.

The Academy of Motion Picture Arts & Sciences and many studios and equipment companies have all contributed to this projector improvement problem. As a result, we very frequently photograph screens in color more than 20 feet wide, and have photographed, in color, process screens approximately 28 feet wide. This size was used in the Paramount-de Mille production *Reap the Wild Wind*. A shot has recently been made by the same studio using a split screen including a total camera spread of 50 feet. This was accomplished with the aid of two triple relay projectors incorporating the recent improvements previously mentioned. In this emphasis on large screens it should not be forgotten that miniature screens also have their uses, and can be successfully handled on the same general basis as the large screens.

The problems faced by the color cameraman in handling process photography are generally about the same as those found in all process work. However, he must be very color-conscious and on his guard against an off-color projector light and improperly burning foreground lights. He must also be very careful of his foreground-to-background balance, as a background that is carried too high will often present a burned-out appearance that greatly alters the color values of the plate, and destroy the illusion of realism that he is striving to create.

Modern Technicolor camera equipment closely parallels the black-and-white studio equipment in its principal operational features and functions. There are available, for the camera, lenses of 25, 35, 40, 50, 70, 100, and 140-mm focal-lengths. They are all in carefully calibrated mounts that fit onto a master focusing mount on the camera. In almost all cases focusing is accomplished by actual measurement to the focal plane desired, and then the lens is set on this indicated calibration. Repeated tests have shown that this method is more accurate than eye focusing. Eye focusing is seldom resorted to unless the focal distance is so short that it exceeds the lens calibrations. The stop calibrations on the lenses are all photometrically determined and calibrated on an arbitrary arithmetic scale. These lenses have all been specially corrected for Technicolor work. A very interesting and very valuable follow-focus aid, which has been standard equipment since the manufacture of the cameras, is available to the assistant or technician in the form of a pair of selsyn motors. One is attached to the lens mount, and the controlling motor is held in the technician's hand, or fastened to some support if desirable, permitting the technician to be 50 feet or more away from the camera, and yet maintain accurate control over the lens focus. This is of especial value when the camera is put into the sound "blimp," making actual rigid mechanical connection with the lens-mount unnecessary. This is very helpful on sound shooting inasmuch as the camera unit inside the blimp is actually floating in rubber and has no direct mechanical contact with the blimp except through this sponge rubber.

The non-rigid relationship between camera and blimp suggests another problem that has been solved in a very successful manner. That is the problem of attaching a finder for the use of the camera operator. Obviously, if it were attached to the outside of the blimp, the camera, inasmuch as it is floating, could be framed differently from the way indicated by the finder. This was solved by designing a very compact finder, and attaching the main optical elements to the camera. Auxiliary optical elements are available for use depending upon whether the camera is used with or without the blimp. This compact design has the additional advantage that this same finder is used with the camera for almost 100 per cent of the work; thus only one finder and one set of mattes are necessary for each camera, and the camera operator has only one set of finder conditions for which to make allowances. Auxiliary finder allowances are *always* necessary to compensate for the parallax errors both in front of and behind the focal plane for which the camera is adjusted.

The camera motor arrangement is highly flexible and worthy of special note. There are eight types of motors and eight combinations of motor-to-camera gears, all of which can be changed in the field. The only requirement of the cameraman is to specify the kind of shooting expected and the electrical current or the kind of distributor system to be used. The regular cameras can also be successfully operated running backward at full speed. Speeds higher than 24 pictures per second, either forward or backward, are not permitted with the standard cameras.

The camera unit has available all the standard camera mounts to which the industry is accustomed. The wild camera can be mounted on anything from a camera spider to a high tripod, and on any other piece of equipment as may be desired, such as dollies, three-wheel perambulators, four-wheel velocilators, booms, rotating mounts, *etc.* The camera, incidentally, has been successfully operated in all possible positions.

For sound shooting the standard camera is used in connection with either a "barney" or a blimp. The barney is necessarily not so efficient from a sound standpoint as the blimp, but it is very useful in a great many places. The regular blimp is a highly efficient piece of equipment, and of course requires heavier mounts than the wild camera, but it can be accommodated on all types of mounts. Those most popularly used are the blimp "high-hat," four-wheeled "velocilator," and a variety of booms.

There are many items of special equipment available to the Technicolor photographer that are far too numerous to mention in detail. Among them should be mentioned, however, the variety of equipment and mounts used for air photography; the camera blimp and mounts used for underwater photography; and the speed-cameras capable of consistent operation at so-called six times normal speed, or 96 pictures per second.

The question has been asked if an extra standby camera was kept on the set at all times to replace the camera in use when the film ran out, because it took so long to thread the Technicolor cameras. This is not true. The actual threading time of a Technicolor camera is only about three minutes, for a skilled technician, and many units work with only one camera. On major production units, however, an extra camera is usually kept on hand, threaded, to prevent any possible loss of production time due to many reasons. Sometimes a reduction of the three-minute threading time is desirable, and when sound shooting is involved and a certain emotional tempo or mood has been established with the principals, unnecessary mechanical interruptions are highly undesirable. Frequently the director requires two cameras on a shot, and the fact that the supply of extra cameras is often many miles from the stage has an important bearing upon the desirability of this extra camera. The additional cost of the extra camera is a very minor item and the camera usually saves much more than its cost by the saving of production time.

This equipment has been in service for many years, and has successfully met the test of almost all climates, altitudes, and conditions. The cameras have been in all parts of the world—into the crater of Mt. Vesuvius, under the sea near Nassau, almost 20,000 feet above the Andes in South America, in tropical climates, and in subzero temperatures.

Cartoons and all types of animation photography also should be mentioned. The bulk of the cartoon and animation work is now handled by adapted black-and-white cameras using the successive-exposure method. These cameras are set up with a balanced set of three-color filters in the optical system at some point, the filters either rotating or sliding, and the color-exposures are made by exposing one frame of film through each filter successively. At the head end of each roll of film a special chart is photographed, permitting the laboratory to identify the various frames. This negative, after development, is printed on a step printer that prints each third frame only. Thus the records are separated and the prints handled in a manner similar to other standard prints. This method is limited to work where no movement takes place during the exposure, and great care must be exercised in the lighting, exposure, registration, development, and color-balance of the film. The cameras must be serviced to rigid mechanical specifications, and the lenses should be color-corrected. A great deal of careful work must be done to set up such a system, and reasonable care observed in the shooting. Once the system is set up, however, these items are handled largely on a routine basis and with reasonable facility. This type of photography can not be intercut with the standard three-strip negative unless dupe negatives are made.

Other very valuable technics and facilities that are available and are very successfully executed in current production today are glass shots; double and multiple exposures; double and multiple printing; wipes, fades, and lap dissolves made in the laboratory; and many combinations of these. The possibilities are numerous.

While speaking of effects photography, fluorescent materials, paints, inks, *etc.*, should be mentioned. This is a field that has not received much attention due to lighting equipment limitations; however, it can be accomplished in Technicolor. A very simple test was recently made to indicate some of its possibilities. Fabrics colored with fluorescent materials were photographed using as an ultraviolet source a Type *170* M. R. HI arc, covered by a 12-inch ultraviolet Corning filter. The arc unit was positioned 12 feet away from the illuminated subject and the spread obtainable with the filter was about $6^1/_2$ feet at this distance. The brightness of the fluorescent fabrics were sufficient to give an acceptable Technicolor negative with the camera operating at the normal speed of 24 pictures per second.

Routine studio Technicolor photography has long since passed the experimental stage. It is now handled with the same efficiency and dispatch as many black-and-white units. The negative is developed at night and the negative reports, negative clippings, and estimated printer points are delivered to the Technicolor cameraman on the set the following morning. Black-and-white rush prints, if ordered, are generally delivered the following afternoon, and the color rush prints are delivered the following evening.

The negative reports and all laboratory contacts are handled for the cameraman through the Technicolor camera department, which also checks the daily log sheets, and by these log sheets keeps a very complete record of every production and of every scene photographed on that production. The records have proved invaluable, not only to the cameraman, but on many occasions to the director and others participating in the production. This most excellent coördinating agency is extremely valuable.

Further production flexibility would be available if a single film capable of being exposed in any ordinary black-and-white camera could be used for a full color record. Technicolor's Research Laboratory has spent many years in the development of a monopack type of film that would fulfill this requirement. Progress on the project was reported by Dr. Herbert T. Kalmus, President of Technicolor Motion Picture Corporation, to its stockholders in his Annual Report for 1940, as follows:

"Your company's research engineers have also been engaged in cooperation with Eastman Kodak Company on a process of photography employing a single negative or monopack instead of the three strips, and on which three emulsions are superimposed on a single support. Your company's officers and technicians are frequently asked when Technicolor monopack prints will be available. Their current interest in the monopack process is not primarily for release prints because the triple-layer raw film appears inherently to be so expensive that it could hardly compete in cost with Technicolor imbibition prints in the long run.

"But your company's officers and engineers do believe that monopack will be developed to be satisfactory for use as originals from which Technicolor imbibition prints can be made. Such an original could be exposed through any standard black-and-white motion picture camera and should thus have mechanical and cost advantages over three-strip negative.

"Work on this monopack process for originals has been in progress for several years, and has lately reached a point of decided encouragement for certain purposes. At present the monopack research program includes a number of experiments of semi-commercial character which are promising for photography where camera size, mobility, operating speed, or other special considerations are of extreme importance. The expectation is that it will first be tried in a limited way for the special purposes indicated, to be matched and cut in with the larger part of a picture photographed by the three-strip method. It should be borne in mind that Technicolor three-strip photography is constantly improving in quality so that imbibition prints from monopack have not yet overtaken the present quality of imbibition prints from three-strip."

The expectation outlined in Dr. Kalmus' report has been largely realized, and since that time monopack has been used in several pictures, including *Dive Bomber* and *Captains of the Clouds*, where shots from airplane wing-tips and other difficult locations were required; in the industrial field; in military training films; and in special-effects photography where mobility and high speed are important. These uses of monopack are considered as commercial experiments serving the dual purpose of fulfilling a special need of increased flexibility in the field of color photography and of pointing up production requirements which are not easily determined even on the large-scale test basis that characterizes Technicolor's research program.

Technicolor does not consider that the quality of prints from the monopack method of photography has reached the level of quality of prints from its three-strip process. This resides in part not in the absence of progress with monopack research but in the rapid improvement of three-strip Technicolor which, like all phases of Technicolor's process, receives emphasis from its research group.

The present monopack process, in latitude, visibility, and tone rendition is satisfactory, but the picture texture, in grain and uniformity, has not attained the smooth, fine texture of three-strip. The problems involved in correcting these deficiencies are receiving attention and progress is being made.

Technicolor is now and has been for some time definitely on a routine production basis, with almost all the technics used in black-and-white available in color also. The experimental phases have definitely long since left the production field, and have taken their place in the Technicolor research department, which is currently very active and from which the results flow quietly but efficiently to the production field without disturbing changes.

TECHNOLOGY IN THE ART OF PRODUCING MOTION PICTURES*

LEON S. BECKER**

The motion picture and the automobile were born at the turn of the century and grew up together. Both have their foundations in science and technology, and both have profoundly affected our individual and national lives. Their maturity has placed them among the five largest American industries, yet one is fundamentally an art. An automobile is something concrete, tangible, something real; a motion picture is light and shadow, laughter and tears, speech and music. The motion picture is an art as well as an industry. The motivating forces of the film are drama, comedy, human experience—yet it could not exist except for the organized efforts of the many craftsmen and technicians that make it an industry. Since art and industry are so interwoven, a change in technology affects the art of the film, while the demands of the art bring about technical improvements.

This report illustrates the role that technology plays in the conception of the film as an art, and the changes that the demands of the art itself have brought about in technic. The cameraman's universal focus, the soundman's reverberation chamber, the set designer's cloth ceiling—all have their share in telling a story realistically and dramatically. Someone's story idea sets this intricate machinery in motion, and from the writer, actor, artist, and engineer comes a living entity—a combination of arts that have been in development since man first learned to record his experiences for posterity.

When we go to the theater to see a motion picture, we usually go because we want to be entertained. We like to feel the presence of other human beings around us, because we are gregarious; and we want to know about their experiences, because we are curious. If the experiences of the characters on the screen are colorful and told well, we like the picture and call it entertaining; we recommend it to our friends. If the characters are colorless and inconsistent, either because of poor acting or poor story, we say that the picture is dull; we do not recommend it to our friends.

Our reaction to a picture is determined by its realism and its dramatic content. The index of realism is dependent upon how closely the experiences of the characters in the story coincide with our

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** Warner Bros. Pictures, Inc., Burbank, Calif.

own, or how closely they approach our own ideas of what those experiences would be in a similar circumstance. A picture about colonial days, for example, can not be made using the speech idioms or specific behavior of the people of that time, since our ideas of their behavior are in terms of today—how we would act in the clothes, carriages, houses of that century. In other words, for realism, accurate physical environment in terms of the material things of everyday living is necessary, but the psychological processes must be in those terms we understand today.

The index of dramatic content depends upon the story material and continuity, the choice of dramatized incidents, camera work, editing, sound-effects, music, acting, direction, and numerous other elements. A picture about the Civil War may have an extremely accurate reproduction of the battle between the Monitor and the Merrimac down to the last rivet. But unless that battle has drama for the purposes of the story, adequate acting and direction, and comparable quality in the other elements, its dramatic content in terms of the film as a whole will be practically nil.

The industry has achieved a notably high standard of realism from the standpoint of set design, costuming, research, and the things concerned with the physical environment of the dramatized story. Sound, lighting, make-up, camera, miniature work, process shots, are technically adequate and consistently dependable. But it is in the application of the technical instruments for the purposes of telling a story dramatically and colorfully that the variation in product occurs, and that we, as technicians, should attempt to clarify for ourselves and for the benefit of the industry. The field is obviously vast in scope, and would require the collaboration of many specialists to cover the subject adequately. The writer's particular work is in sound. Therefore this paper, which attempts to explore the region between the purely technical and the artistic, where the technician's knowledge of his tools and his individuality and imagination make the difference between an outstanding production and just another adequate picture, is written from that point of view.

The story of the motion picture industry as an art is one of continual growth and development from the time that Muybridge, in 1878, took a series of consecutive pictures to study the motion of a horse. The purpose was scientific, but the entertainment possibilities were quickly recognized. Pioneers built crude cameras of various shapes and sizes, experimented with film of varying dimensions and light-sensitive coatings, and photographed anything in motion. The first films had nothing more than side-show value, and pictures of any moving objects were sufficient to gain an audience. A moving train, a falling building, a bicycle rider, were all adequate subjects for the very short films of that day. The possibilities of the film as a story-telling medium were not long overlooked, however, and as early as 1898 a series of shots were spliced together to form a continuous story.

It was not long before the producers of those days recognized that this new medium, the moving picture, would revolutionize the art of story-telling. The new freedom in space and time opened up unlimited story possibilities. The film could transport the audience within a fraction of a second from the equator to the pole, from the highest mountain peak to the most arid desert. The physical restrictions of the stage upon action and story locale were shattered. Because of the new freedom in space and time, the early film stories were built around physical spectacles, such as forest fires, train wrecks, or crumbling bridges, that could never have been reproduced satisfactorily on the stage. Now, for the first time in human experience, the whole world was truly a stage.

The characters in the first films were "black-and-white" types; the hero was handsome, strong, and silent, the heroine pure and feminine, the villain mustached and vile. There was no real delineation of character, for we must remember that the acting technic was directly related to the stage of that time, when the melodrama was popular. The physical limitations of the stage, the poor lighting, and the distance of the actor from the audience necessitated broad gestures and easily recognizable heroes and villains.

The mobility of the new camera-eye quickly wrought a change in acting technic, however. Since the camera and projector could magnify the image on the screen to many times its normal size and bring the character that much closer to the audience, the broad, sweeping gestures of the stage actor had to be subdued in order to be credible. This modification in acting technic was so rapid that after a decade of development the exaggerated motions of even the greatest of the stage stars, when transposed to celluloid, appeared as ridiculous to the audiences of the silent days as the early silent pictures appear to us now. In 1912, a picture starring the great French actress Sarah Bernhardt was released in this country, and was laughed off the screen. She had used her stage technic for the film.

In only a few years, therefore, the motion picture had severed many of its ties with its parent, the stage. In fact, it was such a lusty, self-willed fellow that it succeeded in changing the ways of its parent. The appetite of this voracious youngster for greater screen illumination improved stage lighting, and the comparative richness of screen sets influenced stage scenery and props. Because of the competition, stage playwrights had to place greater emphasis upon delineation of character through dialog, which the screen was unable to do because it had not yet learned to speak. Conversely, the film writer concentrated upon stories of action rather than of character.

But the complementary element in dramatic story-telling was still lacking in the motion picture—sound, or rather, synchronized sound. The dramatic need for sound was so strongly felt in the silent days that directors like D. W. Griffith and von Stroheim suggested sound by means of pictures and titles, and even made the actors speak their lines for greater realism, though not a syllable came from the screen. A title, such as "the sound of the surf told them the sea was near," or a picture close-up of a dog howling at the grave of its master, were used to give the film more realism and dramatic enhancement. Even lapse of time was measured by "pictorial sound" suggestion—a milk-wagon clattering on the cobblestones to indicate the arrival of morning, or a dissolve to the pendulum of a clock to suggest the passage of time. And, of course, we remember how music and even sound-effects were invariably an accompaniment for the old silents, either by a tinny piano, a wheezy organ, or in the case of the first-run movie palaces, by a 20-piece orchestra with a specially composed score. It was recognized, therefore, long before the synchronized sound-track, that since sound and sight together were closer to human experience, a motion picture plus music or sound suggestion would be more realistic—hence more dramatic.

The birth of the sound-film stimulated technical progress to an amazing degree and resulted in standardizations that proved of great benefit to the industry. The speed of the projected film was fixed at 90 feet a minute for the reason that the high frequency voice sounds, which give to speech intelligibility and to music its timbre and brilliance, could not be recorded at a slower rate and still retain their definition. For sound-track development purposes film emulsion had to be made more uniform, which not only resulted in more consistent sound, but in a better picture as well. The camera, though shackled at first by the unwieldy booths and blimps, quickly regained its mobility and even became more articulate. Set lighting was forced to go to the incandescent lamp, because the arc light was too noisy for the microphone, and the whole problem of lighting was revolutionized. Set design, film processing, stage construction, and even make-up were benefited by the new addition to the art.

But as impressive as the technical advances were, the implications and possibilities of the enhanced medium as a record and interpretation of life were even more imposing. Here, at last, man had found a means of transposing his experiences into permanence with the greatest realism he had ever known. The art-forms of centuries became available. Both the spoken word and literature were now translatable. Music could heighten the emotional experience to the point of pain. And certainly acting again was profoundly affected to the extent of a redefinition of the art in terms of the sound-film. Gradations of character and naturalness were imperative to the realism of the synthesis of sound and picture.

With the birth of synchronized sound, the spoken word, to the actor, meant the ability to play a character instead of a type. The close-up of sound as well as of camera made underplaying the rule and overplaying a caricature. Subtle relations could now exist among the characters of a story, and abstract intellectual ideas could be expressed. The possibility of portraying characters instead of types opened up wider vistas of possible screen material. The vast field of human psychology was thrown open to exploration.

When we hear a sound in real life, such as of someone speaking to us, or from a bird in a tree, we can locate the source of the sound because we have binaural perception, two separate ears, each of which transmits its message to the brain independently of the other. If there are two birds in two different trees, we can not only tell them apart, but can also distinguish their locations. When we cover up one ear, we lose the ability to tell the two sounds apart—we put one of our direction-finders out of commission; and we lose also our aural ability to distinguish depth or space, except by loudness. With only the one ear we have monaural perception. Of course, we still have our eyes to provide a sense of depth and space, but a blind man, whose aural sensitivity has been greatly sharpened, can tell the space and even the size of a room by the faintest sounds. He does it by the amount of reflected sound from the walls and ceiling, as compared to the amount of direct sound. Singing in the shower is a popular pastime because the ego is bolstered by the reverberation of the room and the smoothing out of voice imperfections by the roar of the water.

For the film audience, the source of sound is the loud speaker array behind the screen. The original source of sound was the microphone on the studio stage. Since there were one microphone and one recording channel, the sound, for the audience, is monaural. We can not distinguish movement or position across the screen. But we can create an illusion of movement to or away from the camera, and even the feeling of space and environment in the picture, by the use of, first, loudness, and second, reverberation. A scene shot in a tunnel, or in a mediaeval castle, will be realistic only when the ratio of reflected sound to the original sound is high, and we get the feeling of space.

With the two-dimensional camera, which bears the same psychological relation to the eye as monaural sound does to the ear, the illusion of depth can be achieved by the proper use of lighting and contrast, just as by the manipulation of loudness and reverberation with the microphone. And just as the eye can be drawn to particular persons or objects by the adjustment of focal-length, so can the ear be arrested by the intensification of important sounds and the rejection of unimportant ones. If in a scene we wish to draw the attention of the audience to a child's toy in the center of the floor, we can, by employing an appropriate lens, focus sharply on the toy and blur the background. But if we want to draw attention to a music-box, and yet keep the other props in focus at the same time, we can have the muxic-box play a tune, which will arrest the ear and draw the eye.

The ear, however, is much more imaginative than the eye, and can be used for purposes of suggestion to a much greater extent. The sound of a coloratura soprano gradually becoming a basso conjures up a picture of a phonograph record slowing down, but a visual image of the record slowing down does not define the sound—it might be a symphony or it might be a baby crying. The ear associates more imaginatively than the eye. We hear the sound of crickets and we imagine night; but a picture of a night scene does not necessarily make our brain hear the sound of crickets. We associate the chirping of birds with trees and the country, a siren with an ambulance. The eye will not violate action experience, but varying impressions to the ear will be credible to the brain. The implications of these psychological phenomena for the purposes of the motion picture are tremendous, and have not been fully realized.

In the decade and a half of the sound-film's existence we have learned many things. The writer, actor, and director have developed a mode of approach and a background of technic through experience as have the technicians. It was learned rather early that if the motion picture was to be dramatic and realistic, the technical elements that go into its creation should be so utilized that they return into oblivion as they do their work. And, axiomatically, if the film is to be effective as a medium of expression, the elements that go into its creation must merge into the whole. Music, dialog, sound-effects, the camera close-up, pan-focus, acting, set design, lighting, cutting, and so forth can not be utilized alone, but must be used intelligently in conjunction with each other. For the successful synthesis of these elements into an organic whole an analysis of these different elements *in relation to each other* must be made.

The cameraman has a wealth of devices he can use in unfolding the story he is telling in conjunction with the other craftsmen. He can vary the depth of field or the size of the image. He can choose the amount and kind of lighting to be used in a particular scene to create a mood or enhance a character. He can undercrank or overcrank to change the pace. The camera records a two-dimensional picture, yet the cameraman has a three-dimensional point of view. He can shoot an object from below or above, from the back or the side. Through a knowledge of the habits of the eye and of pictorial composition he can draw the attention of the audience to any object he may desire for the purpose of the story. It is obvious, then, that the cameraman must not only be competent technically, but should also be artistically capable. To him with the director, belongs the responsibility of making the most of the efforts of the scenic artist, prop man, actor, and all the other arts and crafts that go into the preparation of the picture for photographing.

There are, in general, two methods of approach to the problem of presenting a specific scene to an audience through the eye of the camera; the objective and the subjective. The camera may record an incident through the eyes of a fictitious person on the sidelines, or through the eyes of one of the characters. For instance, we are shooting a scene of a delirious person in a hospital bed. To put over the fact that the person is delirious we might show him tossing in his bed, or we might show the doctor questioning the nurse about his chart: this is the objective approach. Or, we might photograph the scene as if through the eyes of the sick man, with the camera going in and out of focus on the objects in the room as he is supposed to see them in his feverish condition: the subjective approach. The objective method is more generally used since it is more direct and straightforward. The subjective method is employed more rarely, because it usually requires carefully prepared establishing shots to be successful.

The imaginative employment of sound is as unlimited as the angles and shadings of the camera. With the wave-filter and equalizer, dialog may be improved, or purposely distorted to simulate telephone or radio quality. Music can be thinned to give it a feeling of eeriness or distance. The reverberation chamber may give speech the quality of an empty hall or the illusion of a voice from another world, and music a bigness for dramatic emphasis. Varying the speed of the sound-track can make Paul Robeson sound like Minnie Mouse, or a chair squeak sound like the creaking of an old pirate ship. In the re-recording process, the proper balance between music, dialog, and effects can be achieved for maximum enjoyment. Unwanted sounds can be deleted and others added. A dramatic sequence can be enhanced and the emotional experience greatly heightened. A comedy scene can be made more humorous through the imaginative use of sound-effects and music. Just as there are fades and dissolves of the picture image, so can there be fades and dissolves of sound for time-lapse and continuity.

Since the human mind can not concentrate on more than one thing at a time, it is necessary, for greatest dramatic effect, to point up either the visual or the aural element in a scene, but not both simultaneously. In John Ford's classic, *The Informer*, for instance, the tapping of the blind man's cane on the pavement is a beautiful example of the subordination of picture to sound, and the dramatic impact it can have. We are interested in the picture of the cane only for information as to the source of the sound: the important thing is the fear and mounting suspense Gypo feels when he hears the tap of the cane, which to him is the forewarning of doom. In *Algiers*, the scene in which the stool pigeon is killed to the musical background of the player piano is an illustration of sound in a completely subordinate role. The climax of the scene is actually the picture—the close-up reactions of Pepe, members of his gang, and the informer. The piano and dialog create a mood only—no dramatic punch standing alone.

Sometimes the impact of the important element can be accentuated and the pace accelerated through the use of a rhythmic pattern in the subordinate element. Any device that tends to increase the concentration of the eye or the ear for the end in view is legitimate. For example, we may have a scene in the box car of a freight train, showing a man crouched in the corner. The man has committed a crime and is escaping. We are interested in showing his reactions by the use of a camera close-up of his face. The visual element, therefore, is the important one. However, the rhythmic clickety-clack of the wheels on the rails plus music is used to heighten the visual picture of the man's abject fear of being caught.

There are times when a rapid shifting of emphasis from sound to picture to sound can do much toward relieving monotony and building up the pace. A simple example of a plane trying to find the landing field in a fog, with shifting emphasis from close-ups of the frightened passengers to the sound of the plane's motors from the ground, back to the interior of the plane, and so forth, illustrates the point.

Dramatically, one of the unfortunate results of the employment of sound-effects has been its over-use—the cluttering-up of a film with sound-effects because they are suggested by the environment. Psychologically we shut out sounds in real life—then why not in the film? Suppose a scene opens with a mother sewing. She is waiting for her child to come home from school. Initially, we hear the sound of a ticking clock in the corner, the laughter and shouts of children as they dawdle on their way, and the chimes of an ice cream man. The mother knows that her child is among them. Suddenly we hear the screech of brakes and a scream. The mother rushes to the window, the camera panning with her. Now, from the moment she hears the scream, there is no need for the ticking clock and the noises below. Everything suddenly goes dead, except the chimes of the ice cream man.

We achieved two things in this scene with sound: first, the cessation of the natural sounds after the scream pointed up the woman's reactions with picture; and second, increased the dramatic effectiveness by the use of sound contrast in the tinkling chimes. The suspension of background sounds is acceptable, because subjectively it occurs similarly in real life. Sound contrast is an excellent device for sharpening the dramatic content of a scene. In *Dark Victory*, when Bette Davis realizes that she is going blind, we hear the sounds of children playing—an effective use of sound contrast.

Another type of sound contrast that could be used very dramatically is silence. By its very nature, sound-film, with its almost continuous use of either sound-effects, music, or dialog, could use silence as an integral part of the sound technic. Silence could be considered as a sound-effect, and treated as such. A picture produced some years ago employed silence very effectively. A musician is shown in his country cottage composing a symphony. An exterior shot shows a landscape of pouring rain and strong wind, with occasional lightning flashes. The sounds of rain, thunder, and howling wind are heard. The camera moves into the cottage to a close-up of the musician as he works on the score. The sound suddenly goes dead, simultaneously with a picture cut to a face close-up. The manner in which the musician's deafness was put over had a marked effect upon the audience, and illustrated what could be done by treating silence in contrast as a sound-effect.

Sound symbolism has been used effectively in several films either as a time-bridge or as a binding agent between scenes. In *39 Steps*, the landlady finds the body of the dead woman, opens her mouth to scream; out of her mouth comes the sound of a train whistle as the picture dissolves to a train speeding on its way to Scotland. Here sound, in place of the more usual picture, was the binding agent between scenes. Sound can be used in association: toward the end of *Goodbye, Mr. Chips*, we see a close-up of the old professor and hear the sounds of the boys arriving at the beginning of the school year, just as he had heard them many years before. The sounds of the boys are used in association, and recall the professor's youth as an inexperienced school teacher. Sound can be used in anticipation of a dramatic climax: the tapping cane in *The Informer*, or the child murderer in *M*, who whistles five bars of "In the Hall of the Mountain King" each time he is about to commit a crime. Sound can be suggestive: the train whistle in *Vivacious Lady* that goes "woo, woo" at the end of the picture, or when the sound of bells is heard each time Ginger Rogers and Burgess Meredith embrace in *Tom, Dick and Harry*.

Much of the really creative work in the use of sound has been in the cartoon field. The investigations and experiments that Disney and his associates have made with sound-effects and stereophonic sound will someday bear fruit and result in much more colorful and dramatic live-action production. Such devices as the sonovox, as used in Disney's *Dumbo*, and the vocoder, which makes speech artificially, will undoubtedly find their place in telling a motion picture story more dramatically.

STOP CALIBRATION OF PHOTOGRAPHIC OBJECTIVES*

E. W. SILVERTOOTH**

Summary.—*The principle of a null-indicating densitometer has been adapted to the measurement of camera lens iris settings.*

An optical system calibrated in accordance with the described technic is rendered amenable to precise calculation of the luminous flux per unit area in any part of the field, with particular stress laid on the axial condition.

It is a matter of common knowledge that the practice of photographic exposure has had inherent variables, the determination of which was subject to large, and often in practice, unpredictable errors. Of these undetermined elements such measurements as absolute object brightness and the graduations thereof, and effective film speed with the plurality of factors affecting that rating, were significant quantities which so eminently enhanced the essential virtue of latitude in photographic emulsions.

With the advent of useful scientific methods of light measurement, coupled with the more general adoption of precise control in laboratory developing procedure, difficulties resulting from correlated operations made themselves known and in some circumstances became predominant in their effects.

Of these variables, one in particular, the stop calibration of camera lenses, has received the attention of Technicolor and of 20th Century-Fox,[1] the former in conjunction with their color process, the latter as a refinement of their new silent camera.

Paramount Studio, recognizing the merit of standardized lens speed ratings, but at the same time wishing to proceed on a purely quantitative basis, set up the following requirements to be met in the operation of a calibrating device:

(*1*) Results should be reproducible without dependence upon any arbitrary standard.

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

(*2*) The method should be amenable to exact calculation of effective actinic energy per unit of area in the focal plane.

(*3*) It should be reproductive of axial densities.

(*4*) Independent of brightness of light-source.

(*5*) Independent of amplifier, photocell, and meter linearity, as well as of amplifier gain.

(*6*) It must be foolproof, accurate, and rapid in operation.

With the above-listed desired properties in mind, a device was constructed for use by our Camera Department. Referring to Fig. 1, light from source *A* is collimated by the low focal ratio objective *B*, forming a parallel beam of uniform cross-section. Either the lens under test or the standard aperture may be placed at *C*. The standard aperture consists of a metal plate with a circular perforation of area equal to the theoretical aperture of the lens, diminished by a factor determined from the transmission characteristic of the given objective. Since studio production camera lenses (treated, in our case) do not vary widely in this respect, this factor has been assigned a value of 90 per cent. Untreated lenses, or more highly absorbing optical systems in wide variety could similarly be calibrated, but with an auxiliary notation of percentage transmission incorporated in the engraving operation.

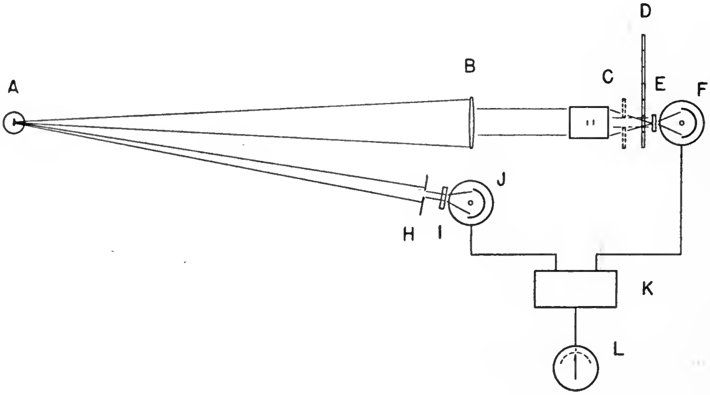

FIG. 1. Device for stop calibration of photographic objectives.

The lens at *C* is followed by the factor-of-two step-wedge *D*, thence by the diffusion disk *E* and the photocell *F*. Somewhere in the vicinity of objective *B* is included an auxiliary photocell *J*, illuminated from source *A* through the adjustable iris *H* and diffusion disk

I. Photocells *F* and *J* are meshed to the input of a two-stage direct-current amplifier[2] *K* the output of which is fed to a zero-center-scale microammeter, or null indicator *L*. The sensitivity of the instrument is adequately controlled by means of a meter shunt.

The method of operation is as follows:

(*1*) The standard stop (one for each focal length lens) is placed at *C*.

(*2*) By means of *H*, a light balance is secured between photocells *F* and *J*.

(*3*) The standard stop is replaced by the lens under test; the lens iris is adjusted until balance is again attained.

(*4*) Wedge *D* is shifted one stop, and the lens iris setting is altered to compensate. This step is repeated until the lens is completely calibrated.

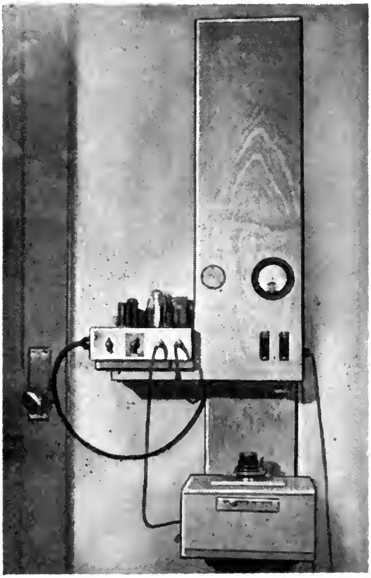

FIG. 2. Photograph of the device.

Because of the limited window area at *E*, it is necessary in the described unit to match standard stops with iris openings of *f*/11 or *f*/16. A more elegant method would be that of replacing the diffusion disk *E* with an integrating sphere of adequate size.

It is evident from the foregoing description that camera lenses so calibrated will yield duplicate densities in the center of the focal surface under similar conditions of exposure. The importance of this feature is best appreciated when consideration is given to the wide variation from lens to lens of off-axis illumination curves.[3] The very individuality of this circumstance in a lens system dictates the necessity for axial calibration if the useful prediction of focal-plane illumination is to be available for the more significant calculation of optimum light level requirements on sets. This conclusion is predicated on the assumed condition that the center of the scene is generally of greatest importance. An interesting ramification of the device in this connection lies in the possibility of rotating the lens under test about the rear nodal point, thus conveniently securing information related to the off-axis flux values.

In conclusion, it is believed that a precision method of lens-stop calibration has been adequately defined for all practical photographic applications; and further, that the elimination of an arbitrary standard for comparison purposes has provided a generally available calibrating technic.

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A REVIEW OF THE QUESTION OF 16-MM EMULSION POSITION*

WM. H. OFFENHAUSER, JR.**

Summary.—*There are several standards anomalies in 16-mm little realized no only by many engineers but also by many of those who daily use the medium.*

While there is but one 35-mm emulsion position—the standard position, the emulsion facing the light-source—there are two emulsion position in 16-mm—the "standard" position, in which the emulsion faces the screen; and the "non-standard" position, in which the emulsion faces the light-source. What the non-standard position films may lack in millions of feet used per month, is made up in great measure by their 5 to 1 processing-cost ratio and their higher first cost.

Commercial projection equipment generally has ignored these more costly films and chosen to compete in the low-cost low-quality black-and-white print market. Not one projector manufacturer supplies as standard equipment today a directional loud speaker of suitable efficiency and transient characteristics for high-quality reproduction; only one manufacturer supplies as standard equipment a sound projector whose sound optics are one-half mil in width and may be refocused properly to project "non-standard" emulsion position prints.

While 16-mm black-and-white print quality is generally bad and the resultant projected picture and sound likewise bad when compared with 35-mm theatrical projection, this condition can be corrected almost overnight if Government specifications for 16-mm prints and for 16-mm sound projectors and loud speakers will call for modern 16-mm materials, modern specialized 16-mm methods, and modern equipment. Unit cost increases for the improved quality are inevitable; the increase in effectiveness, however, will far more than compensate for the relatively small increases in unit costs that result. One commercially available system for achieving the desired standard of quality is described.

It has become quite common in the last few years for a projectionist of 16-mm film to ask himself the question: "Which side is up on this film?" and in many cases the quality of the projected show, in particular the sound quality, hinged on whether the all-important answer was right or wrong. When a 16-mm sound-film is properly threaded in a projector, the emulsion of the film may face the screen, which

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

position is called the "standard emulsion position," or it may face the projector light-source, the "non-standard" emulsion position. Sixteen-mm sound-films for projection today may be expected to be found in both kinds.

When the original emulsion position question was first brought up for consideration, it was the feeling of all concerned that reversal originals would be of key importance, and accordingly, the present standard 16-mm emulsion position was agreed upon. Since in a camera the emulsion of the film faces the lens, the standard emulsion position in a 16-mm projector therefore would be the position in which the emulsion also faces the lens of the projector. (The film used is the original film—the original reversal.)

Optical reduction printing from 35-mm was then made to conform to this standard, and since the decision was made, all reduction printing equipment for copying 35-mm to 16-mm has been adjusted to produce only standard emulsion position prints. In the meantime, original reversal film with sound as a potential source never really developed, and in the earlier stages of 16-mm sound-film, practically all 16-mm sound-films available for projection were made by optical reduction from 35-mm original negatives.

Later on, the cost of 16-mm film for amateur use became prohibitive, and with the improvement of films, lenses, cameras, and projectors in 8-mm, amateur interests began to be transferred almost entirely to this medium. Today, the relative costs and the technical results of the 8-mm medium are such that we can safely say that 16-mm is almost exclusively a professional medium and 8-mm is almost exclusively an amateur medium. We must, therefore, consider the question of 16-mm emulsion position in the light of the fact that 16-mm sound-films produced from 16-mm originals are almost entirely of commercial origin.

Emulsion Position in 35-Mm Practice.—When 35-mm negative is threaded in a camera, the emulsion of the film faces the camera lens. When this negative after development is contact-printed, the emulsion of the print faces and is in contact with the emulsion of the negative. When the print that results is then threaded in a 35-mm projector, the emulsion on the print is opposite that of the emulsion on the negative, and, therefore, the emulsion of the print faces the light-source of the projector. This emulsion position of the print is called the 35-mm "standard emulsion position." When 35-mm film is used, therefore, its application, so far as emulsion position is concerned, is quite simple. Essentially, all original 35-mm black-and-white picture is taken as negative, and prints are made by contact-printing upon positive raw film. Despite the rapid and continued growth of the industry, even including the introduction of sound, the 35-mm medium still remains a negative-positive medium in which films are still developed and printed in exactly the same way they have been handled for some forty years or more.

Our 35-mm standards recognize the standard emulsion position as the one and only emulsion position to be used in 35-mm release prints. Once a projector has been installed in a theater and adjusted to give the proper size of picture on the screen and to scan the sound-track in the proper manner, no further adjustment is required except for maintenance. Any 35-mm film received for projection will automatically be in proper focus for both the picture and the sound; there are no non-standard emulsion position 35-mm films released for commercial use.

Since negative-positive processing is and always has been the only processing generally available in 35-mm, it was only natural that the jargon of the industry would take account of that fact. It is not uncommon, therefore, for the terms, "original" and "negative" to be used interchangeably in 35-mm slang, and many who are beginning to work in both media after having worked previously only in the 35-mm medium, attempt to carry over the interchangeability of terms into 16-mm, where the use in that manner is definitely in error.

The Early History of 16-Mm Reversal Film.—About 1924, the Eastman Kodak Company made available to the American market a 16-mm film product that is still unknown in commercial 35-mm films—reversal. In order to encourage amateur movie making, it was necessary to eliminate, if possible, the second piece of film, the print, in order to reduce the cost of the product to the user.

Reversal had, commercially, two important advantages. The same piece of film was returned to the customer that the customer sent to the company for processing (which avoided alibis on the part of the customer), and at the same time, the second piece of film normally necessary, that is, the print, did not have to be made.

Reversal was recognized in our 16-mm standards only by the caption, "In the projector, the base (not emulsion) side of the positive, made . . . by the reversal process . . . faces the light source." It is interesting to note that even at this late date, duplicate reversals are given no formal consideration whatever in our dimensional standards, despite the fact that they became commercially important as early as 1931.

Reversal and Kodachrome—What They Are.—Reversal (in the broadest sense) may be most simply defined as a direct positive. When properly handled, black-and-white reversal film is one of the finest materials available for use today as a 16-mm picture original. It always produces a reduction in grain size; the larger grains are most affected by the first, or negative, exposure that the film receives, but these larger grains are later removed in the subsequent bleaching operation, leaving only the smaller grains of the emulsion to make up the final image. A study of the relative graininess of optical reductions from 35-mm negatives in comparison with original reversal as a 16-mm original material appeared in the JOURNAL in November, 1940, in a paper entitled "Commercial Motion Picture Production with 16-Mm Equipment," by J. A. Maurer.

Kodachrome goes a step farther; the final image in Kodachrome is a grainless dye image. Just as in the case of reversal, the silver emulsion in Kodachrome is bleached out after the initial exposure and development; dyes form the image in development after the second exposure. Practically, Kodachrome has one other advantage: its development is usually less contrasty than that of reversal. This, too, makes for an improved original.

Kodachrome as an original 16-mm material has another advantage that can hardly be overlooked in these days of emergency. It is possible to print excellent Kodachrome sound duplicates at the same time excellent black-and-white prints are being made. This is possible since the Kodachrome sound duplicates are manufactured from the Kodachrome original and a positive black-and-white sound-track, while the black-and-white prints are made from a black-and-white duplicate negative of the picture and from the original negative sound-track.

Early History of 35-Mm Sound-Film.—When sound-film was commercially introduced in 1929, it was forced to adapt itself to the negative-positive procedure of the 35-mm picture. It is obvious that if the sound is to appear on the same piece of film with the picture in the combined print, both picture and sound must be developed in the same developer solution. This sound-recording procedure was pinned down into a negative-positive procedure to conform with the processing of the picture. The production of the release prints from the original negatives was quite satisfactory so long as the sound negative could be made in relatively long lengths without splices.

In the early stages, scenes were quite long, often as long as two minutes. As the sound motion picture grew, the length of the individual scene became shorter and shorter until now the average length of a scene is considerably less than one-tenth of what it was in 1929. For this and other reasons, a demand for re-recording and for lip synchronization grew, all of which implied a large number of scenes per reel, and, consequently, a large number of splices in the original sound negative. It was only logical, therefore, that the industry would attempt to produce some sort of direct sound positive which, when re-recorded for release purposes, would eliminate one copying step between the original sound-track and the release print. (Direct positive—to—re-recorded negative—to—release print.)

In the case of sound, however, reversible film did not come to the rescue as it did in the case of the 16-mm picture in 1924. Another difficulty had arisen which is characteristic of all silver emulsions in some degree that would prevent the successful application of reversible film in this manner. For want of a better description, it will be called here the "graying" effect. In the JOURNAL are to be found numerous papers on the subject of envelope and other types of film distortion in which this graying effect plays an important part. We have been counter-acting this distortion effect in the negative by attempting to produce an equal and opposite effect in the print by the choice of proper exposure and of proper development of the print. In this procedure, we have been more or less successful, and this method is the one that is preferred commercially today.

An attempt was made, however, to record directly on fine-grain positive stock with the recording system optics and the electrical elements so modified as to produce a direct positive. The distortion in the direct positive was considered low enough in certain cases to be ignored. For purposes of identification, we shall call this form of direct positive recording "optical reversal" to distinguish it from "chemical reversal." The term "optical reversal," while not strictly correct, will be assumed to include the recording of variable-density direct positives such as variable-density toe-recorded sound-film.

The successful direct positives required film of the fine-grain, high-resolving-power type. Due to the difficulty of obtaining enough exposure and for other reasons, direct positives have not been commercially adopted. The customary 35-mm procedure is to record the original sound as a negative, edit it, then make a 35-mm sound positive—and then re-record that 35-mm sound positive using the resulting sound negative for making the release prints.

Early History of 16-Mm Sound-Film.—After the initial failure in 1930 of 16-mm sound negatives made by re-recording, direct 16-mm sound remained dormant for a number of years. A 16-mm sound camera put in its appearance in 1932, operated by the single-system method. So far as sound was concerned, this unit fell heir to the poor resolution encountered in the commercially unsuccessful re-recording attempts of 1930. One important factor in the failure of this unit was that the film used did not have satisfactorily high resolution since it was a negative-type film.

It was evident that the only commercially practicable solution in 16-mm would be double-system sound-recording—just as it had been the solution in 35-mm sound-recording. It was not long afterward that 16-mm double-system sound-recorders were put on the market. Plans were being formulated for their marketing as early as 1936.

Current Status of Direct 16-Mm Sound.—By far the largest volume of direct 16-mm sound is produced by the double-system method with negative-positive processing of the sound-track. Studies have been made of the application of reversal to sound, but it has been concluded so far that what we have called the "graying" effect prevents any reasonable use of the distortion cancellation technic such as we daily find so valuable in negative-positive 16-mm commercial operations. This factor becomes more important as the number of copying operations required between the original and the release print increases; this is especially true of variable-area sound, with which there has been more commercial experience in the 16-mm medium.

Kodachrome Sound Duplicating and Its Implications.—At the present time, practically all sound to be duplicated on Kodachrome is recorded as a negative, and a black-and-white positive track print is made from that negative. It is the positive sound-track print that is used in the printing operation to the combined duplicate. For the purpose of this discussion, it makes little difference whether the original sound-track is recorded originally on 35-mm film or on 16-mm film.

It seems likely that one of the reasons why so few direct sound positives can be used for Kodachrome printing is that the distortion due to the graying effect is excessive. This does not mean, however, that all positives are afflicted with the same handicap; positives of the dye type seem to be less affected by this peculiar characteristic of silver emulsions. Considerable development and research work has been carried on in this direction that seems to hold promise for the future.

The 16-Mm Emulsion Position Question.—It can be seen from the foregoing that the 16-mm emulsion position question can not adequately be dealt with in a casual manner. Reversal and Kodachrome, which do not exist commercially in 35-mm motion pictures, are used almost to the exclusion of negative in 16-mm for picture originals. Kodachrome sound duplicates, of which there are possibly some quarter of a million feet per month or more currently used in 16-mm, do not exist in 35-mm at all. These distinctions between 35-mm and 16-mm would certainly seem to merit some form of standards recognition.

A few years ago, the author submitted to the Standards Committee of the Society a memorandum classifying the methods of producing 16-mm release-prints then in use. Sixteen-mm sound-prints may be produced by a wide variety of methods. They may be classified as follows:

Class 1. Film Width of Original

- (*a*) Originals supplied on 35-mm.
- (*b*) Originals supplied on 16-mm.
- (*c*) A combination of both 35-mm and 16-mm, either
    - (*1*) 35-mm picture with 16-mm track, or
    - (*2*) 16-mm picture with 35-mm track.

Blow-ups from 8-mm picture to 16-mm are not uncommon even now, and it is possible that this procedure will grow.

Class 2. Sound Recording Processes

- (*a*) Variable-density. Full-width, squeeze, push-pull; with or without noise reduction.
- (*b*) Variable-area. Unilateral, bilateral, duplex, others (such as multiple).
- (*c*) Combinations of variable-area and variable-density (not in common use).

Class 3. Processing Methods

- (*a*) Negative-positive processing (where the image black-and-white aspect is reversed in printing).
- (*b*) Second exposure or direct positive processing (a positive from a positive, such as a reversal dupe; a Kodachrome dupe.
- (*c*) Single exposure processing (where the image is reversed optically or electrically, as in the case of a sound-track master record made for direct playback, one exposure and one processing).

Combinations of these classes are not at all uncommon; our standards, if comprehensive, should encompass any reasonable combination of any or all of the preceding classes, methods, or sizes. At the present time, we are especially concerned with:

(*1*) Reduction of 35-mm negatives, both picture and sound, to 16-mm.
(*2*) Combinations of a 16-mm original with a 35-mm original (such as Kodachrome or reversal picture and 35-mm negative track, or 35-mm negative picture with 16-mm negative track).
(*3*) Direct 16-mm where the picture original is either a 16-mm negative, reversal, or Kodachrome, and the sound-track is an original 16-mm negative.

The Problem of 16-Mm Prints from 35-Mm Originals.—Whenever 16-mm prints are needed from 35-mm originals, one important question must be answered *before* the sound is recorded if the final result is to be of optimum quality. It must be *definitely* decided whether 35-mm prints are to be made at all; if they are, it is manifestly impossible to record a single sound-negative that is suitable both for 35-mm prints and for 16-mm reduction prints due to the difference in the recording equalizing required. The reason is readily apparent if we examine the equipment situation.

If a Hollywood studio sound-track is run upon a 35-mm sound system that meets the specifications of the Academy of Motion Pictures Arts & Sciences, the result is standard. The reason is that the recording is so made as to reproduce most effectively upon equipment with the Academy characteristic.

Such a negative, if optically reduced without fidelity loss, would also operate most satisfactorily with equivalent equipment having Academy characteristics. The characteristics under such conditions are:

(*1*) The slit width should be 1.3 mils multiplied by 36/90 (the film-speed ratio) or one-half a mil. One manufacturer of projectors, Eastman Kodak, manufactures equipment with that slit width; no other major manufacturer does.

(*2*) The resolution of the 16-mm film should be in the inverse ratio of the film speeds, or 90/36 = 2.5. Fine-grain 16-mm film *accurately controlled* will readily approximate this requirement when compared with regular 35-mm positive as commercially processed.

(*3*) A really good optical printer designed to expose *fine-grain* 16-mm film with the proper *chromatic and intensity characteristics*, will "hold up" in our comparison with the usual 35-mm non-slip printers printing upon regular 35-mm positive.

(*4*) The amplifiers, obviously, should be at least the equal in signal-to-noise ratio and in distortion, to 35-mm booth equipment. This is no chore as there is on the market a wide variety of amplifiers of reputable make and performance suitable for the purpose. Needless to say, the best 16-mm projector amplifiers, while somewhat inadequate, are not too far wide of the mark.

(*5*) Last but not least, the loud speakers must be comparable with those considered in connection with the 35-mm Academy characteristic Unfortunately, this is probably one of the worst 16-mm bottlenecks. While we cling to the idea that the performance of a 16-mm loud speaker is immaterial just so long as a frail ninety-pound schoolteacher can lift said loud speaker, we might as well give up our search for 16-mm sound-quality in projection. In order to obtain performance somewhat comparable, the loud speaker should have the following characteristics:

(*a*) Directional radiation—not much more than a sixty-degree lateral spread and a thirty-degree vertical spread. This is readily obtained with a suitable horn.
(*b*) Good efficiency; also obtained if a suitable horn is used.
(*c*) Good transient characteristics on speech; also obtained if a suitable horn is used.

A loud speaker, to meet the above requirements, would have to be a directional horn; the present flat baffle type of equipment is hopelessly inadequate.

Unfortunately, it is not possible to obtain, as regular articles of commerce, all five of the items exactly as enumerated above.

A Commercial Solution to the Problem of 16-Mm Prints from 35-Mm Originals.—There are several obvious commercial steps in the solution of the problem of good 16-mm reproduction from 35-mm originals. They are:

(*1*) Re-record the sound-track using a 16-mm equalizing characteristic. If this record is made by direct 16-mm on high-resolving-power yellow-dye film exposed in a good 16-mm sound-recorder through the proper filter, 6-db equalization broadly tuned at 5500 cycles is sufficient for excellent films. A 6000-cycle low-pass filter may prove of advantage.

(*2*) Make a 35-mm fine-grain lavender of the picture, and then make a fine-grain dupe negative of that lavender.

(*3*) Make the 16-mm combined prints on fine-grain film, printing the sound with an optical one-to-one sound printer (contact sound printing is inadequate).

(*4*) Use a commercial projector that will meet the specifications set forth by the Non-Theatrical Equipment Committee in the July, 1941, issue of our JOURNAL, "Recommended Procedure and Equipment Specifications for Educational 16-mm Projection." A Bell & Howell Utility Filmosound will substantially meet the requirements.

(*5*) Use a *good* loud speaker such as the Bell & Howell Orchestricon. When projecting, set it in such a position that its horn radiates directly to the audience.

(*6*) For safety's sake (projection requirements are rarely properly analyzed), use a matte screen.

The Current Status of 16-Mm with Regard to Emulsion Position.—When a 16-mm sound-film is properly threaded in a 16-mm projector, the emulsion of the film may face the screen (which position is called the "standard" position), or it may face the projector light-source (the "non-standard" position). Any well-designed projector of today should be capable of projecting either "standard" or "non-standard" prints.

All 16-mm combined prints from 35-mm originals such as those previously described have the "standard" emulsion position. The best quality 16-mm black-and-white combined prints from 16-mm originals also have the "standard" emulsion position. At the present time the output of such prints amounts to several million feet of film per month.

Most 16-mm combined Kodachrome duplicates have the "non-standard" emulsion position. At the present time, the output of such prints amounts to something like a quarter to a half million feet per month. When it is considered that the cost of a 400-foot combined duplicate in Kodachrome is approximately $50, whereas a similar black-and-white print costs but $9, it becomes even more apparent that the existence of Kodachrome sound duplicates is entitled to consideration from projector manufacturers especially.

When projecting Kodachrome duplicates, it is found necessary to refocus the picture; the emulsion position is non-standard. It would seem obvious, therefore, that if the picture must be refocused in order to be clearly seen, the sound optics must likewise be refocused if the sound is to be clearly heard. The surprising feature in the projection of Kodachrome sound duplicates is that more than 90 per cent of the projectors in use are *not* equipped to refocus the sound optics for proper projection. Only one manufacturer of 16-mm sound projectors has so far included this feature on most of his sound projectors as standard equipment; only one other manufacturer has offered such a feature as optional on all his machines at slight additional cost.

It is well to remember that, *with present-day sound optics, there is no satisfactory compromise fixed adjustment* suitable for both "standard" emulsion position black-and-white prints and "non-standard" emulsion position Kodachrome duplicates. The usual adjustment is in the form of a small lever with two definite settings.

There are other sources of "non-standard" emulsion position film today, but the quantity in use in such that they are of minor importance from the standpoint of volume. It is quite possible that, with a wider distribution of 16-mm apparatus immediately after the War, they will acquire additional importance.

The Question of Optical Picture Printing.—In all the foregoing, it may rightfully be charged that the possibility of optical printing of

16-mm picture has been ignored in this discussion, and only contact printing of 16-mm picture has been presumed. This charge is quite true—and it will no doubt continue to be true, at least for the duration of the War. If optical printing of picture is as desirable as many think, why is it that the 35-mm theatrical industry which spends millions of dollars on its productions and on their exhibition still makes all its release prints by contact printing? Sixteen-mm costs must be kept low, very low in comparison with 35-mm costs, and it would seem that if there is to be a trend in the direction of optical picture printing, 35-mm should lead the way. Sixteen-mm costs must be lower than 35-mm costs; if optical printers are at all worth using, their disadvantages must be overcome; their operating speeds are very low and their first costs and operating costs very high.

While the present War emergency continues, it seems unlikely that any reputable optical manufacturer can be induced to divert his energies to the marketing of suitable optics for a 16-mm picture printer that will correct emulsion position at a price to compare in a practicable way with the present price for a contact printer.

Conclusion.—At the present time, it seems clear that neither emulsion position can be successfully dispensed with as a standardizing matter. The dollar value of the non-standard prints produced is now considerable when compared with that of the standard prints. For the duration of the War, at least, both emulsion positions will continue to be of indispensable importance.

TECHNICAL APPENDIX

16-Mm Sound Negatives.—Direct 16-mm sound negatives are usually recorded upon a high-resolving power yellow-dyed film exposed through a blue filter. Two windings of raw stock are available, Winding *A* and Winding *B*. The rules for their use are:

USE WINDING *A* for sound negatives for

(*1*) *Kodachrome sound duplicates* with the sound-track printed from a fine-grain sound-track print of the sound negative.
(*2*) *Combined prints from original reversal or Kodachrome picture* made from a fine-grain duplicate negative of the picture and from the sound negative.
(*3*) *Combined prints from 35-mm picture negative and 16-mm sound negative.*

USE WINDING *B* for sound negatives for

(*1*) *Combined prints from original picture negative* and 16-mm sound-track negative.
(*2*) *Fine-grain sound-track prints to be used for re-recording.*

16-Mm Picture Original.—In 16-mm picture original and in all steps where sound does not appear on the film, use double perforated film to avoid laboratory and other handling difficulties.

Preparation Rules.—(*1*) In all cases, use only double perforated leader with doubly perforated film, and single perforated leader with single perforated film.

(*2*) In all cases, splice in the leader with base to emulsion so that the same side of the film is up on the leader, as on the picture proper.

(*3*) In all sound-films without picture, mark the head of the film *H* and the tail of the film with a *T* to avoid confusion due to emulsion position.

Emulsion Position of Prints.—Prints with "Standard" emulsion position result from:

(*1*) Original 16-mm black-and-white reversal—to—intermediate negative—to—print (the 16-mm sound negative is recorded upon film of *A* winding).
(*2*) Original 16-mm Kodachrome—to—intermediate black-and-white negative—to—black-and-white print (the 16-mm sound negative is recorded upon film of *A* winding).
(*3*) Optical reduction from 35-mm negatives.

Prints with "Non-Standard" emulsion position result from:

(*1*) Original 16-mm negative—to—print (the 16-mm sound negative is recorded upon film of *B* winding).
(*2*) Original 16-mm Kodachrome—to—16-mm Kodachrome duplicates (the 16-mm sound negative is recorded upon film of *A* winding. Sixteen-mm track negative—to—16-mm black-and-white track print—to—Kodachrome duplicate of sound).

A well planned picture takes into account the emulsion position of the release print and how it is to be obtained quite as much as it does the photographic images to be recorded on the film.

After the presentation of the above paper at the Convention, a demonstration film, made as described, was projected with an arc projector on an 8 × 12-ft. screen through a sound system of the type described, in order to demonstate the theatrical quality of the sound and picture.

THE PRODUCTION OF INDUSTRIAL MOTION PICTURES*

LLOYD THOMPSON**

Summary.—*The production of industrial sound motion pictures is similar to production in the major studios. Limited budgets mean that certain short-cuts must be taken but the final screen results must be such that the audience is not aware of the limited budget. If satisfactory results are to be obtained, close coöperation is required between the director who has his special problems and the technical department which also has its special problems.*

The paper lists a number of these problems and also discusses what can be expected of industrial producers.

Today industrial motion picture producers are being called upon to produce a greater variety of shows than ever before. Many of the productions needed call for the industrial (and I say industrial for the lack of a better term) technic. To an industry which, of necessity, has been mainly concerned with entertainment production, this comparison of industrial and entertainment technic may be of interest.

The industrial producer of today must have three things, and it matters not whether he is using the 35-mm method or the direct 16-mm method of production. These three things are: (*1*) the personnel, (*2*) the experience, (*3*) the proper facilities.

If he has the above qualifications he must do two things to do business at a profit. (*1*) He must solve his own technical and production problems so that he can make a finished production both technically and artistically. (*2*) He must give his customers true value, and leave them with the feeling they have enjoyed a pleasant and profitable experience.

The production of industrial sound motion pictures is in many ways carried on the same as the production of straight dramatic shows. In other ways it is different. Probably the first big difference is in the amount of money that the producer has to spend. With enough money many of the problems of any business disappear. It

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** The Calvin Company, Kansas City, Mo.

is the solving of many of these problems without spending too much money that makes the life of an industrial producer interesting and at times hectic.

A million dollar budget is rather common for a Hollywood production. The average cost of an "A" feature is nine hundred thousand dollars. If someone allots one hundred thousand for an industrial it becomes news and is given wide publicity. More often industrial shows are made for three or four thousand dollars. Seventeen or eighteen thousand dollars is an excellent price for an industrial in color and sound.

On the other hand the buyer of any picture expects a show that will train his employees, sell his product, or make the public look with favor on his product. In other words it must do the job for which it was intended. To do this it must be at least reasonably well photographed. It must be edited in a logical sequence and should unfold on the screen in at least a fairly smooth manner. This, of course, calls for good planning and good direction.

To turn out a job that will fulfill all the requirements means close coöperation between every department from the sales department who sold the picture to the shipping clerk who must see that the prints are shipped in time, quite often to meet deadlines. This means the proper personnel with the experience that will enable them to work together most efficiently. An organization producing industrial shows works most efficiently if the different members of the group understand the problems involved in the various departments of the organization.

The sales department must sometimes work for years to sell a single picture. This means that a long line of prospects must always be in the process of being sold. Equally important the salesman for industrial pictures must thoroughly understand the whole production business of making a show. If not he can easily oversell. We like to tell the story about a salesman who did not understand the production business. This salesman once wrote a scene into a minimum priced script, showing ten thousand Macedonian soldiers in a *V* formation. The scene would have been about two feet long. In this case the production was not sold and so that problem did not have to be solved. A smart salesman is the one who does not even mention the impossible scenes.

Many things have been sold by salesmen that the producer was unable to deliver, but the ethical producer wants to sell repeat business and is therefore careful not to promise anything he can not deliver. The salesman of dramatic shows might be likened to a salesman of ready-made suits and a salesman for an industrial production might be likened to a tailor. The salesman of dramatic shows may sell whole blocks of pictures to theater exhibitors and about all the customers know about them is that they will be some sort of entertainment. On the other hand, an industrial show must be made to order, and the salesman must at least know how to take the measurements. If the original measurement is not made right the chances are that the finished production will be pretty sloppy.

We often read of the difficulties Hollywood directors have with authors of books that are being made into shows. In an industrial show this man is usually represented by someone from the advertising department of the client. This representative can be of great help and his services are badly needed to be certain that misstatements or inaccuracies do not creep into the final production. On the other hand this person can make the director's life miserable for a time unless the director has enough salesmanship about him to convince the advertising man that certain things should be done and others should not.

Many times it is the representative's first experience with motion pictures and he lets his enthusiasm carry him away. He may try to get four or five pictures into one, or he may show so much useless detail that the picture will be uninteresting to his audience. He may let the various departments of his company influence him too much and as a result he will want to show too much of, let us say, the laboratory. A good director will point out these things and they will be eliminated from the script. Occasionally the representative can not be convinced, and no one knows what may happen after that. It is safe to say, however, that these shows usually end up with retakes, re-editing, rewritten script, usually miss the deadline, and are not as smooth as they should be.

In planning the show the director and the writer must always keep in front of them the amount of money that can be spent in producing the show. Here experience counts a great deal, and without this experience a producer can easily lose his shirt. Most scenarios must not call for large expensive sets. Many times the shows are shot on location—as a matter of fact many times they must be shot on location. Frequently long shots are made on location and close-ups are made in the studio, especially where synchronous sound is to be used.

This technic is, of course, not new or novel. The industrial producer must avoid using scenes that might be difficult and expensive to shoot. A simple set may tell the story just as well—and if the audience has not seen the expensive set they will not miss it. This does not mean that locations must not be established. They must. Optical effects are especially useful in establishing such locations.

The industrial script writer and director must always be thinking of his actors. His budget is limited and this must limit the amount of high-priced talent that he can use. On the other hand he must use talent that can give a fairly good performance or the final result will be distinctly unsatisfactory.

Since the director may have to use talent that is not as experienced as some of the stars, it means more rehearsals and sometimes more takes. Direct 16-mm production helps here because more takes can be made without worrying too much about raw-stock costs. If the director must limit his number of takes because of the cost of raw stock, the finished production will probably not be smooth. In color this item becomes even more important.

A director of industrial shows must interpret a script differently from the way a director of dramatic shows would interpret it. Without the proper experience a director is likely to become too dramatic and many times when an industrial show becomes too dramatic it stands out as something distinctly "phoney." Of course this characteristic can quite easily be created by an inexperienced script writer. An "Elmer Blurp" type of presentation is funny on the radio or in an entertainment production, but this same sort of technic used in an industrial show would probably appear utterly ridiculous.

After the picture has been sold and the script written and put into shape for production, the industrial producer then has the problem of getting the picture on the film so that it will be good both artistically and technically.

To do a successful job the picture must have sound that is clear and easily understood. Volume level and tone quality should be uniform. It may need music and sound effects. It may need synchronous sound taken at different locations. If all these things are to fit together smoothly it will almost always need re-recording. The photography must also be smooth and easy-flowing. If an editor is to make a smooth picture he must be able to insert at the proper places in the photography wipes, fades, dissolves, and so on, that may have come from stock or from some other show, or may have been made in different parts of the world. To put these effects into an original is sometimes impossible and nearly always more costly than doing it in the laboratory. This means that the producer must have some method of making these effects either in his own laboratory or be able to purchase them from an outside laboratory. The buyer of an industrial and his audience are used to all these little refinements. They compare an industrial show with what they see in their local theaters. It is therefore almost necessary that the present-day industrial producer be able to give all these little refinements or enhancements in a picture costing perhaps less than ten thousand dollars, although the theatergoer compares it with one that cost a hundred thousand dollars.

As we have already stated the director has a limited amount to spend on talent. Usually the better the talent the easier it is to record, photograph, and direct. This means that the industrial producer must always work to get the best quality he is capable of making in his sound. Most of the sound that he does record will be played on 16-mm projectors in the field. This means that the quality must be kept good if the final results in the field are to be satisfactory. Since top-flight talent can not always be used, this means a double handicap for the sound recording technician doing an industrial. I believe that most of us would be amazed at some of the sound that is regarded as satisfactory in the theaters were it to be taken and optically reduced to 16-mm and then played on the ordinary 16-mm projector in the field. It would be almost as enlightening as if the commercial producer were allowed to set up his equipment on the best Hollywood stage with a cast of stars and then play his track back only in a big theater. He would probably be amazed at his own quality.

During the past few years a number of people have been surprised at the quality obtained in direct 16-mm recording. In a number of cases direct 16-mm has shown up better than 35-mm reduced. There are several things that might account for this technically. It is also partly due to the experience of the sound man making these tracks. He knows the unfavorable conditions under which most of these sound-tracks will be played and he has learned to compensate for some of the deficiencies that must be expected in the field. It is much easier to make passable sound when it is to be played back on the best of equipment. The problem of the industrial producer is to make sound that is at least passable on almost any equipment encountered in the field. This is no reflection on the manufacturer of the equipment because a great many of the difficulties in the field are no fault of his, and as many of the people in the field gain more experience many of these difficulties will be eliminated.

There are many camera problems in industrial production. Frequently shots must be made in factories and on production lines. These must be made without stopping the work, or with the least amount of waste time. This means that it is not always possible to use as many lights as are wanted or it means that the lights can not always be placed where the cameraman would like to have them. In color it means that angles may have to be picked that will keep daylight from being mixed with Mazda. Here again the 16-mm producer has an advantage because he can use much smaller equipment and angles that would be impossible with larger equipment. In shooting by the direct 16-mm method, the producer of color pictures has still another advantage. It is a simple matter to shift from daylight to Mazda type Kodachrome. The Mazda type Kodachrome can be used to photograph under photofloods, which are easily obtainable and which do not need any special color correction filters. Experience has shown that the film is not too critical to color-temperature, and even under rather unsatisfactory conditions good color pictures can be obtained without too much difficulty. Here again the experience of the crew is all-important.

There is the problem of music for industrial productions. Music is a comparatively simple matter when you can go out and hire someone to write a score for the picture and hire an orchestra to play it. This method produces excellent results but it also increases the cost of the production to such an extent that a great many minimum-priced industrials or even medium-priced industrials are not able to put it into their regular budget. The industrial producer has solved this in several different ways. There are stock music tracks he may use. There are stock transcriptions available to him, some on a free basis and some on a royalty basis. However, it is often very difficult to find the proper music in this library material. There is also at least one organization that will produce musical tracks on special order at a comparatively low price.

In the past few years a number of producers have used the electronic organ as background music. This has been fairly successful, but music that has been made by this method seems to show up "wows" rather easily, and unless the projectors in the field are quite free from these wows the music may be objectionable when it gets into the field. There is still another solution. We have found that the regular pipe organ such as the one formerly used in most theaters records very well. It also re-records very successfully, and if the producer has available an organist who knows how to get the most out of the pipe organ a great many different types of music can be played that will produce almost any mood the producer may desire. It has been found that music made in this manner does not seem to show up the wows nearly so badly as some other types of music.

Furthermore, if the industrial producer can record special music for each individual reel, it simplifies the production problems considerably. Once the music has been arranged it can then be recorded directly onto the film in synchronism with the picture. This soundtrack can then be re-recorded with the voice, sound-effects, and so on. If all the music is on one track, only one channel of the amplifier needs to be tied up, and it is much easier to mix it smoothly than if the music is coming from a number of different sources that must be cued very carefully. Since the industrial producer must always be thinking about time and cost, this is important.

A few industrial producers own their own laboratories for developing their original film, making their first prints and in many cases making their release prints. If a producer does not own his own laboratory he should use care in picking such a laboratory and this is especially true if he is working in direct 16-mm. If the operations of an industrial producer are extensive enough, it will undoubtedly be to his advantage to own his own laboratory because he will be able to do certain things that are almost impossible to get from any commercial laboratory. This is no reflection on the commercial laboratories, who are doing a very good job in general, but it quite frequently happens that a producer wants something special. This may take a great deal of explaining and sometimes a considerable amount of experimenting to get. If the producer owns and operates his own laboratory mainly for the benefit of his own productions, he will be much more willing to try something special once in awhile. I think we can almost say, then, that an industrial producer must have everything a major studio has, only on a smaller scale and designed to operate as economically as possible.

FIFTY-SECOND SEMI-ANNUAL MEETING

OF THE

SOCIETY OF MOTION PICTURE ENGINEERS

HOTEL PENNSYLVANIA, NEW YORK, N. Y.
OCTOBER 27th–29th, INCLUSIVE

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HOTEL RESERVATIONS AND RATES

Hotel Rates.—The Hotel Pennsylvania extends to SMPE delegates and guests the following special *per diem* rates, European plan:

Room with bath, one person	\$3.85–\$7.70
Room with bath, two persons, double bed	\$5.50–\$8.80
Room with bath, two persons, twin beds	\$6.60–\$9.90
Parlor suites: living room, bedroom, and bath	\$10.00, 11.00, 13.00, and 18.00

Reservations.—Early in September room-reservation cards will be mailed to the members of the Society. These cards should be returned to the hotel as promptly as possible to be assured of desirable accommodations. Reservations are subject to cancellation if it is later found impossible to attend the meeting.

Registration.—The registration headquarters will be located on the 18th floor of the Hotel at the entrance of the *Salle Moderne*, where most of the technical

sessions will be held. All members and guests attending the meeting are expected to register and receive their badges and identification cards required for admission to all sessions.

TECHNICAL SESSIONS

Technical sessions will be held as indicated in the Tentative Program below. The Papers Committee is assembling an attractive program of technical papers and presentations, the details of which will be published in a later issue of the JOURNAL.

FIFTY-SECOND SEMI-ANNUAL BANQUET AND INFORMAL GET-TOGETHER LUNCHEON

The usual Informal Get-Together Luncheon for members, their families, and guests will be held in the Roof Garden of the Hotel on Tuesday, October 27th, at 12:30 P.M.

The Fifty-Second Semi-Annual Banquet and dance will be held in the Georgian Room of the Hotel on Wednesday evening, October 28th, at 8:00 P.M. Presentation of the Progress Medal and Journal Award will be made at the banquet, and the officers-elect for 1943 will be introduced. The evening will conclude with dancing.

LADIES' PROGRAM

Mrs. D. E. Hyndman, Hostess, and members of her Committee promise an interesting program of entertainment for the ladies attending the meeting, the details of which will be announced later. A reception parlor will be provided for the Committee where all should register and receive their programs, badges, and identification cards.

MISCELLANEOUS

Motion Pictures.—The identification cards issued at the time of registering will be honored at a number of New York *de luxe* motion picture theaters listed thereon. Many entertainment attractions are available in New York to out-of-town delegates and guests, information concerning which may be obtained at the Hotel information desk or at the registration headquarters.

Parking.—Parking accommodations will be available to those motoring to the meeting at the Hotel garage, at the rate of $1.25 for 24 hours, and in the open lot at 75 cents for day parking. These rates include car pick-up and delivery at the door of the Hotel.

Golf.—Arrangements may be made at the registration desk for golfing at several country clubs in the New York area.

Note: The dates of the 1942 Fall meeting immediately precede those of the meeting of the Optical Society of America at the Hotel Pennsylvania, New York, N. Y., to be held on October 30th and 31st.

The Convention is subject to cancellation if later deemed advisable in the national interest.

TENTATIVE PROGRAM

Tuesday, Oct. 27

9:00 a.m. *Hotel Roof;* Registration.
10:00 a.m. *Salle Moderne;* Business and Technical Session.
12:30 p.m. *Roof Garden;* SMPE Get-Together Luncheon for members, their families, and guests. Introduction of officers-elect for 1943 and addresses by prominent members of the motion picture industry.
2:00 p.m. *Salle Moderne;* Technical Session.
8:00 p.m. *Museum of Modern Art Film Library;* Technical Session.

Wednesday, Oct. 28

9:00 a.m. *Hotel Roof;* Registration.
9:30 a.m. *Salle Moderne;* Technical sessions.
12:30 p.m. Luncheon Period.
2:00 p.m. *Salle Moderne;* Technical session.
8:00 p.m. *Georgian Room;* Fifty-Second Semi-Annual Banquet and Dance.

Thursday, Oct. 29

9:00 a.m. *Hotel Roof;* Registration.
10:00 a.m. *Salle Moderne;* Technical Session.
12:30 p.m. Luncheon Period.
2:00 p.m. *Salle Moderne;* Technical Session.
8:00 p.m. *Salle Moderne;* Technical Session and Convention adjournment.

Note: Any changes in the location of the technical sessions and schedules of the meeting will be announced in later bulletins and in the final program.

W. C. KUNZMANN,
Convention Vice-President

S. M. P. E. TEST-FILMS

These films have been prepared under the supervision of the Projection Practice Committee of the Society of Motion Picture Engineers, and are designed to be used in theaters, review rooms, exchanges, laboratories, factories, and the like for testing the performance of projectors.

Only complete reels, as described below, are available (no short sections or single frequencies). The prices given include shipping charges to all points within the United States; shipping charges to other countries are additional.

35-Mm. Visual Film

Approximately 500 feet long, consisting of special targets with the aid of which travel-ghost, marginal and radial lens aberrations, definition, picture jump, and film weave may be detected and corrected.

Price $37.50 each.

16-Mm. Sound-Film

Approximately 400 feet long, consisting of recordings of several speaking voices, piano, and orchestra; buzz-track; fixed frequencies for focusing sound optical system; fixed frequencies at constant level, for determining reproducer characteristics, frequency range, flutter, sound-track adjustment, 60- or 96-cycle modulation, etc.

The recorded frequency range of the voice and music extends to 6000 cps.; the constant-amplitude frequencies are in 11 steps from 50 cps. to 6000 cps.

Price $25.00 each.

16-Mm. Visual Film

An optical reduction of the 35-mm. visual test-film, identical as to contents and approximately 225 feet long.

Price $25.00 each.

SOCIETY OF MOTION PICTURE ENGINEERS
HOTEL PENNSYLVANIA
NEW YORK, N. Y.

JOURNAL OF THE SOCIETY OF MOTION PICTURE ENGINEERS

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JOURNAL OF THE SOCIETY OF MOTION PICTURE ENGINEERS

SYLVAN HARRIS, EDITOR

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* Term expires December 31, 1942.
** Term expires December 31, 1943.

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REPORT OF THE PROJECTION PRACTICE SUB-COMMITTEE

OF THE

THEATER ENGINEERING COMMITTEE

PROJECTION ROOM PLANS

The projection room plans that follow constitute the third revision of the original plans published by the Committee in August, 1932. The two prior revisions were made in October, 1935, and November, 1938. Such revisions are necessary from time to time in order to keep pace with the changes and developments in the art and practice of projecting sound motion pictures and to assure that the projection room is so planned that it will permit maximum efficiency of operation of the equipment installed within it. The Committee urgently recommends the adoption of these Recommendations by all architects and builders in designing and remodeling projection rooms so that greater uniformity of construction and greater efficiency in projection will exist in the future.

In following these Recommendations, proper authorities should in all cases be consulted for possible deviations therefrom as may be required for conformance to local rulings. All fire-protection requirements specified or referred to herein are in accordance with the National Board of Fire Underwriters and the National Electric code, which should be consulted for details.

Projection space facilities shall consist of (*1*) the projection room proper, (*2*) film rewind and storage space, (*3*) a power equipment room, and (*4*) a lavatory.

PROJECTION ROOM PROPER

(*1.1*) *Construction.*—The projection room shall be of fire-resistant construction throughout and shall be supported by or hung from fire-resistant supports. The projection room shall have a minimum height of 8 feet. The width and depth of the projection room shall be governed by the quantity and kind of equipment to be installed within it, and also by whether the film-rewinding and film-storage

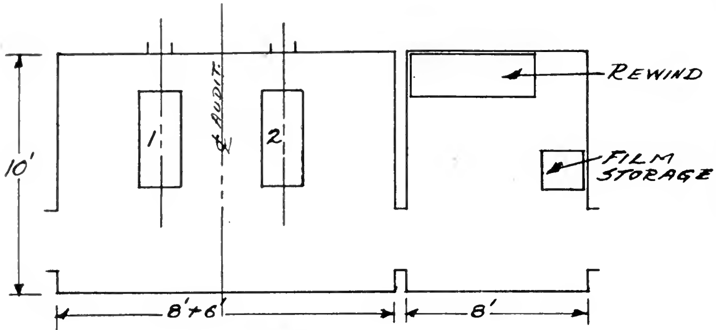


FIG. 1

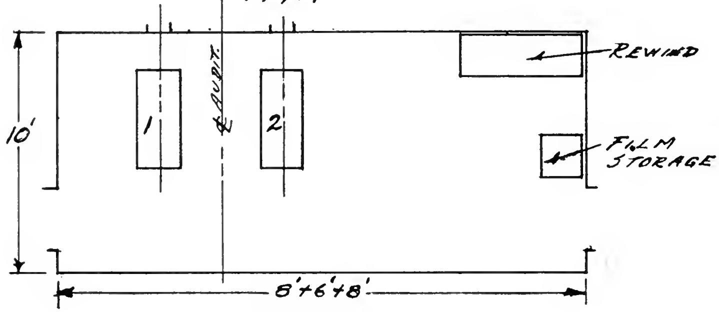


FIG. 2

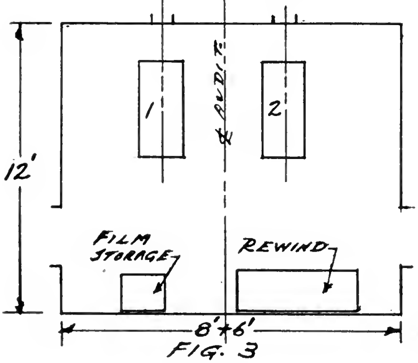


FIG. 3

FIG. 1 (*Upper*). Layout with separate rewind room.
FIG. 2 (*Center*). Layout with rewind bench and storage cabinet at end of room.
FIG. 3 (*Lower*). Layout with rewind bench and storage cabinet behind projectors.

facilities are to be incorporated in a separate room or be a part of the projection room proper.

The minimum width of the projection room, for one projector, when film-rewinding facilities are provided for in a separate room, shall be not less than 8 feet. For each additional projector, spotlight, stereoptican, or floodlight machine shall be added an additional 6 feet in width. The minimum depth of the projection room, when film-rewind and storage facilities are provided for in a separate room, shall be not less than 10 feet (Fig. 1).

When film-rewinding and storage facilities are incorporated within the projection room proper, which may be desirable under some conditions, the minimum width of the projection room when the film-rewinding and storage facilities are placed in line with the projectors, shall be not less than 16 feet for one projector. For each additional projector, spotlight, stereoptican, or floodlight machine, an additional 6 feet in width shall be added. When film-rewinding and storage facilities are within the projection room proper and placed in line with the projectors, the minimum depth of the projection room shall not be less than 10 feet (Fig. 2).

When film-rewinding and storage facilities are incorporated within the projection room proper and are located to the rear of the projectors, the minimum width of the projection room for one projector shall be not less than 8 feet. For each additional projector, spotlight, or floodlight machine, an additional 6 feet in width shall be added. When film-rewinding and storage facilities are incorporated in the projection room proper, and placed at the rear of the projectors, the minimum depth of the projection room shall be not less than 12 feet (Fig. 3).

Great care should be exercised in selecting the film-rewinding and storage facilities layout that will be most efficient for each particular theater. Efficient operation requires that the screw shall be in view of at least one member of the working projection room staff whenever a picture is being projected to the screen.

Generous consideration should be given to all probable future needs for additional projection room space.

The projection room proper shall be so located with respect to the screen that the vertical projection angle shall not exceed 14 degrees. Since the ideal projection angle is one of zero degrees, it is recommended that every consideration be given to keep the projection angle at as near the ideal as possible. Optical axes of the projectors shall be five feet apart. When two projectors are used, the optical axes shall be equidistant from the centerline of the auditorium; when three projectors are used, the optical axis of the center projector shall be on the centerline of the auditorium. Motion picture projectors shall be given preference over stereopticans, spotlights, or floodlight machines, for installation nearest the centerline of the auditorium.

(*1.2*) *Floor.*—The floor of the projection room shall be sufficiently strong and solid for the load it is to bear. A minimum strength of floor construction of 200 pounds per square-foot plus the dead weight of the construction proper is recommended. A generous factor of safety should be allowed. A type of floor construction recommended consists of (*1*) a reinforced concrete floor-slab not less than 4 inches thick, (*2*) a tamped cinder fill above the floor-slab not less than 4 inches thick, and (*3*) a troweled cement finish above the cinder fill, not less than 2 inches thick. Items (*2*) and (*3*) have been provided in order to accommodate concealed electric conduits, which should be installed prior to placing the fill and finish. The cinder fill of the projection room floor may be eliminated where there is a plenum space beneath the projection room area proper, and which area is available for the running of conduit.

(*1.3*) *Walls and Ceiling.*—The projection room walls shall be built of brick, tile, or plaster blocks plastered on the inside with $^3/_4$-inch cement or acoustical plaster, or all concrete. The core of the wall shall be not less than 4 inches thick. When plaster block is used, it shall be supported upon steel framework. All electrical conduits shall be in masonry chases in the wall construction so that they shall not project beyond the finished plaster line (*see Sec. 6.1*). In all cases, the inside surface of the front wall shall be smooth and without structural projections. The ceiling shall be constructed of 4-inch concrete slabs or pre-cast concrete, or of 3-inch plaster blocks supported by a steel structure and plastered on the inside with $^3/_4$-inch cement plaster or acoustical plaster. All electrical conduits in the ceiling shall be concealed (*see Sec. 1.10*).

(*1.4*) *Doors.*—A door shall be provided at each end of the projection room. Doors shall be not less than 2 feet 6 inches wide and shall be 6 feet 8 inches high. Doors shall be approved fire-doors of a type suitable for use in corridor and room partitions (Class *C* openings, as defined in the *Regulations for Protection of Openings in Walls and Partitions*), shall be self-closing, swinging outwardly, and shall be kept closed at all times when not used for egress or ingress. It shall be possible at all times to open either door from the inside merely by pushing it. Door jams shall be made of steel.

(*1.5*) *Windows.*—Where a projection room is built against the exterior wall of a structure, one or more windows may be provided in the wall. Window construction shall be entirely of steel, and the glass shall be of the shatter-proof type. Adjustable metal louvres or equal means shall be used to exclude direct light. Extreme caution should be taken to prevent dirt and dust from entering the projection room area through windows opening directly to the outdoors.

(*1.6*) *Portholes.*—(*General*) Two portholes shall be provided for each projector, one through which the picture is projected, known as the "projection port" (*see Sec. 1.7*), and the other for observation of the picture screen by the projectionist, known as the "observation port" (*see Sec. 1.8*).

The observation port shall be located above and to the right of the projection port. The distance between the horizontal centerlines of the projection port and the observation port shall be 15 inches; the distance between the vertical centerlines of the projection port and the observation port shall be 21 inches.

Where separate spotlight, stereopticon, or floodlight machines are installed in the same projection room with motion picture projectors, not more than one port opening (*see Sec. 1.9*) for each machine shall be provided for both the projectionists' view and for the projection of the light, but two or more such machines may be operated through the same port.

(*1.7*) *Projection Ports.*—The finished ports shall be 10 inches by 10 inches, measured on the inside wall.

The required height of the centerline of the projection port from the finished floor varies with the make and the design of the projection and sound equipment to be used, and also with the vertical projection angle. The manufacturers of the equipment being installed should be consulted for these dimensions. In no case shall any part of the projector be less than 4 inches from the front wall of the projection room. Table I lists two constants for various angles of projection which, when substituted in the formula, will permit calculating the height of the centerline of the port from the finished floor level when certain dimensions of the projector are known.

(*1.8*) *Observation Ports.*—The finished observation port shall be not greater than 200 square-inches in area, measured on the inside wall of the projection room. A recommended size for the observation port is 14 inches wide and 12 inches high, when measured on the inside wall of the projection room.

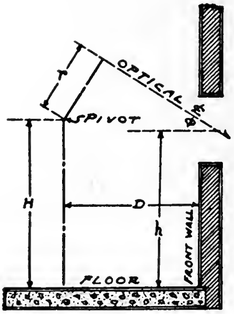
(*1.9*) *Other Ports.*—All other ports, such as for spotlight, stereopticon, or floodlight machines, shall be as small as practicable and in no case shall exceed $7^1/_2$ square-feet in area per machine. The size and location of these ports will, of course, be determined by the types of such machines to be used. These dimensions should be obtained from the manufacturers of such machines.

TABLE

Method of Locating Projector Port

$$h = H + rA - DB$$

Projection Angle (Degrees)	*A*	*B*
0	1.00	0.00
2	1.00	0.04
4	1.00	0.07
6	1.01	0.11
8	1.01	0.14
10	1.02	0.18
12	1.02	0.21
14	1.03	0.25
16	1.04	0.29
18	1.05	0.33
20	1.06	0.36
22	1.08	0.40
24	1.09	0.45
26	1.11	0.49
28	1.13	0.53
30	1.16	0.58



H is the height of the center of the projector pivot from the floor; *r* is the radial distance of the optical centerline above the center of the pivot; *D* is the distance of the center of the pivot from the front wall of the projection room; ϕ is the angle of projection; and *h* is the required height of the center of the port from the floor of the projection room. Select the values of *A* and *B* corresponding to the angle of projection, and substitute in the formula.

(*1.10*) *Acoustic Treatment.*—It is recommended that an approved fireproof acoustical material be applied to the walls above a height of 4 feet from the floor, and on the ceiling of the projection room, to reduce the transmission of noise into the auditorium and to reduce projector and machine noise within the projection room proper.

REWIND ROOM

(*2.1*) *Construction.*—The rewind room, if separate from the projection room proper, shall be of fireproof construction. It shall have a minimum area of 80 square-feet (Fig. 1).

(*2.2*) *Floor.*—(*See Sec. 1.2.*)

(*2.4*) *Doors.*—The door shall be an approved fire-door of a type suitable for use in corridor and room partitions (Class *C* openings, as defined in the *Regulations on Protection of Openings in Walls and Partitions*), shall be arranged to be self-closing, swinging outwardly, and shall be kept closed at all times when not used for egress or ingress. Door jams shall be made of steel.

(*2.6*) *Ports.*—Where the rewind room is adjacent to the auditorium, an observation port shall be provided through which the picture screen may be seen from within the rewind room. This port shall be at the same height from the finished floor as the observation ports in the projection room proper (*see Sec. 1.6*).

(*2.8*) *Observation Port.*—(*See Sec. 1.8.*)

(*2.9*) *Other Ports.*—An observation window shall be provided between the projection room and the rewind room, consisting of a fixed fireproof frame and polished plate wire glass. This window shall be not more than 200 square-inches in area, and shall have its horizontal centerline 5 feet from the finished floor level.

(*2.10*) *Acoustic Treatment.*—(*See Sec. 1.10.*)

POWER EQUIPMENT ROOM

(*3.1*) *Construction.*—The room shall be fireproof and shall be constructed in accordance with Sections *1.2, 1.3, 2.4,* and *1.10.* The size shall be governed by the quantity and kind of equipment to be installed. Generous consideration shall be given to probable future needs.

(*3.2*) *Special Equipment.*—It is recommended that wherever rotary power equipment, such as motor-generator units, is employed having an input rating in excess of 15 horsepower, such equipment be installed remote from the theater auditorium, such as in the basement, to prevent acoustical hum or mechanical vibration from reaching the auditorium section of the theater. Extreme caution should be taken to insulate properly all rotary equipment that may be located at the projection room level, regardless of size, against the possibility of excess mechanical vibration and hum. All arc-supply equipment located in the power-equipment room, including projection arc rheostats, shall be at least 4 feet from all sound-amplifier units.

LAVATORY

(*4.1*) *Construction.*—The lavatory shall be provided with running water and modern sanitary facilities, with tiled floor and built-in, flush-type medicine closet.

EXITS

(*5.1*) *General.*—Two exits shall be provided, one at each extreme end of the projection room, permitting direct and unobstructed egress (*see Fig. 1 and Sec. 1.4*). Any stairs forming part of these exits should have risers not in excess of 8 inches and a minimum tread of not less than 9 inches. The distance between walls in any section of the exits shall not be less than 36 inches. Winding or helical stairs should be avoided. A platform at least equal in length to the width of the door shall be provided between the door and the first riser. Neither ladders, scuttles, nor trap-doors shall be used as means of entrance or exit.

CONDUITS AND CIRCUITS

(*6.1*) *Locations and Sizes.*—Locations and sizes of conduits and wiring for projection control and sound equipment units are determined by the quantity, types, and designs of the equipment to be installed. Manufacturers of the equipment should be consulted with regard to proper layout and sizes of conduit and wiring systems before floors, walls, and ceilings are finished (*see Secs. 1.2 and 1.3*). Conduits shall in all cases be concealed, and all boxes shall be of the flush type, when located in the floors, walls, or ceiling. Conduits terminating in the floor shall extend 6 inches above the finished floor level. The wiring and conduit layout shall be in accordance with the National Electrical Code. Wiring shall be provided for the following usual circuits, and wiring for special or additional equipment shall also be provided:

(*1*) *Projector mechanism*
    (*a*) Drive motor
    (*b*) Change-overs
    (*c*) Pilots
(*2*) *Projectors, spotlights, and floodlight machines*
    (*a*) Arc supply
    (*b*) Arc ballast rheostats

- (*3*) *Sound equipment*
  - (*a*) A-c supply
  - (*b*) Amplifier controls and power-supply units
  - (*c*) Loud speaker circuits
  - (*d*) Ground wire
  - (*e*) Sound heads
- (*4*) *Projection room lighting*
  - (*a*) General
  - (*b*) Emergency
- (*5*) *Theater auditorium lighting*
  - (*a*) Regular
  - (*b*) Emergency
- (*6*) *Projection room ventilating system*
  - (*a*) Normal
  - (*b*) Emergency
- (*7*) *Projector ventilating system*
  - (*a*) Normal
- (*8*) *Miscellaneous*
  - (*a*) Stage curtain control
  - (*b*) Telephones
  - (*c*) Buzzers and signal system
  - (*d*) Receptacles
  - (*e*) Clock outlet

(*6.2*) *Power-Supply to Equipment.*—Where line-voltage variations are greater than ±3 per cent, the local power company should be requested to correct the condition. In cases where it is impossible normally to maintain steady line-voltage to the equipment, suitable voltage regulators shall be used.

LIGHTING

(*7.1*) *Projection Room Lighting.*—Approved indirect or semi-indirect ceiling fixtures of the vapor-proof type shall be used for general illumination, and should be arranged to be lighted from either the normal or emergency lighting circuit. A single reel-light of the vaporproof type with wire guard shall be centrally located on the projection room ceiling, and shall be equipped with sufficient approved cord to allow extension of this reel-light to all parts of the projection room proper.

Individual ceiling fixtures of the vaporproof type shall be installed at the operating side of each projector spotlight, stereopticon, or floodlight machine. All projection room lighting fixtures shall be equipped with keyless sockets and shall be controlled from wall switches. All lights in the projection room and associated rooms shall be properly shaded so as to prevent light from entering the auditorium through the porthole openings.

(*7.2*) *Rewind Room.*—An approved vaporproof ceiling fixture shall be installed for general illumination. A drop-light or wall-bracket fixture of an approved vaporproof type shall be provided over the rewind table. These lights shall be controlled from a wall switch independently of any lights in the projection room proper.

VENTILATION

(*8.1*) *Projection Room.*—The projection room proper shall have the following ventilating facilities:

(*a*) Carbon arc exhaust
(*b*) Fresh air supply
(*c*) Projection room exhaust, including an emergency exhaust

The carbon arc exhaust system shall be a positive mechanical exhaust system independent of all other ventilating systems of the theater. Each projector, spotlamp, stereopticon, or floodlight machine, if of the carbon arc type, shall be connected by a flue to a common duct, which duct shall lead directly out of doors. Reduction of the ventilation to each projector as required shall be accomplished by means of a local damper between the projector lamp-house and the projection room ceiling, and in addition, by means of the damper on the lamp-house proper if provided.

This exhaust system shall be operated by an exhaust fan or blower having a capacity of not less than 50 cubic-feet of air per minute for each arc lamp connected thereto. The exhaust fan or blower shall be electrically connected to the projection room wiring system and shall be controlled by a separate switch, with pilot lamp, within the projection room proper. There shall be at no time less than 15 cubic-feet of air per minute through each lamp-house into this exhaust system. Fig. 4 shows the general arrangement. The ducts shall be of non-combustible material, and shall be kept at least 2 inches from combustible material or separated therefrom by approved non-combustible material, not less than 1 inch thick.

The fresh-air supply to the projection room shall consist of not less than two intake ducts located at or near the floor and at opposite ends of the room, and shall be connected into the main air-supply ducts of the building. There shall be no connection between this air-supply system and any of the exhaust systems of the projection room. It is recommended that gravity-operated dampers connected to the emergency port-hole release system be installed in the fresh-air intake registers to prevent smoke from entering the main theater fresh-air duct system, in case of a fire in the projection room area.

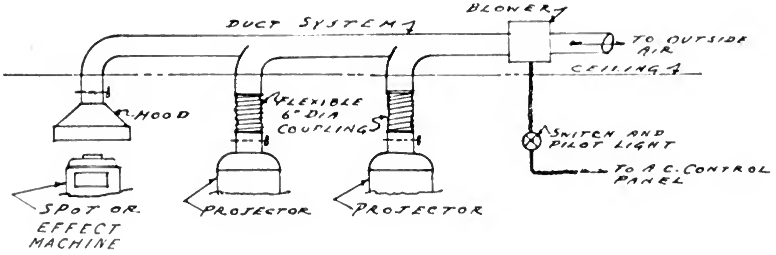


FIG. 4. Equipment ventilation system: blower capacity 400 cu-ft per min; minimum air movement through lamp houses with blower idle, 15 cu-ft per min.

The projection room exhaust system shall be a positive mechanical exhaust system having a normal capacity of not less than 200 cubic-feet per minute and having an auxiliary emergency capacity of not less than 1000 cubic-feet per minute for operation in emergency, *i. e.*, fire. The ventilation system shall terminate in ceiling grilles in the projection room, which shall not be less than two in number. In no case shall this room exhaust system be connected into any of the ventilating systems of the theater proper. The emergency position of this fan shall be controlled by a switch (Fig. 5) operated auto-

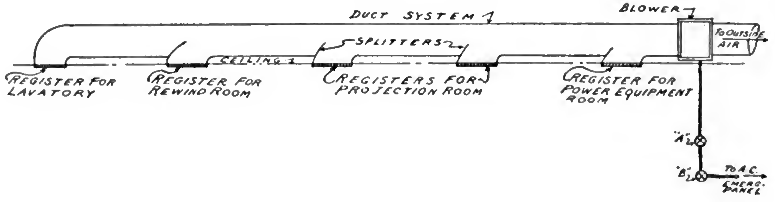


FIG. 5. General and emergency ventilation system: normal blower capacity 200 cu-ft per min; emergency capacity 2000 cu-ft per min. (A) Switch and pilot lamp for normal operation, inside projection room; (B) switch and pilot lamp for emergency operation, outside door of projection room; also connected to port fire-shutter control mechanism. (Two or more fresh-air intakes required at or near the floor at opposite ends of the room.)

matically by the shutter control system, when the latter is actuated either manually or by melting of the fusible links. This exhaust fan

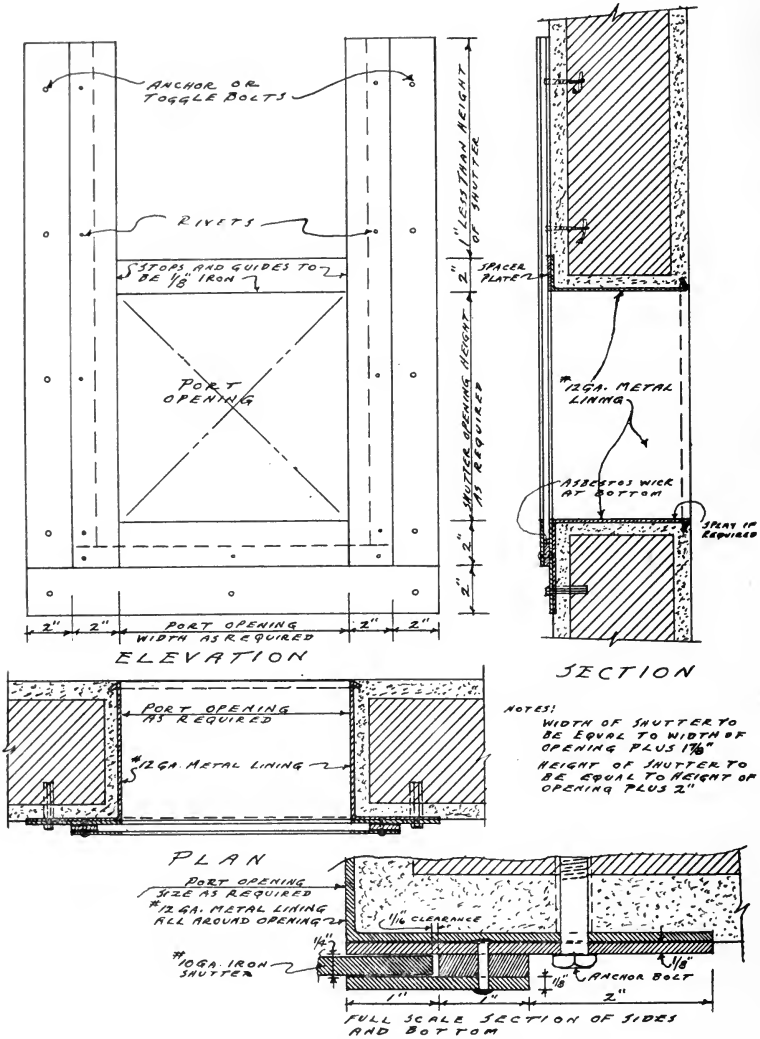


FIG. 6. Example of port shutter construction. Although this construction shows rivets, spot welding is preferable.

shall be electrically connected to the emergency lighting system of the building. Control shall be provided for manual operation of this fan from a point immediately outside the projection room proper, in addition to the emergency control in the shutter system.

(*8.2*) *Rewind room.*—The general ventilation of the rewind room, *i. e.*, fresh-air supply and room exhaust, shall be a part of the projection room fresh-air supply system and the projection room exhaust system. There shall be no connection between the projection arc exhaust system and any part of the rewind room ventilating system.

Film cabinets, if of the single-compartment type shall be vented to the outside air by means of a gravity vent (*see Sec. 12.2*).

(*9.1*) *Port-Hole Shutters.*—Each port opening shall be provided with a gravity shutter of approved construction. The shutter and its guides shall be constructed of not less than No. 10 gauge iron and the shutter shall be set into the guides not less than 1 inch at the sides and bottom, and shall overlap the top of the port opening not less than one inch, when the shutter is in a closed position. Shutter guides shall be of welded construction, and should be built into the masonry of the projection room walls (Fig. 6). Shutters shall be suspended, arranged, and so interconnected that they will all close upon the operation of some mechanical releasing device or the operation of some fusible link, so designed to operate automatically in case of fire or other emergency requiring immediate and complete isolation of the projection room from the other portions of the building. Each shutter shall have its individual fusible link above it. A fusible link shall be located also above each upper projector magazine which upon

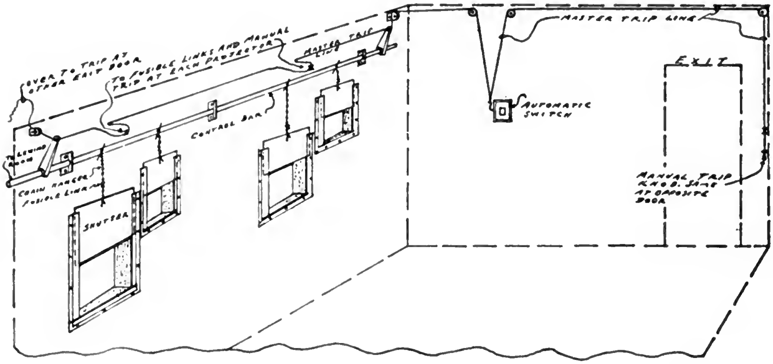


FIG. 7. One of many possible arrangements of the port fire-shutter control. The automatic switch operates the exhaust fan and emergency lights.

operation shall close all the port shutters. There shall be provided also a suitable means for the manual release of the shutter system from any projector head and from a point near each door within the projection room. Shutters shall be free-acting. Shutters on openings not in use shall be kept closed always. It is recommended that shutters be closed each night at the close of the show as a daily check on their operation. Fig. 7 shows a recommended method for arranging the port shutter system. All large shutters such as for spot-lamps, stereopticons, and floodlight machines (when used) shall be hung in counterweighted systems to facilitate manual operation. All such large shutters, however, shall be so arranged that the release of the regular shutter system will close the large ports also.

(*9.2*) *Noise Transmission.*—The Committee recommends the use of means other than glass in projection ports to prevent transmission of noise from the projector room to the auditorium, such as by reducing the free aperture of the port to the minimum size necessary to pass the projection beam, or by the use of fireproof sound-baffles. Observation ports shall be fitted with a good grade of plate glass set in metal frames at an angle to the vertical to avoid direct reflection, and such glass shall be easily removable from the projection room side for cleaning. The purpose of this glass is to reduce noise transmission into the auditorium.

HEATING

(*10.1*) *General.*—Proper provision shall be made for heating the projection room. The same facilities used for heating the theater shall be extended to the projection room.

PAINTING AND FLOOR COVERING

(*11.1*) *Painting.*—The color of the walls shall be olive-green to the height of the acoustical plaster. The latter shall be painted in accordance with the instructions of the manufacturer of the material, and preferably a dull buff color. The ceiling shall likewise be painted in accordance with these instructions but in a white color. All ironwork of the projection ports shall be covered with at least two coats of flat black paint.

(*11.2*) *Floor Covering.*—Where local regulations permit, the floors of the projection room and rewind room shall be covered with a good grade of battleship linoleum cemented to the floor. The floor covering shall be laid before the equipment is installed.

EQUIPMENT

(*12.1*) *Projection Room.*—All equipment to be used in the projection room, including the projectors, arc lamps, sound equipment, *etc.*, shall be of approved type.

All shelves, furniture, and fixtures within the projection room suite shall be constructed of metal or other non-combustible and approved material. An approved metal container shall be provided for hot carbon stubs. Adequate locker space for projectionists' clothing shall be provided.

(*12.2*) *Rewind Room.*—In the rewind room shall be provided an approved fireproof film-cabinet or safe, a rewind table, approved rewind equipment, a mechanical film-splicer, an approved film-scrap can, and an approved storage cabinet for film-leaders, snipes, *etc.*, used only at various intervals.

The film-cabinet, or safe, shall be capable of holding 25,000 feet of 35-mm film on standard reels. Doors on film-cabinets or safes shall be of the automatic tight-closing type, and either of the single-reel compartment or single-compartment type. Film-cabinets of the single-compartment type holding in excess of 50 pounds of film (10,000 feet) should be vented to the outside air by means of a gravity vent. The vent should not be less than 36 square-inches in area for each 50 pounds of film stored. This vent shall be constructed of non-combustible material and shall be kept at least 2 inches from any combustible material, or shall be separated therefrom by approved non-combustible material not less than one inch thick. Film-cabinets of the single-compartment type having a capacity of more than 50 pounds of film (10,000 feet) also should be equipped with an automatic sprinkler-head, of the $^3/_4$-inch size, connected to the theater water-supply. It is recommended that pressure at such sprinkler head be not less than 15 pounds.

All tables, racks, and all furniture shall be of metal or other approved non-combustible material, and shall be kept at least four inches away from any radiator or heating apparatus. Tables shall not be provided with racks or shelves beneath them whereon may be kept film or other materials.

The film-scrap can shall have an automatic, self-closing lid, and shall be of approved type. It is recommended that a type designed to keep scrap-film immersed in water at all times be used.

Quantities of collodion, amyl acetate, or other inflammable cements or liquids kept in the rewind room for any purpose shall not exceed one pint.

No stock of inflammable materials of any sort whatever shall be permitted within the rewind room except as mentioned above.

Film shall be kept in the film-cabinet at all times except when it is being projected, rewound, or inspected. Any films in addition to those used for the current showing or in excess of that permitted by local authorities shall be kept in their original shipping containers. Film-leaders used occasionally may be kept in an approved cabinet designed for that purpose.

All film splices shall be made with approved mechanical cutting and splicing machine. No hand cutting or splicing shall be permitted.

(*12.3*) *Fire-Extinguishing Equipment.*—Local authorities having jurisdiction with regard to fire-extinguishing equipment should be consulted regarding the proper types, numbers, and locations of such equipment.

It is the recommendation of this Committee that fire-extinguishers of the carbon tetrachloride or carbon dioxide types be considered for use in projection rooms, as they have proved to give the most effective protection for the specialized equipment within the projection room. In addition to their being the most effective fire extinguishers, they do not cause the ruin of the precision equipment installed within the projection room proper, if it is necessary that they be used for any emergency.

MISCELLANEOUS

(*13.1*) "No Smoking" signs shall be posted in prominent places, and matches should not be carried by any employee having access to the projection room.

(*13.2*) *Operation.*—Motion picture projectors shall be operated by and shall be in charge of qualified projectionists who shall not be minors. A projectionist should be stationed constantly at the operating side of a projector while it is in operation. A proper factor of safety in operation, as well as avoidance of imperfect operation of projection equipment or unjustified interruptions of service can be attained only by having an adequate personnel in the projection room.

(*13.3*) *Action in Case of Fire.*—In the event of film fire in the projector or elsewhere in the projection or rewind room, the projectionist shall immediately shut down the projector and all arc lamps, operate the port shutter release at the point nearest him, turn on the auditorium lights, leave the projection room immediately, and notify the manager of the theater or building.

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MOTION PICTURE LABORATORY PRACTICES*

JAMES R. WILKINSON **

Summary.—*The function of laboratory service to studio production departments and to the release distribution field is discussed. The size and scope of laboratory operations are illustrated graphically by an organization chart showing the number of sub-departments. These in turn are classified into three major divisions, namely, Control, Processing, and Maintenance. Analysis of individual department activity begins with the Control division, and emphasis is placed upon the recent trend toward more scientific approach to the problems of processing. Discussion continues with the Processing division, starting with negative development, and the processing method of each successive department is described showing the inline flow of the work for both studio and release print operations. Problems relating to proper mechanical and electrical maintenance are also discussed.*

The motion picture laboratory is, essentially, a service organization. Its operations, while of an extremely technical nature, are not creative in any sense of the word, and possibly because of this fact its efforts are unsung and little in the way of publicity has been released from the industry relative to its activity or its contribution to motion picture entertainment. Papers on the subject have been written by G. M. Best and F. R. Gage, and by C. L. Lootens.[1]

The scope of laboratory service normally embraces the studio production division, *i. e.*, Camera, Sound, and Editorial departments; also the distribution division, including both Foreign and Domestic departments. Viewing the laboratory as a part of a major studio organization, it is considered as a single department similar to the Camera, Make-up, or Art departments. Actually the laboratory is one of the largest of the studio units, normally employing from 150 to 250 workers, and is itself divided into approximately twelve subdepartments, each with its operating foreman and a crew ranging from five to thirty workers. The specialized nature of the various laboratory operations foster this departmentalization and, under ex-

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* Presented at the 1942 Spring Meeting at Hollywood, Calif.; received May 10, 1942.

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

isting conditions, it is very seldom that an overlapping of departmental activities occurs.

To assist in visualizing laboratory operating methods Fig. 1 shows a typical organization chart and the relationship of the various departments to the supervising personnel. While the chart is typical of the average laboratory, variations can and do occur within the individual plants. Laboratory activities seem to be naturally divided into three rather separate and distinct divisions, namely, the Control division, the Productive or Processing division, and the Supporting or Servicing division. Within these divisions the departments are identified as follows:

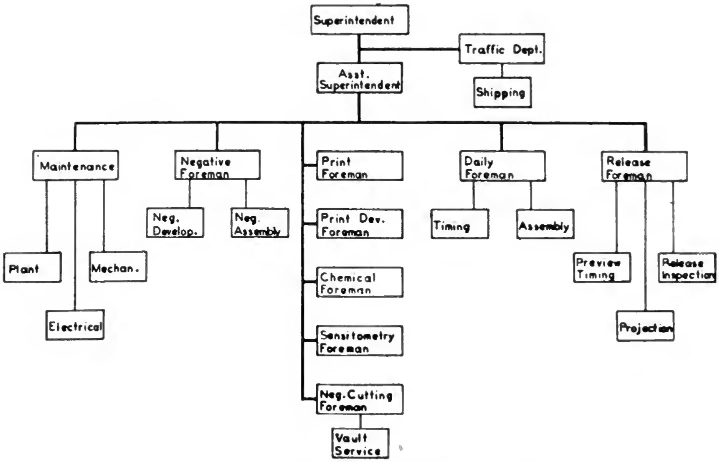


FIG. 1. Laboratory organization chart.

Control	Sensitometry
	Chemical
Processing	Negative Developing
	Negative Assembly
	Negative Cutting
	Printing
	Positive Developing
	Positive Daily Assembly
	Release Inspection
	Projection
	Timing

Service	Mechanical Maintenance Electrical Shipping and Receiving

Before analyzing the various departmental functions it might be well to state briefly the nature of the work performed by the laboratory. Fundamentally it comprises the development of exposed negative, both sound and picture, and developing of positive rush prints for studio purposes; also the timing, printing, development, and shipment of completed prints for release distribution. The work for both production and distribution divisions generally passes through the plant at the same time, yet the segregation of the work for the two divisions is rather clean-cut. Each normally follows a fairly straight-line method of procedure and the physical arrangement of departments, starting with the receiving room, is so planned to route the work through the various operations back to the point where distribution, is effected, with a minimum amount of lost motion. Fig. 2 illustrates the progressive in-line flow of daily and release operations.

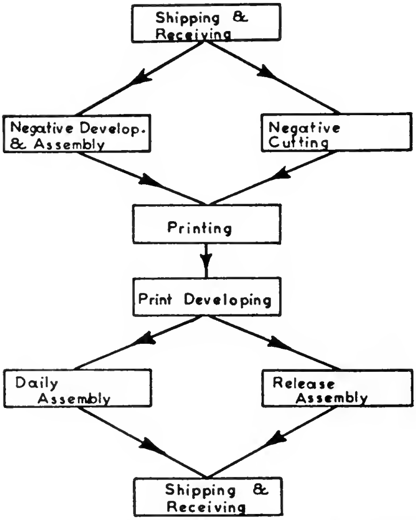


FIG. 2. Production line of daily and release print operations.

CONTROL DIVISION

Sensitometry Department.—Yielding first place only to the sound department, in the technical nature of its work, the laboratory has made noteworthy progress during the past few years in the more scientific approach to its processing problems. In the control division this progress has been particularly marked. Sensitometry, actually the junior of all laboratory departments, has assumed a measure of importance undreamed of originally. It is now the function of this department, through countless tests and calculations, to establish the optimal exposure and development specifications for both negative and positive materials, whether for sound or picture purposes.

The wide increase in the use of specialized emulsion coatings, plus the intensive research program conducted prior to the general adoption of fine-grain film, has made necessary the broadening of sensitometric methods to include many tests not originally a part of classical sensitometry. This, in turn, called for the development of new types of equipment and, as a result, the dynamic analyzer together with improved photoelectric densitometers,[2] have become two of sensitometry's most useful tools. Other equipment includes the II*b* sensitometer; the microdensitometer; a sound-reproducer with suitable amplifiers, filter circuits, and volume indicator; a projection microscope; and a cathode-ray oscillograph.

It is not the intent here to go into the technical details of classical sensitometry. The subject has been amply covered by D. Mackenzie and by L. A. Jones.[3] However, it is appropriate to review here some of the present duties and responsibilities of this department. A partial list of its activities include the following items:

(*1*) The testing of all emulsions, whether negative or positive, to determine their characteristics. On certain emulsions the determinations of only speed and contrast are sufficient; while on others, such as are used for sound recording, dubbing prints, master positives, *etc.*, a very detailed and complete analysis is made. In addition to density and gamma characteristics they are checked for frequency reponse, distortion, printer gamma, grain size, *etc.*

(*2*) The exposure, measurement, and analysis of the II*b* gamma strips to aid the chemical department in its chemical control. This applies to all processed film.

(*3*) The recording of densities on all sound-track negative and the selection of the proper printing light to give a correct print density.

(*4*) Furnish complete reports to the sound department on daily sound prints as well as special copies such as preview prints. These include the gamma, density, and dynamic test data.

(*5*) The checking of variable-area sound-prints by the use of the cancellation or cross-modulation test,[4] by frequency response and by projection microscope examination.

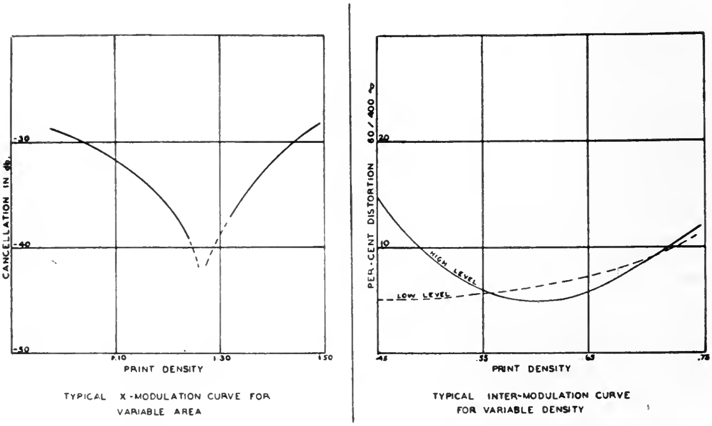
(*6*) The checking of variable-density sound-prints by the use of intermodulation,[5] delta-db, frequency response, light-valve gamma, and projected gamma tests. Fig. 3 shows typical graphs for cross-modulation and intermodulation analyses. Areas of print densities giving minimal distortion are clearly indicated.

(*7*) The checking of printer equipment for exposure, field coverage, printer gamma, light increment, contact, image shift, flicker, and noise introduced by mechanical imperfections such as worn gears, backlash, *etc.*

(*8*) The checking of developing machine equipment for 96-cycle hum, directional effect, and drying imperfections.

(*9*) Continuous collaboration with engineers of the sound department with a view to constant improvement in quality or technic.

The influence of sensitometric activity is felt throughout the laboratory, but its greatest importance lies in its relation to the chemical department through the establishment of specifications and processing tolerances that govern developing activities.



TYPICAL X-MODULATION CURVE FOR VARIABLE AREA

TYPICAL INTER-MODULATION CURVE FOR VARIABLE DENSITY

FIG. 3. Typical intermodulation and cross-modulation curves for sound-processing control.

Chemical Department.—The chemical department might readily be termed the heart of the laboratory. It is here that all processing solutions originate, and are pumped and circulated through a maze of hard-rubber piping to the various negative and positive developing machines. Fig. 4 shows a general view of tanks and equipment. In no other department has there existed a greater opportunity for scientific progress. The photographic process wherein a silver halide, which has been exposed to light, is reduced by a developing agent is one of the oldest of the arts. The action itself is a simple scientific phenomenon that is well known, yet it sets in motion a train of complex chemical reactions which, due to the volume methods of modern technic, affect the very foundations of our work. Dr. C. E. Kenneth Mees states:[6]

> Until recently, photographic science tended to consist of a chaos of observations, some of them of real value and others of very doubtful value, with little in the way of theories to connect them properly. It is only within the last few years that fact after fact has been falling into place in an ordered network.

Just as it is the function of sensitometry to establish the complete range of specifications and tolerances for all developing procedure, so it is the responsibility of the chemical department to establish and maintain chemical control over all solutions. Each developing bath, whether it be picture negative, sound negative, or positive, is designed for a specific purpose and is so compounded that it will produce the best possible quality for its particular task and do so continuously. Since film development is a continuous operation it is only logical that solution replenishment likewise be continuous and proportionate to the bath exhaustion occasioned by the footage volume. The detail of procedure and the benefits to be derived from continuous replenishment are described by H. L. Baumbach.[7]

FIG. 4 General view of Chemical Department installation.

Both developing solutions and replenishers are prepared from chemicals that are tested in advance for their purity. These chemicals are supplied and controlled within certain tolerances which, in many instances, are more exacting than C. P. limits. Water that has been filtered, softened, and chemically analyzed is used, and is available hot or refrigerated as well as at room temperature. It has been established[8] that large volumes of footage passing through a developing solution cause reactions that necessitate control over its chemical constituents; namely, hydroquinone, metol, potassium bromide, sodium sulfite, and the alkalies that affect the *p*H. Fixing baths likewise require control for their silver content, hardening action, *p*H, stability, and rate of fixation. These controls are fundamental in nature and are based upon established chemical reactions during analyses. Standard solutions of iodine, silver nitrate, and potassium thiocyanate are used for this purpose, and *p*H measurements are determined by the Beckman *p*H meter (laboratory model) using the glass electrode. In no sense is the system of solution control dependent upon any particular film of any manufacturer.

FIG. 5. Corner of chemical storage room.

Chemical control, due to its extreme sensitivity, makes it possible to narrow processing tolerances, and once these have been established the chemical department must maintain solutions at constant values for all important ingredients regardless of wide variation in film footage. Cleanliness is strongly emphasized and all solutions are carefully filtered to remove the insoluble by-products of development. Silver from fixing baths is reclaimed electrolytically in a continuously replenished system. In the discard the last traces are precipitated by zinc.

Occasionally sensitometric measurements will reveal a variation in emulsion characteristics of sufficient proportions to require modification of the developing solution. When this occurs, changes in concentrations are performed, and the developer is modified quickly and accurately to its new standard, thus maintaining the quality of the product at the optimal point.

The processing of tremendous volumes of footage, normally handled by a release laboratory, requires vast quantities of chemicals. Fig. 5 shows a partial view of the supply maintained. These chemicals are costly and the chemical department foreman is forced by necessity to become somewhat cost-conscious. The first consideration in every laboratory is the quality of the product. The laboratory is well able to defend this position and can point with forceful argument to the fact that chemicals are the least expensive of the many ingredients used in the processing of pictures. However this attitude does not justify, nor does it make a virtue of, wastefulness. The alert chemical engineer observes, with no small concern, the large unused portion of chemicals in the average discarded solution. While a relatively new development, it is becoming increasingly the practice to analyze these solutions, quantitatively, for their known content. The solution can then be modified and made suitable for a different function. This is but another instance of chemical control which has now advanced to the point where solutions may be held completely within specifications at all times. The photographic element enters into consideration only when emulsion characteristics require a change in formula balance.

Exact developing formulas are of no great significance. This is due to the differences in the types of developing machine, variations in operating speeds, degree of turbulation, *etc.* However, it is possible to present what can be considered an average Hollywood formula for positive, picture negative, variable-density sound negative, and variable-area sound negative developers. The densities obtained with these formulas are obviously dependent upon (*1*) exposure, (*2*) developing time, and (*3*) developing machine characteristics. The formulas, together with the gamma range within which they operate are as follows:

Positive

Elon	1.50 grams
Hydroquinone	3.00 grams
Sodium sulfite	40.00 grams
Potassium bromide	2.00 grams
*p*H*	10.20
Water	1.00 liter
Gamma range	2.00 to 2.75

Picture Negative

Elon	1.50 grams
Hydroquinone	2.50 grams
Sodium sulfite	75.00 grams
Potassium bromide	0.50 gram
*p*H*	8.90
Water	1.00 liter
Gamma range	0.60 to 0.70

Variable-Density Sound Negative

Elon	0.50 gram
Hydroquinone	1.00 grams
Sodium sulfite	55.00 grams
Potassium bromide	0.25 gram
*p*H*	8.90
Water	1.00 liter
Gamma range	0.35 white-light exposure, to 0.85 with ultraviolet exposure

Variable-Area Sound Negative

Elon	1.00 gram
Hydroquinone	10.50 grams
Sodium sulfite	50.00 grams
Potassium bromide	1.50 grams
*p*H*	10.20
Water	1.00 liter
Gamma range	2.75 to 3.10

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* The *p*H values of the positive and variable-area sound developers are obtained with sodium carbonate. The negative picture and the variable-density sound developers are buffered solutions, and the *p*H values are obtained by borax buffered with boric acid.

PROCESSING DIVISION

Negative Developing Department.—In describing the work of the departments that were grouped earlier in the processing division, it seems logical to start with negative development. It is the first of the many operations that culminate in the final release print for exhibition. Early pioneers within the industry gave much thought to the development of their negatives, and the reason for this is obvious even under changed and modern conditions. Exposed negative represents value, and it is not unusual for the negative of a single day's work on a picture to have actually cost from ten to twenty thousand dollars. Obviously, only trained personnel and operating equipment that has been perfectly maintained can be entrusted with this important task. Guesswork is out of the question and all hazard, as far as is humanly possible, must be eliminated.

Much has been written and more will be written regarding the theoretical considerations of negative development. The subject is large in scope and productive of considerable divergence of opinion. It is well known that the overall gamma or contrast of the final screen print is the product of the negative *and* the positive gamma. It therefore follows that compensation for variation in negative gamma can be obtained by an inverse variation of the contrast of the positive bath. Normal picture negatives, in Hollywood, are developed within a gamma range of 0.60 to 0.72, and positive solutions are adjusted to give satisfactory screen quality at both extremes. A negative in the low-gamma range requires very full exposure and fairly rapid development. By this procedure grain size is held to a minimum; however, emulsion speed is proportionately reduced. These conditions may be graduated progressively over the gamma range to the other extreme, where exposure is held to the minimum, development is prolonged, grain size is increased, and the emulsion speed is fully utilized or even forced. Excellent results can be and are obtained by developing to a gamma of 0.66, which is in the center of the range. In a properly balanced negative solution, development to a gamma of 0.66 permits full advantage to be taken of emulsion speed, yet development need not be extended to a point where grain size becomes objectionable. This procedure likewise has its economic advantage in that extremely high levels of illumination by the cinematographer are avoided.

There are two schools of thought regarding negative development.

Certain laboratories are using what is commonly known as the test-system while others are developing to a constant gamma. Those using the test-system require the cameraman to make tests for the laboratory whenever a change in set-up or an important change in lighting occurs. These tests are broken out of the exposed roll of negative, properly identified, and developed in advance to a standard time. The negative developer, after examining the developed tests may, at his discretion, increase or decrease the development time on scenes that he believes could be improved by greater or lesser development. In developing to a constant gamma the solution is controlled to give constant gamma and density at a given developing time, and all negative is developed to this standard. It is not the purpose of this paper either to acclaim or condemn these two systems or to argue the relative merits of the two systems. It is sufficient to acknowledge that major studio laboratories are employing both systems at the present time with apparently satisfactory results.

Negatives of both sound and picture are developed on continuous developing machines. These machines are often identical in type, differing only in speed of operation and nature of solution. Both density and gamma specifications for sound-track negative vary over a wide range. Specifications are affected not only by the type of recording system used, *i. e.*, variable-area *vs.* variable-density, but also by variations in emulsion speed, contrast, frequency response, and distortion characteristics of the several different fine-grain recording stocks now widely used. The sound department makes the decision relative to optimal negative processing levels, and upon being notified of these specifications, the laboratory adheres to them rigidly until subsequent tests dictate a change in levels.

Prior to actual developing operations the machines are serviced and solutions are tested both analytically and by sensitometric strips. The negative has been made up into rolls of practical size for efficient machine operation, and development proceeds. On picture negative the time consumed, from the moment the film enters the developing solution until it has passed through the various stages of fixing, washing, and drying and is spooled on the take-up reel, is approximately forty-five minutes. Sound negative, being a positive type of emulsion, requires less time in the different stages of machine development, and passes through the equipment in thirty-five minutes. In addition to rigid solution control, temperature and humidity of the drying cabinets must be maintained within very close limits.

Temperature normally runs 80°F and relative humidity is held at 55 per cent.

Negative Assembling Department.—Following development, the negative passes to the negative assembling department. Here the negative is broken down into individual scenes, and is carefully inspected for defects that may have been caused by the camera or the developing machine equipment. During this operation the worker has before him the camera or sound reports upon which all scene numbers have been logged. Scenes that have been selected for printing are segregated from the takes on which no print is desired. The latter are classified as "out negative," and are carefully identified and filed in vaults for possible future use. The "print" takes are assembled in numerical continuity, and a light-card is prepared for each reel. This card shows the date, the production number, all scene numbers within the reel, and the type of raw stock to be used for printing and a column is provided for future printing lights.

As this operation is completed the assembled sound-track negative is sent to the sensitometry department, where densities are measured and the proper printing light is indicated on the light-card opposite each scene. The assembled reels of picture negative, together with their light-cards, proceed to the cinex testing room and the work of the negative assembly group is completed.

Timing.—Upon arrival of the assembled negative in the cinex testing room, each scene is carefully examined and test exposures are made for timing purposes. These tests, when developed and dried by a standard developing procedure, afford the timer a strip of single-frame pictures made by a series of exposures precisely calibrated to parallel the light-increment steps of the printing machines. By visual examination of these tests over a uniformly diffused light-source of approximately 20 foot-candles, the timer selects the particular printing light which, in his judgment, will represent the best visual result on the screen. Fig. 6 shows the timer checking the cinex tests.

Frequent discussions with cameramen are valuable to the timer in order that he may understand and faithfully interpret, through the print medium, the particular type of lighting or key of photography for which the cameraman or director is striving. This work approaches the artistic field more closely than any laboratory task and demands a high degree of skill, experience, and personal judgment.

As the printing lights are selected they are indicated on the light-card opposite the appropriate scene number. Following printing and development of the prints, the timer inspects his work on the screen; and if a scene has been missed widely, corrections are made and a reprint is ordered. Reprints are costly; thus it naturally follows that the fewer the corrections the higher becomes the timer's individual reputation.

Printing Department.—The printing department is responsible for the printing of all positive film, whether for studio use or for release distribution. Beyond the fact that these two types of work must both travel through a printing machine past an aperture, they have little in common. Production work for the studio comprises a large number of widely varying specialized requirements, while release printing has been harnessed to mass production methods. Film for studio purposes is printed on the Bell & Howell Model *D* printer. These machines are continuous in operation and are designed for single printing, either sound or picture. Should composite prints be desired, the printing operation must be repeated, both negatives being printed to the same positive. All daily rush prints, except in rare instances, are printed on dual film.

FIG. 6. The positive timer selects printer lights.

Due to the variation in negative densities normally encountered, it is necessary to provide a wide latitude of exposure range for printing purposes. This range is divided into approximately 30 steps, each step representing a light-increment of 10 per cent, or 0.06 in print density. A graph wherein printer-light increment is plotted against print density shows a linear characteristic. On the Model *D* machines the intensity of the light-source remains constant, and the change in exposure value is accomplished by a variable aperture which is manually operated. Their normal speed is 62 feet per minute.

FIG. 7. Battery of Bell & Howell *119A* release printers.

The printing of release positive is a volume operation. For this work a number of the laboratories use the Bell & Howell Model *119A* printers. Fig. 7 shows a typical installation. These machines are designed to handle quantity footage. They operate at higher speed, have more automatic features, and both track and picture negatives are printed simultaneously. Their light-increment and intensity parallel the values of the Model *D* machines. They are reversible in direction, and many copies are printed by simply supplying new positive stock, the negative itself never leaving the machine.

Each reel of release positive is accompanied through the plant by a work-card upon which each successive department logs a record of machines and personnel handling the film. This work-card originates in the printing department; and upon completion of the printing operation, the printed positive is placed in a metal container, the card is attached, and the material passes to the developing department.

Positive Developing Department.—In the development of positive film, as in the printing operation, both studio and release work are handled simultaneously. Here, even less discrimination exists inasmuch as positive solutions are maintained at constant values and the development requirements of both types of work are identical. Segregation occurs only at the "take-off" end of the developing machine, where each type of material is routed to its proper department. The positive developing machine is very similar to that used for negative but, due to the volume requirements, is geared to operate at much higher speeds. Figs. 8(*a*) and (*b*) show general views of this equipment. A number of considerations affect the developing time of positive film, but broadly speaking, it ranges between $2^1/_2$ and $3^1/_2$ minutes. The complete span of the machine's operations requires about

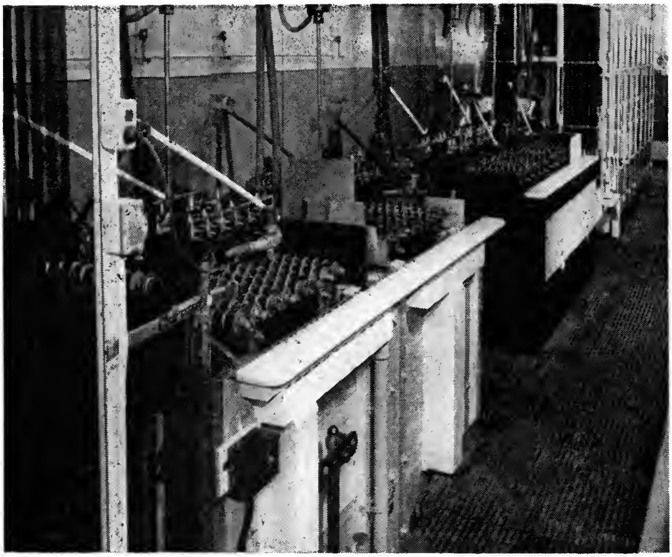

FIG. 8(*a*). Film-developing machine; feed-in end.

30 minutes, and the close control of temperature and humidity, as previously mentioned in connection with negative, are likewise important to the positive development.

Following the development it is general practice to apply some type of film preservative to the prints. There are a number of film preservative processes in use, all of which are designed to protect the freshly developed emulsion surface from undue abrasion and damage as well as to lubricate the edges of the film to facilitate projection without emulsion pick-up. Various aspects of this subject are discussed in a Bulletin published by The Research Council of The Academy of Motion Picture Arts & Sciences.[9]

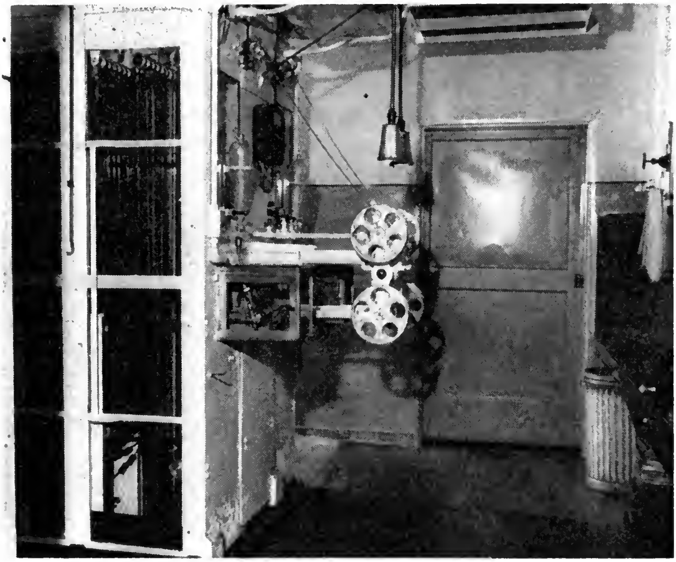

FIG. 8(*b*). Film-developing machine; take-off end.

Daily Assembling Department.—All developed prints that are to be used by the studio, both sound-track and picture, are routed from the developing machines to the daily assembling department. Here they are sorted as to picture, and the sound-track is synchronized to the picture print. Identification leaders are installed with proper "start-marks" to facilitate projector thread-up, and all prints are inspected in a sound-projection room for both sound and picture quality. Following this inspection a log of scene numbers is prepared for each reel, and if defects are present they are noted opposite the proper scenes. The reels are then delivered to the editorial department which arranges the screening for the producers. The material is retained in the editorial department and is used by the film editors in preparation of their first work-print.

Negative-Cutting Department.—As the preliminary editing is completed and approved, the work-print together with an order for a first negative cut is sent to the laboratory. From the moment that printing of daily rushes is completed until a picture has received its final negative cut, the custody of its negative is the responsibility of the negative-cutting department. Here also is handled the work of breaking down all reels into individual scenes. Proper identification is affixed to each scene showing production scene and code numbers, and all scenes are filed in large fireproof vaults. Reprints are often required by the editorial department and the filing system must be so devised that, out of the many thousands of scenes on hand, any desired scene can be located at a moment's notice.

The work-print received from the editors consists of a sound-track and a picture print; thus on a 10-reel production there are 20 reels of negative to be cut. Negative scenes of both track and picture are brought from the vaults to the cutting room and the negative cutters proceed to cut the negative, matching each scene to the corresponding scene in the work-print. As the reel is completed the scenes are spliced together, and each scene is notched to provide for printer-light changes. Light-cards are prepared for each reel showing scene numbers, scene footages, descriptive data, and printer lights.

Due to the necessary music and sound-effects that are re-recorded into all pictures, and to editorial changes following test previews, the first negative cut on a picture is never final. It is quite normal to rematch the negative to a new and changed work-print at least once or twice before approval is given for a final negative cut. Prints prepared between the first and final negative cut are for preview, censorship, and studio library purposes. These copies afford opportunities to both the picture-timer and the sound department for printer-light balancing corrections prior to release-printing operations. The final printing lights have therefore been checked and re-checked, thus bringing the inter-scene balance for both sound and photographic values to the optimal point.

Release Assembling Department.—The printing and development of release footage having been previously described, let us pass to the work of the release assembling department. The material has been delivered to this department from the positive developing machines and it will be recalled that each reel is accompanied by its work-car which originated in the printing department. From the information on this work-card a small paper sticker is prepared and attached to the protective leader spliced to each release reel. This sticker remains on the reel permanently, eventually accompanying it to the exchange, and provides a record of all machine numbers as well as the initials of the workers who handled the film during its processing routine. It is similar to the inspection sticker found on many factory-made garments, and provides a ready reference for checking processing records should a complaint be received from the field.

Following the installation of leaders and stickers, the reels are inspected by projection. All approved reels are sent to the spooling machine, while those wherein defects have been noted are sent to the reprint inspectors where reprints are ordered if required. As reprints are received, they are inspected and cut in, and that section of the reel is again checked before being released for spooling. After spooling, the reel is wrapped in tissue paper and placed in an individual container carefully marked in advance with the reel identifications. As the copies are completed in this manner they pass on to the shipping department for final packing and shipping.

SERVICE DIVISION

Film Shipping Department.—Upon reaching the shipping department the completed copies are packed in fiberboard cartons. These cartons are manufactured to certain specifications of weight and strength, and conform to the requirements of The Interstate Commerce Commission and The National Board of Fire Underwriters.

Five methods of shipment are utilized by the laboratory: ocean freight, rail freight, railway express, air express, and parcel post. Packing specifications for foreign shipments vary greatly according to destination, and the shipping department must be thoroughly informed on all traffic requirements and regulations. Necessary documentation for export shipments must be provided, and it is the responsibility of the traffic manager to see that all forms are correctly executed and properly certified. Under the present stringent regulations this feature has become a considerable problem, and it is not unusual to execute and certify as many as five sets of documents to effect an export shipment. Domestic shipments to exchanges are relatively simple and are normally sent by either rail freight or railway express. The distribution department is advised daily, by teletype, all the details of each day's shipments.

Maintenance Department.—To effect an uninterrupted flow of work through the various departments, provision must be made for proper and efficient maintenance of plant and equipment. This is a major problem common to all laboratories. Much of the equipment is of complex design and of high precision, requiring the services of expert technicians for maintenance and adjustment. Electrical circuits employed likewise demand engineering knowledge of the highest order.[10] A considerable proportion of the required electrical energy must be generated as direct current, and the regulation of supply to the various power and light-source units must be accurately controlled. This control for printer-lamps is accomplished by electronic regulators, and a tolerance of 0.1 volt is maintained constantly.

Equipment of the developing and chemical departments is subject to the action of chemicals and fumes, making constant care necessary to insure efficient operation. The proper maintenance and operation of a large air conditioning installation demands a thorough understanding of refrigeration and humidity and temperature control, as well as the principles of air-washing and filtering. Cleanliness is vital to laboratory processing and these units must operate at maximum efficiency at all times.

The laboratory occupies a unique position in that a considerable portion of its equipment is not readily available for purchase in the open market. The maintenance staff must therefore be competent to design new equipment or to modify existing machines to effect the many improvements in technic that are brought to light through research and experience.

CONCLUSION

In conclusion it may be stated that the various natures of the many laboratory duties, together with departmental segregation, make the principles of organization and coördination of utmost importance to successful operation. Each department not only must function smoothly within itself but likewise must have an appreciation of the problems and efforts of the other departments, thus contributing to a well balanced efficiency in the overall task of service and research. With the importance of the technical phases of motion picture production well established and gaining increased recognition, the laboratory takes a just pride in its contribution to this field.

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A MODERN MUSIC RECORDING STUDIO*

M. RETTINGER**

Summary.—*This paper represents a broad analysis of a music recording studio recently completed at the RCA Manufacturing Co., Hollywood, Calif. Discussed herein are constructional details considered important toward the achievement of good recording conditions in the stage. In particular, the action of convex wood splays is considered in some detail, especially in regard to their influence on the reverberation characteristic of the room.*

In planning the remodeling of the local RCA scoring stage, special consideration was given to the preference among musicians and music-lovers for rooms which contain a large amount of wood paneling. This preference can be attributed largely to the ability of such a material to vibrate over a wide range of musical pitch, unlike a panel of plaster or fiber board. The energy employed to set the wood sheet into vibration is partly re-radiated in a manner that does not follow the regular law of equal angle of incidence and reflection. A vibrating surface, because of its size and shape, may therefore emit plane or cylindrical waves, although it is excited by spherical waves. In this sense, the walls of the band shell may also be considered to be an extension of the instruments—an extension which, although loosely coupled to the sources of sound, nevertheless emphasizes many of the frequency components of music sufficiently to lend pleasant support to the music. It is the sounding board again—a device that magnifies the tonal area of the instrument by creating sustaining *surface* sources in proximity to a relative *point*-source or sources.

It was deemed desirable to install such wood panels in the form of convex splays to secure a greater diffusion of the sound in the room. As is well known, the wavefront of a beam of sound reflected from a convex surface is considerably longer than that from an equally large flat surface, provided that the wavelength of the incident sound is small compared to the dimensions of the reflecting surface. Fig. 1 shows this relationship graphically, and it is seen that the wavefront

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* Received April 1, 1942.

** RCA Manufacturing Co., Hollywood, Calif.

reflected from the convex splay is, for the condition illustrated, considerably longer than the sum of the two reflected from the flat panels. The figure shows also the construction of the wavefronts, analogously to the optical case, the center of the reflected wavefront coming from the curved surface being one-half the radius of the convex splay (assuming the source is at some distance from the surface).

The fact that the wavefront from a convex reflector is longer tends also to reduce the interference effect between direct and reflected sound. This is illustrated in Fig. 2. Since the energy of a propagating wavefront varies inversely with the square of its length, the reduction of the interference effect is appreciable, a factor that may assume considerable importance in the recording of slow-moving music.

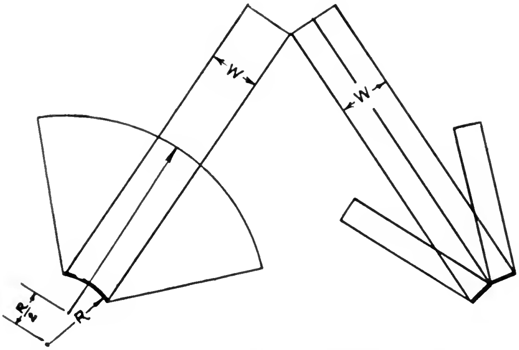

Fig. 1. Illustrating length of reflected wavefront from convex splay and flat panels.

A convex splay is also excellent insurance against echoes in a room, particularly when it is intended to keep this surface reflective. For this reason, convex surfaces are helpful in providing a smoother decay of the sound, as well as one that is more nearly logarithmic with time, since the reverberation persists longer in the direction in which echoes occur in a room.

One may therefore summarize the advantages of properly designed convex wood panels in a confined space as follows:

(*1*) More uniform distribution of the sound pressure, due to the longer wavefront of the reflected sound, particularly pertinent for the high frequencies.

(*2*) Creation of surface sources of sound, also helpful in increasing the diffusion of the sound in the room, and being of special importance for the low frequencies.

(*3*) Provision of a wall or ceiling section that is more absorptive for the low than the high frequencies. The fact that work is being done on the panel in moving it, and that sound is radiated from the back as well as front, describes the device also as a relatively efficient low-frequency absorbent.

(*4*) Reduction of interference effect between direct and reflected sound.

(*5*) Production of a relatively smooth sound-decay curve.

(*6*) Erection of reflective surfaces which will minimize echo.

The use of vibrating wood panels in a room has, in the past, sometimes given rise to a cautious consideration of the resonance qualities of such a construction. The uninitiated believe that a pronounced tone-bias is produced by such a vibrating panel. Indeed, one is frequently asked "What is the resonance frequency of this or that splay?"

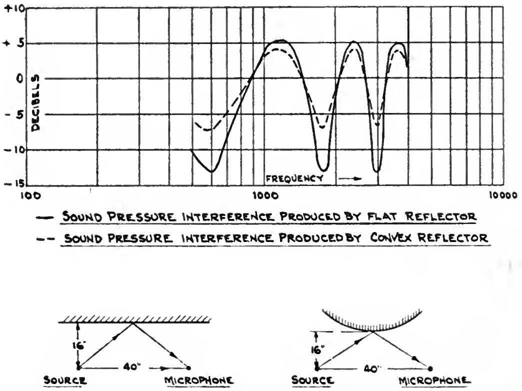

FIG. 2. Sound pressure interference effect produced by a flat and convex reflector.

To avoid such a cautious regard of wood membranes as used in this room, it may be well to enumerate their resonance qualities thus:

(*1*) A wood splay of the type employed has many resonance frequencies. Fig. 3 shows the response characteristic of a splay at two points on it, randomly chosen, and approximately 5 feet apart. The curves were obtained by fastening a crystal pick-up to the two points and then exciting the splay into vibration by generating in the room a sound of a continuously varying warbled tone.

(*2*) The resonance frequencies are not harmonically related.

(*3*) The amplitude distribution is made up of the various modes of vibration.

(*4*) Nodes are not sharply defined, owing to the presence of more than one mode.

The only pronounced resonance to which a splay of this type is subject is that produced by the air-chamber back of it. The natural, low-frequency modes of vibration of this chamber, if it had been kept reflective, would have been transmitted into the stage in an objectionable measure. In the case where the chamber had been kept highly reflective, a "hang-over" effect or prolonged reverberation would have resulted at certain low frequencies, none of which was desired to have a reverberation time markedly longer than those of the middle or high registers, a point that will be discussed in greater detail later. Hence the space back of the splays was kept absorbent, and care was taken not to permit the acoustic material to come into contact with the panel itself, which, to note, consisted of two quarter-inch sheets of plywood. Application of fiberboard or other sound-absorbent to the wood surface would have exerted a damping effect upon the natural modes of vibration of the wood membranes, which was not considered necessary or desirable for the purpose.

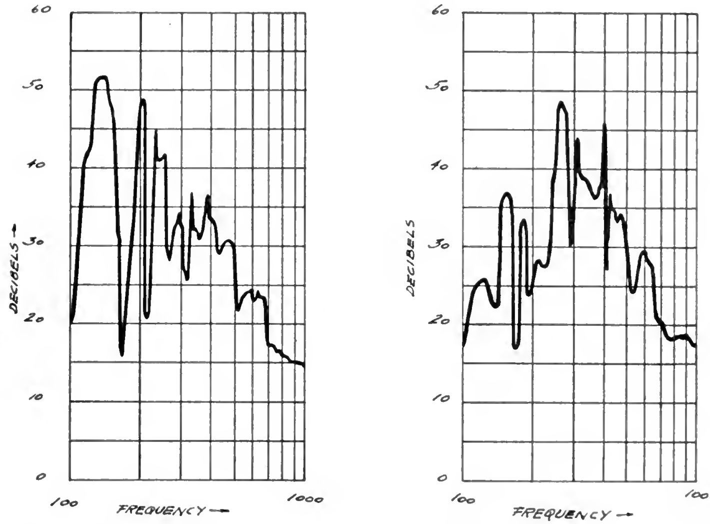

FIG. 3. Response characteristic of a splay at two different points on splay.

The use of wood panels was welcome also because with their aid it was possible to achieve a nearly flat reverberation characteristic in the room. As is well known, the absorptivity of most acoustical materials is considerably smaller for the low than for the high frequencies. The only way by which this condition can be reversed is by employing a thin material which by vibration will absorb the low frequencies while acting as a reflector for the highs. In order, however, to avoid a pronounced selective low-frequency absorption it is desirable to vary the size and radii of these convex splays, as was done in this room. This condition was further improved by irregular bracing back of the splays.

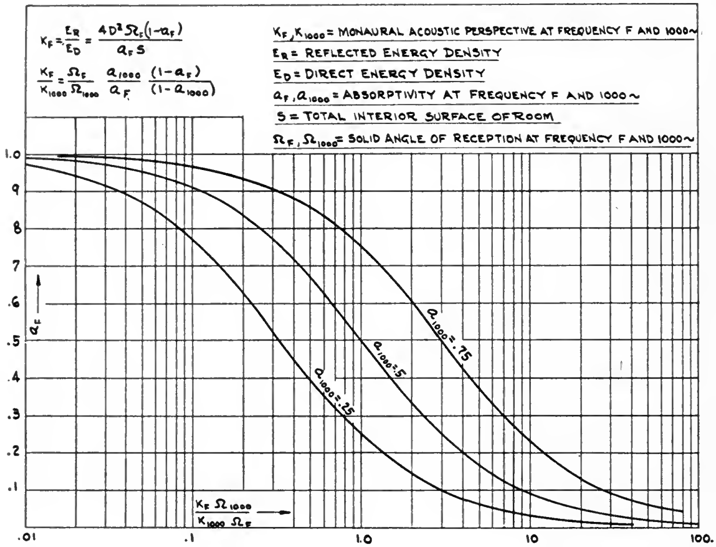

FIG. 4. Relation of monaural acoustic perspective and absorptivity.

A nearly flat reverberation characteristic in this room was considered desirable inasmuch as it was held that the determining factor for a recording studio is not so much the reverberation characteristic as what H. F. Olson terms the recorded reverberation characteristic. It should be said here that the term "recorded reverberation" is believed to be somewhat confusing, and that it might be better to speak of a monaural acoustic perspective when considering the ratio of reflected to direct sound-energy density. Fig. 4 gives the equation for this ratio, which obviously has no dimensions, but merely states how much more reflected than direct sound exists at any point in the room. It is this ratio that gives to the recorded sound the impression of depth and, indeed, an impression of reverberatoriness, without actually giving a measure of reverberation time in seconds.

The reason for attaching so much importance to the monaural

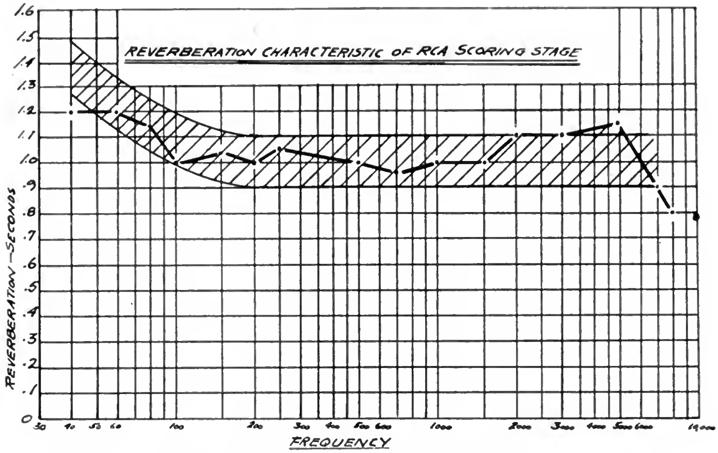

FIG. 5. Reverberation characteristic of RCA scoring stage.

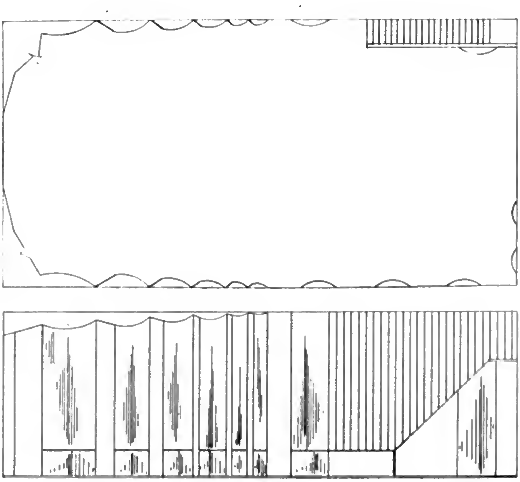

FIG. 6. Plan and elevation of the room.

acoustic perspective is that the microphone represents but one ear. As is well known the reverberation in a room appears considerably longer when observed with but one ear than when observed with both ears. The reason for this lies in an unconscious suppression of reflected sound, which appears to the ear as undesirable in the case of speech, since it tends to detract from intelligibility. In the case of music the ear accepts a certain amount of this reflected sound, apparently because it tends to improve the quality of the music. It is for this reason that the reverberation time in music rooms is usually made longer than in speech room. The microphone, however, records the true acoustic conditions at the point of its location, and once the sound is recorded, the ear can during reproduction no longer ignore or discriminate against the reflected sound that was present at the microphone position, since this reflected sound is now part of the direct sound from the loud speaker.

FIG. 7. Front view of stage.

Now, in order not to obtain excessive ratios of monaural acoustic perspective for the low frequencies, care must be taken to avoid long reverberation times for these frequencies. When the average absorptivity at a given frequency is cut in half, the reverberation time in a room is practically doubled. The monaural acoustic perspective for this case, however, becomes more than twice, and may reach values of three or four times, depending upon the value of the reduced absorptivity. This condition of increased values for the monaural perspective at the low frequencies is further aggravated by the fact that the solid-angle of reception for most microphones is larger for the low frequencies than for the high.

Fig. 5 shows the reverberation characteristic of this stage, which has a volume of 70,000 cu-ft. The measurements were made with a reverberation meter of the rotating commutator type described by H. Olson and F. Massa in their book "Applied Acoustics."

Fig. 6 shows a plan and elevation view of the room. The color scheme was prepared by the well known industrial designer, Mr. John Vassos, and employs a pastel shade of blue for the splays and a maroon for the trim (door, baseboard, chair-rail, *etc.*)

FIG. 8. Rear view of stage.

Several other studios have lately been constructed employing convex splays on the sidewalls with very good results. Among these are the *WFAA* and *KGKO* broadcasting studios in Dallas, Texas, the RCA recording studio in South America, the RCA film recording studios in New York, and the Walt Disney scoring stage. The only undesirable feature in these rooms, including this stage, is presented by the comparatively large expanse of the flat floor. However, the use of players' platforms, chairs in the room, and the judicious use of rugs does much to ameliorate this condition.

The floor of this stage is of the elastically floated type. The joists rest on resilient steel chairs grouted in concrete. A sound-absorbent filler is placed between the joists, not only to dampen any resonance effects, but also to assist in reducing the transmission of noise from without.

The monitoring room is paneled with large sheets of wood veneer on the sidewalls except for the wall behind the mixing console, which received acoustic treatment of the type employed in the state. This acoustic material was selected on account of its smooth absorption characteristic and because its low-frequency absorption was comparatively high. The windows in the monitoring room are double panes separated by a 4-inch air-space, and the walls between the two sheets of glass carry sound-absorbent treatment.

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PRODUCTION OF 16-MM MOTION PICTURES FOR TELEVISION PROJECTION*

R. B. FULLER AND L. S. RHODES**

Summary.—*A general report on setting of procedural and dimensional practices for the production of 16-mm sound motion pictures for television projection.*

The paper shows that in the various steps from the original film to the final image on the television receiver, a considerable percentage of the frame area is lost by "cropping" in the projector, in the iconoscope, and in the kinescope. Unless this loss is taken into consideration and compensated for in the original planning of films for television, loss of image area may seriously impair the effect of the motion picture.

The paper makes specific recommendations based upon the conclusions drawn, but does not attempt, in view of present conditions, to fix final aperture standards any further than to urge that such standards be set up by the proper group. Many of the factors directly concerned in production are considered with a view to the ultimate quality to be attained.

Reference is made to experiences and problems met by the authors in the preparation of animated cartoons and other films for television broadcasting.

It is believed that both producer and motion picture technicians can and should review the problems connected with the preparation of films for television projection and telecasting and analyze the difficulties likely to be encountered. This might seem to be effort wasted at this particular time, but the new practices evolving from this particular field may have present and future values in contributing to the effective preparation and presentation of motion pictures for television use.

In the preparation of motion pictures for television a number of facts must be taken into consideration in order to guarantee that the received image will fulfill the requirements of our message. In other words, we know what effect we want to present to the television audience, and so we must take into consideration and make compensations for any variations that may occur in the various steps between film and final image. Roughly, there are at least three

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* Presented at the meeting of the Atlantic Coast Section, Feb. 19, 1942; and at the 1942 Spring Convention at Hollywood, Calif.; received April 16, 1942.

** New York, N. Y.

elements to be considered. First: the color loss or effect, in black-and-white or color: although we have a picture to start with that is clear in respect to its colors will we end up with the same picture? Second: to what extent will television faithfully reproduce the action, outline, or detail of the picture? Third: what loss will there be in the overall frame size in final projection? The last is our primary consideration.

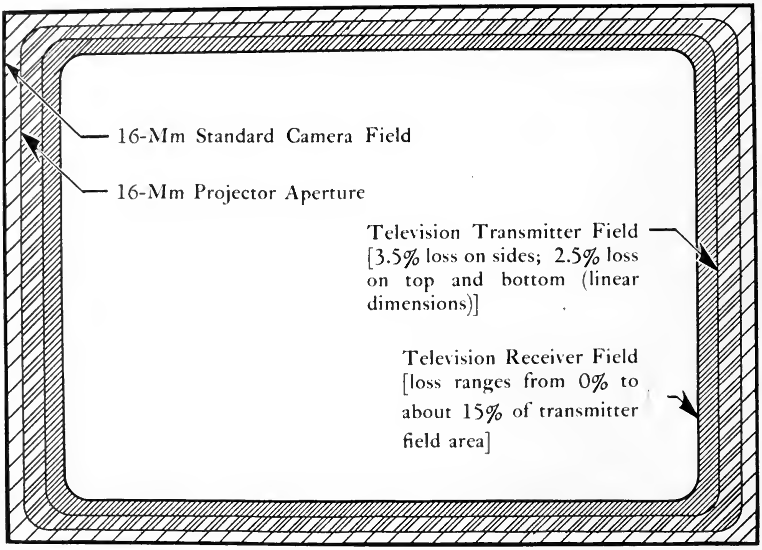

FIG. 1. Shaded area shows approximate reduction of image from original 16-mm frame to the image on the television receiver.

It is generally acknowledged by a majority of workers in the field of production of 16-mm films that, while general and fairly widely accepted standards for dimensions of such film have been set up, final practice policies and standard dimensions have not yet been widely adopted or recognized.

In view of the state of flux and experimentation in which the technique of television now stands, and considering the time required for developmental work, it is believed appropriate to note several special factors, paying particular attention to dimensional practice and procedure.

Moreover, the coming of age of completely satisfactory direct sound-on-film recording in the 16-mm size has presented many problems new to the film-stock and equipment manufacturers and laboratory specialists, the general producers, and the regular users of finished films, whether shown on small-size home-projection screens, or large theater screens, or through the new transmission medium, television.

At present, for 16-mm sound motion picture film, the standard projection aperture is 0.380 × 0.284 inch, with an allowable tolerance of ±0.002 inch. It is understood that the projection aperture should be smaller than the frame on the film for obvious reasons.

Data on actual projection dimensions, as found in the equipment in various television studios, show variations in detail. One of the first factors to be considered is the loss of image size. We can not make a definite statement as to how great this loss is, because we find that in the several studios, and even in separate items of equipment in the same studio, there is considerable variation. Whereas in one instance the projector aperture used in one television studio was slightly smaller than standard, another studio used a slightly larger projection aperture, and the staff of still another studio implies that, although standards may have been established, a reduction of projection aperture dimensions may be tried if demanded by effects in which they are interested.

The following is an example of the kind of problem that arises in processing procedure. In one case, several feet of film that had been optically reduced from 35 mm to 16 mm were included in 16-mm footage for the remainder. Due to laboratory requirements, compensation had to be made in obtaining the combined release print, with the result that the entire footage had proportionately wide spaces between frames. The laboratory had to mask the entire strip of film in order that the one section reduced from 35 mm would not show an objectionable error beyond the frame edge. This necessitated careful alignment in projection and resulted in reduced image sizes all around.

Now, in discussing this problem of loss of image size we find many points other than those directly concerned with television projection. We mention them because, since we are trying to make films that will present ultimately a desired picture, we must consider any element that may change, distort, or affect the picture between, as in animation, the drawing of the background, and the final picture as viewed by the audience.

The second point, which is relatively negligible for the most part.

is film shrinkage—either in the original negative, in the dupe negative, and then later, in any film that is stored over a period of time. Shrinkage will reduce the frame size, but the loss is figured at a general average of about 0.7 per cent, with an extraordinary maximum of 2 per cent. Much of this difficulty is well realized and the laboratories are handling the problem rather well.

In the printing of 16-mm film, with sprocket-holes along one edge and because of the edge guiding (which is not satisfactorily standardized as yet), the pull-down and the head-to-tail printing often result in a loss of the true frame.

Now, let us follow an image through the steps required to bring the image from film to the audience and see what happens to the frame. Having possibly already lost some of the frame size in printing, reduction, shrinkage or ordinary handling, we are ready to project the strip of film into the television camera. The film is projected onto a photoemissive mosaic enclosed in a glass tube, and the resulting image is then scanned line by line.

The photoemissive area or mosaic on which the picture is projected is proportioned like the film frame, roughly in a 4 to 3 ratio. Here we find differences of opinion and practice. Let us assume that the image that is projected fills the mosaic. From one studio we hear that this image is then "overscanned" slightly, in order to insure proper coverage. This means that the resulting edge must be masked out, and it is probable that the masking goes slightly further than the exact amount of overscanning in order to protect against any slight error of alignment. This results in a loss of about $^1/_8$ inch from top to bottom, and about $^1/_4$ inch from side to side. Another studio tells us that it slightly "underscans," and apparently some degree of masking is introduced because of possible loss in definition at the edge. The studio did not so state. At any rate, we note that the image size and the frame size are being progressively reduced.

Another television engineer said in effect that reduction of the original film aperture is due in some degree to the non-linearity of the television scanning procedure.

Two other elements might be included here, although they can not be detailed at this time, partly because complete technical information is not available. The first is keystoning. The image projected on the photoemissive mosaic is scanned at a 30-degree angle, so that the field is foreshortened and distorted. This is corrected before transmission by the "sawtooth voltage," but even though it is corrected this keystoning can cause some distortion, and, hence, loss of frame size or proportions.

Another of these undetermined features is difficult to explain because definite information could not be obtained. We have a feeling that there is loss of definition at the edge of the screen of the television receiver. If one looks at the screen from the side, the end of the tube has a curved surface, which apparently is cause for some distortion. Many kinescope tubes are "blown" or molded, which results in a parabolic or irregular arc for the former, while the latter tube is a two-piece affair molded together, the surface being a true arc with, consequently, no distortion.

One of the largest losses in area is entirely apart from all the features considered above. This is the "personal equation," which may enter not only at the transmission end, but also at the receiving end, where the observer may so tune his instrument that no more than 75 per cent of the image is received. The general average may be nearer 90 per cent in tuning accuracy, but it is still believed that losses do occur in this way.

All these losses must be taken into consideration when film is prepared. While the various factors may occur in lesser degree than described above, we know that we will be wise to make all allowances and compensations in the very first steps. Standards must eventually be prescribed, and to insure faithful reproduction of the film, it is necessary that we put definite thought into these problems and arrive at standards that will save us all loss of effects and many headaches. Let us analize the results of the losses found above:

(*1*) In general, the most serious result is that titles and essential material falling outside the middle two-thirds of the final film image will be in danger of being cut off. The loss of such material will be more serious on the sides than on the top and bottom.

(*2*) In the case of technical and cartoon animation there is a definite possibility that essential action or picture in the outer thirds area will be lost, although a trained animator generally attempts wherever possible to confine his material to the center of the field.

(*3*) In live photography or studio shots, this loss may impair composition or clarity. For example if the scene shows a perfectly normal actor standing at the edge of the field, the cutting down of the image may result in only a part of him on the edge of the television screen.

In producing a recent animated cartoon, we had the idea that we could plan our scenes *framed*. Each picture was centered in and surrounded by a gray mat frame of no importance, which we would gladly lose before losing part of our picture. We are sad about how quickly this ingenious device was rejected.

However, we suggest that field gauges be set up, to be used by studios producing for television films, and to be worked out by careful analysis, showing what compensations must be made for the probable or possible losses.

We suggest also that finders of cameras, both for animation and straight shooting, have inscribed upon their view-finder lines showing the image to be received on the kinescope screen. As far as is known, there is only one make of camera that has a finder that shows only the projection aperture size, thus automatically showing the cameraman the final picture.

To sum up, it is shown that the loss of image is more important than is generally realized, and it is urged that the Society make careful investigation of the problem.

In our work of preparing films for television we have come upon a number of problems that may be of interest here. For example, there are many opinions on the question of the number of tones of grays discernible, and, of course, a great deal depends upon the subject and the way in which it is handled. Estimates on the number of grays discernible in television vary from as high as 25 to as low as 12. It is important to note that these 12 to 25 shades are not all regular shades, because of the tendency of television to black out the darker tones of gray and burn out or wash out the lighter tones. So, although we can safely allow for 12 shades of gray, 8 of these shades could be evenly spaced in the middle range, with more subtle variations, while the extreme darks or lights could be much more widely spaced. In instances where the film is in color, it should be remembered, too, that two distinct colors having the same density may very well come out as identical tones of gray and result in a serious loss of definition or clarity and effect. A dark red and a dark blue may be transmitted as the same shade of gray, and thus care must be taken to consider tones rather than colors.

We have been advised by television engineers that, in general average gray shades reproduce best when the gamma of the film is between 2.0 and 2.5 and when the maximum density range is between 1.5 and 2.5. Apparently very superior results are achieved when the maximum density is between 1.3 for 5 per cent transmission and 1.8 for $1^1/_2$ per cent transmission.

For the most part we can say that any film that will project well on a theater screen will also produce equally fine results on the television screen, but we suggest that attention be given to this question of shades of color advisable in television reproduction, and here the motion picture may have to compromise with television procedure.

We have developed a few little devices to help us in our work. We wanted, in one picture we were directing, to achieve perfect synchronism with a regular piece of music. We played our record a few times until we knew it by heart. Then we played it into the film recorder, and as it played, rather softly, we tapped with a pencil on the front of the microphone. When the sound-track was developed we knew exactly on which frame every lesser and greater beat came and also how the phrases broke. Then, with a bouncing-ball sequence, we counted the frames; the bouncing of the ball indicated the rhythm of the music, with high bounces to give the cues for the narration. The result was a perfectly timed film.

Another idea that has been favorably received in the NBC television studios is what we call the "tuning lead," which consists of a ten-second (240 frames) film exactly or almost exactly of the same general tone as our picture. These are used by the engineer to "tune" the television apparatus. On the ten-second leader are the words "Scene begins in . . . seconds." Every twenty-four frames is a new number and, as the engineer watches—*10–9–8–7–6–5–4–3–2–1*—there are only six frames of *1*. The switch is then thrown and the film transferred from the monitor screen onto the actual television screen, perfectly tuned.

In general, television engineering is meeting the dimensional practices of 16-mm motion picture production rather well; however, the producers may find it advisable to revise some of the practices derived from 35-mm procedure and establish further standardization.

CURRENT LITERATURE OF INTEREST TO THE MOTION PICTURE ENGINEER

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

American Cinematographer

23 (July, 1942), No. 7

British Film Technicians and the War (pp. 294–295, 334)	G. H. Elvin
Warners Build Improved Scene Slating Device (pp. 296–297, 333–334)	W. Stull
Animated Cartoon Production Today. Pt. IV. Clean-ups and Inbetweening (pp. 300–303, 331–332)	C. Fallberg
Release-Print Problems in Professional 16-Mm Production (pp. 304, 330–331)	J. A. Larsen, Jr.
Building a Microphone-Boom for 16-Mm Sound Home Movies (pp. 310–311, 328)	C. N. Aldrich
Try Diffused Lighting for Kodachrome Close-Ups (pp. 314, 327–328)	R. Rennahan

British Kinematograph Society, Journal

5 (April, 1942), No. 2

Speech and the Larynx (pp. 37–44)	H. Hartridge
Direct Processes for Making Photographic Prints in Colour (pp. 45–50)	C. E. K. Mees
The Measurement of Screen Brightness (pp. 51–55)	H. Etzold

Electronic Engineering

15 (June, 1942), No. 172

Harmonic Analysis of Waves, Containing Odd and Even Harmonies (pp. 13–18)	P. Kemp
Television Waveforms (pp. 19–26)	C. E. Lockhart

Institute of Radio Engineers, Proceedings

30 (June, 1942), No. 6

Hearing, the Determining Factor for High-Fidelity Transmission (pp. 266–277)	H. Fletcher
The Effect of Fluctuation Voltages on the Linear Detector (pp. 277–288)	J. R. Ragazzini
The Use of Vacuum Tubes as Variable Impedance Elements (pp. 288–293)	H. J. Reich

The Relative Sensitivities of Television Pickup Tubes, Photographic Film, and the Human Eye (pp. 293–300)	A. ROSS

International Projectionist

17 (May, 1942), No. 5	
War Uses of Motion Pictures Discussed at SMPE Convention (pp. 7–8)	
Maintenance and Repair of Loudspeakers (pp. 9–10)	L. CHADBOURNE
Underwriters Code as It Affects Projection Rooms. Pt. II (pp. 17, 21)	
17 (June, 1942), No. 6	
The New Victory Projector Carbons (pp. 7–8)	E. R. GEIB
The Consumption of the Positive Arc Carbon (pp. 13, 25)	H. G. MACPHERSON
Underwriters Code as It Affects Projection Rooms. Pt. III (pp. 17–18)	
Some New Routine Precautions in the Maintenance of Amplifiers (pp. 19–20)	L. CHADBOURNE

Motion Picture Herald, Better Theaters

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The Film Theater on the Home Front (pp. 13–15)	
How Much Can You Reduce Arc Current to Save Copper? (pp. 26–27)	C. E. SHULTZ

Photographische Industrie

39 (April 16, 1941), No. 16	
Neuere Richtlinien des Kino-Kamerabaus (New Directions in Motion Picture Camera Construction), (pp. 271–272)	
39 (May 28, 1941–July 9, 1941), No. 22–28	
Das Auflosungsvermogen bei der photographischen Aufnahme (Resolving Power in Photographic Emulsions). Pts. 1–6 (pp. 351–356, May 28; 371–373, June 4; 385–388, June 11; 401–403, June 18; 418–420, June 25; 432–434, July 2; 449–452, July 9)	H. ROEDER
Deutsche und amerikanische Kinonormen in vergleichender Darstellung (Comparative Representation of German and American Motion Picture Standards). Pts. 1–3 (pp. 378–379, June 4; 395–396, June 11; 410–412, June 18)	P. HATSCHEK
39 (July 23, 1941), No. 30	
Reinton ohne oder mit Vorausreglung (High Fidelity Sound With or Without Pre-Setting) (pp. 491–492)	P. HATSCHEK
39 (Sept. 24, 1941), No. 39	
Die Einheiten der Beleuchtungstechnik und ihre wechselseitigen Beziehungen (Relative Values for Illumination Units) (pp. 631–632)	P. HATSCHEK

FIFTY-SECOND SEMI-ANNUAL MEETING

OF THE

SOCIETY OF MOTION PICTURE ENGINEERS

HOTEL PENNSYLVANIA, NEW YORK, N. Y.
OCTOBER 27th–29th, INCLUSIVE

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HOTEL RESERVATIONS AND RATES

Hotel Rates.—The Hotel Pennsylvania extends to SMPE delegates and guests the following special *per diem* rates, European plan:

Room with bath, one person	$3.85–$7.70
Room with bath, two persons, double bed	$5.50–$8.80
Room with bath, two persons, twin beds	$6.60–$9.90
Parlor suites: living room, bedroom, and bath	$10.00, 11.00, 13.00, and 18.00

Reservations.—Early in September room-reservation cards will be mailed to the members of the Society. These cards should be returned to the hotel as promptly as possible to be assured of desirable accommodations. Reservations are subject to cancellation if it is later found impossible to attend the meeting.

Registration.—The registration headquarters will be located on the 18th floor of the Hotel at the entrance of the *Salle Moderne,* where most of the technical

sessions will be held. All members and guests attending the meeting are expected to register and receive their badges and identification cards required for admission to all sessions.

TECHNICAL SESSIONS

Technical sessions will be held as indicated in the Tentative Program below. The Papers Committee is assembling an attractive program of technical papers and presentations, the details of which will be published in a later issue of the JOURNAL.

FIFTY-SECOND SEMI-ANNUAL BANQUET AND INFORMAL GET-TOGETHER LUNCHEON

The usual Informal Get-Together Luncheon for members, their families, and guests will be held in the Roof Garden of the Hotel on Tuesday, October 27th, at 12:30 P. M.

The Fifty-Second Semi-Annual Banquet and dance will be held in the Georgian Room of the Hotel on Wednesday evening, October 28th, at 8:00 P. M. Presentation of the Progress Medal and Journal Award will be made at the banquet, and the officers-elect for 1943 will be introduced. The evening will conclude with dancing.

LADIES' PROGRAM

Mrs. D. E. Hyndman, Hostess, and members of her Committee promise an interesting program of entertainment for the ladies attending the meeting, the details of which will be announced later. A reception parlor will be provided for the Committee where all should register and receive their programs, badges, and identification cards.

MISCELLANEOUS

Motion Pictures.—The identification cards issued at the time of registering will be honored at a number of New York *de luxe* motion picture theaters listed thereon. Many entertainment attractions are available in New York to out-of-town delegates and guests, information concerning which may be obtained at the Hotel information desk or at the registration headquarters.

Parking.—Parking accommodations will be available to those motoring to the meeting at the Hotel garage, at the rate of $1.25 for 24 hours, and in the open lot at 75 cents for day parking. These rates include car pick-up and delivery at the door of the Hotel.

Golf.—Arrangements may be made at the registration desk for golfing at several country clubs in the New York area.

Note: The dates of the 1942 Fall Meeting immediately precede those of the meeting of the Optical Society of America at the Hotel Pennsylvania, New York, N. Y., to be held on October 30th and 31st.

The Convention is subject to cancellation if later deemed advisable in the national interest.

TENTATIVE PROGRAM

Tuesday, Oct. 27

9:00 a.m. *Hotel Roof;* Registration.
10:00 a.m. *Salle Moderne;* Business and Technical Session.
12:30 p.m. *Roof Garden;* SMPE Get-Together Luncheon for members, their families, and guests. Introduction of officers-elect for 1943 and addresses by prominent members of the motion picture industry
2:00 p.m. *Radio City Music Hall Studio;* Technical Session.
8:00 p.m. *Museum of Modern Art Film Library;* Technical Session.

Wednesday, Oct. 28

9:00 a.m. *Hotel Roof;* Registration.
9:30 a.m. *Salle Moderne;* Technical sessions.
12:30 p.m. Luncheon Period.
2:00 p.m. *Salle Moderne;* Technical session.
8:00 p.m. *Georgian Room;* Fifty-Second Semi-Annual Banquet and Dance.

Thursday, Oct. 29

9:00 a.m. *Hotel Roof;* Registration.
10:00 a.m. *Salle Moderne;* Technical Session.
12:30 p.m. Luncheon Period.
2:00 p.m. *Salle Moderne;* Technical Session.
8:00 p.m. *Salle Moderne;* Technical Session and Convention adjournment.

Note: Any changes in the location of the technical sessions and schedules of the meeting will be announced in later bulletins and in the final program.

W. C. KUNZMANN,
Convention Vice-President

SOCIETY ANNOUNCEMENTS

AMENDMENTS

At the meeting of the Board of Governors, held at Hollywood, May 3, 1942, the amendments of the By-Laws and Constitution given below were proposed and approved for submittal to the membership of the Society at one of the sessions of the Hollywood Convention.

In view of the fact that a quorum was unobtainable at any of the sessions of the Convention, the amendments were held over until the approaching Convention to be held at New York, October 27th–29th, inclusive.

In accordance with the requirements of By-Law XII, relating to the method of acting upon proposed amendments, these amendments are published in an issue of the JOURNAL prior to the meeting at which they are to be presented for vote of the Society membership. These amendments provide for increasing the number of members of the Board of Governors, and are as follows:

Proposed Amendment of Article V

The Board of Governors shall consist of the President, the Past-President, the five Vice-Presidents, the Secretary, the Treasurer, the Section Charimen, and ten elected Governors. Five of these Governors shall be resident in the area operating under Pacific and Mountain Time, and five of the Governors shall be resident in the area operating under Central and Eastern Time. Two of the Governors from the western area, and three of the Governors from the eastern area shall be elected in the odd-numbered years, and three of the Governors from the western area and two of the Governors from the eastern area shall be elected in the even-numbered years. The term of office of all elected Governors shall be two years.

Proposed Amendment of By-Law III, Sec. 2

Nine members of the Board of Governors shall constitute a quorum at all meetings.

Proposed Amendment of By-Law III, Sec. 1

The Board of Governors shall transact the business of the Society between members' meetings, and shall meet at the call of the President, with the proviso that no meeting shall be called without at least seven (7) days' prior notice, stating the purpose of the meeting, to all members of the Board, by letter or by telegram.

ADMISSIONS COMMITTEE

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

CORCORAN, J. P.
2213 Midvale Ave.,
West Los Angeles, Calif.

DONNELLEY, THORNE
Photographic Science Laboratory,
Anacostia, D. C.

GOLDBERG, H. E.
Eastman Kodak Company,
Rochester, N. Y.

HANSON, GEORGE
2960 Ettrick St.,
Los Angeles, Calif.

JOHNSTON, E. R.
742 Lakeview Blvd.,
Seattle, Wash.

KRAUSS, E. D.
1021 Chavez St.,
Burbank, Calif.

LEGRAND, C. C.
Mole-Richardson Co.
941 N. Sycamore Ave.,
Hollywood, Calif.

LOBALBO, C. F.
3202 Ampere Ave.,
Bronx, N. Y.

NAVE, F. A.
Rt. 2, Box 263,
Oakdale, Calif.

REEDY, W. A.
Weston Electrical Instrument Corp.,
Newark, N. J.

SHERMAN, L. F., JR.
Calton Court,
New Rochelle, N. Y.

WILSON, W. G.
2411 East 15th St.,
Kansas City, Mo.

WOODWARD, H. L., JR.
Signal Photo Laboratories,
Army War College,
Washington. D. C.

In addition, the following applicants have been admitted to the Active grade:

BERTRAM, E. A.
DeLuxe Laboratories
441 West 55th St.,
New York, N. Y.

BARNET, STAN
333 West 57th St.,
New York, N. Y.

DEVRY, E. B.
1111 Armitage Ave.
Chicago, Ill.

OSBORN, L. G.
Western Electric Co., Ltd.,
152, Coles Green Road,
London, N. W. 2, England

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FRANKLIN C. GILBERT

JOURNAL OF THE SOCIETY OF MOTION PICTURE ENGINEERS

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

JOURNAL OF THE SOCIETY OF MOTION PICTURE ENGINEERS

SYLVAN HARRIS, EDITOR

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THE TECHNIQUE OF PRODUCTION SOUND RECORDING*

HOMER G. TASKER**

Summary.—*Although sound recording differs greatly from motion picture photography, it involves many analogous techniques and some similar processes. Sound recording requires special apparatus to transform sound into energy capable of exposing motion picture film. Its reproduction from the film requires additional transformations involving other specialized apparatus.*

Good sound pick-up on the motion picture set involves acoustic conditioning quite analogous to set lighting, camera angle selection, etc. The sound crew is provided with flexible means for microphone placement and with controls and monitoring devices for observation of the results obtained. The film recording machine is a specialized mechanism requiring precision comparable to that of the motion picture camera. Its operation entails skillful adjustments. The sound department coöperates with the laboratory department in the establishment and interpretation of processing controls.

In discussing the aural or sound problems in the production of motion pictures, three introductory tasks must be undertaken:

(*1*) To distinguish the problems of recording the aural elements of a motion picture scene from those of recording the visual elements.

(*2*) To indicate the scope of production sound recording, as distinguished from scoring and pre-scoring, and from re-recording or sound blending.

(*3*) To introduce, in elementary form, the recording and reproducing apparatus common to all three of these recording activities.

(*1*) As entertainment media, the visual and aural elements of a motion picture scene supplement each other in that sound contributes many details of thought, action, or emotion not possible to the pictorial side and *vice versa.* As media to be recorded upon the motion picture film, they differ in the extreme. The visual element, properly illuminated, is capable of exposing the film directly through the agency of the camera lens, but sound is quite as invisible to the camera eye as it is to the human eye. Hence, it requires very considerable transformations or translations before it can be photographed on the film, and again before it can be reproduced in the theater in a form to be interpreted by the human ear.

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

Further, the camera and the microphone differ, as do the eye and the ear, in that off-stage objects are almost entirely ignored by the camera, while off-stage sounds are almost as well recorded as the wanted sounds from the scene itself. The limitations thus imposed may be quite severe.

Although the visual and the aural elements both involve time as the very essence of the entertainment values to be recorded, the characteristics of the eye fortunately permit the simulation of continuous motion through the rapid succession of a large number of still pictures, whereas sound requires *absolute continuity* of the recording and of the subsequent reproduction. Fortunately, both these requirements can be met with motion picture film.

Nevertheless, there are many motion picture processes common to sight and sound, for the record of sound is photographic in character, and there is basic similarity between the laboratory processes involved in producing and multiplying these records and those employed for the picture. Moreover, as they leave the studio for projection in theaters throughout the world, they occupy, side by side, the same piece of film.

(*2*) Production sound recording may be defined as the recording of sound that takes place simultaneously with the photographing of the scene. Ordinarily, this includes dialog and such incidental footsteps, door slams, and other noises as originate within the camera angle.

Scoring is the subsequent recording of music to accompany the scene. Pre-scoring is the prior recording of instrumental or vocal music to be played back during the photographing of a scene to establish musical tempo to which the actors may synchronize their movements.

Re-recording is the final blending together of the dialog, the pre- or post-scored music, the "character" sound-effects such as crowd murmurs and factory noises, and the effects separately recorded to accompany scenes photographed without sound, *etc.*

(*3*) A great deal has been written about the design and characteristics of sound recording and reproducing equipment but not so much about the nature of the work to be accomplished with these tools or about the techniques involved. The emphasis here will be on the latter rather than on the former features. Details of the equipment may be found in the appended bibliography.

For this reason the basic sound-recording and reproducing system will be introduced here in quite elementary form. Subsequent references will be made to specific characteristics of certain apparatus as they bear on matters of technique.

Referring to Fig. 1 and beginning at the lower left of the diagram, the essential elements of a sound-recording system are:

(*a*) *Microphone* (*First Transformation*).—Transforms sound energy into electrical energy. Several different types[1,2] are used depending upon the requirements, but each is a high-quality device responsive to the air pressure changes or air particle movements which characterize sound so that the result is an electrical copy of whatever sound impinges upon the microphone.

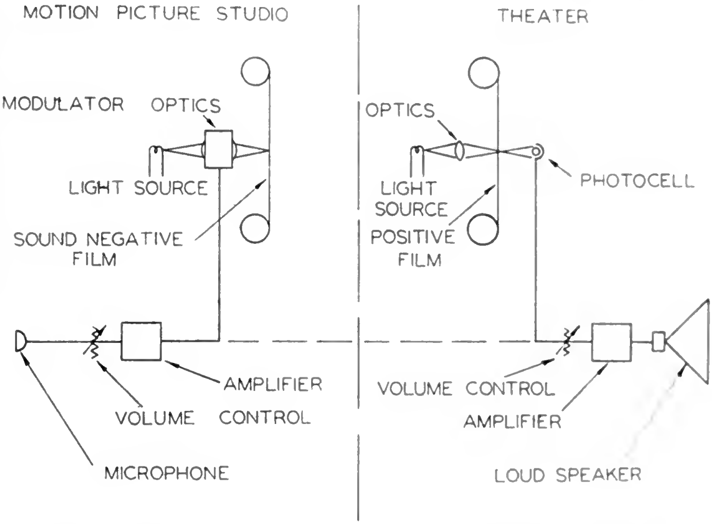

FIG. 1. Elements of sound-recording and reproducing systems.

(*b*) *Amplifier*.—Increases the above-mentioned electrical energy to usable proportions. The output of the microphone is very feeble. One milli-microwatt is typical, although this will vary with the type of microphone and other circumstances from $^1/_{1000}$ to nearly 1000 times that value. About one watt is needed for recording. Hence the amplification must be very great and must also be of the highest quality and controllable with precision.

(*c*) *Electroöptical Modulator* (*Second Transformation*).—Exposes the sound negative motion picture film under control of the above-described amplified electrical energy. The motion picture industry is about equally divided in the use of two types of modulators, both of which employ a steady source of light plus electromagnetic means for controlling the amount of this light that reaches the film. In the "light-valve" type of modulator[3] pairs of metallic ribbons surrounded by a strong magnetic field alternately separate and converge to control the passage of light in response to the amplified current from the microphone. The system is usually so aligned as to expose the sound-track uniformly across its full width but in varying degree along its length, so as to produce the "variable-density" type of sound-track. In the "galvanometer" type of modulator[4] the same purpose is served by the rotary oscillation of a small mirror mounted on an electromagnetic structure in such a way as to be responsive to electrical energy. The system is usually so arranged as to expose a fraction only of the width of the sound-track, the magnitude of this fraction varying lengthwise of the film so as to produce the "variable-area" type of sound-track.

(*d*) *Film-Driving Mechanism.*—Moves the film past the exposure point with a very high degree of uniformity of speed.[5,6] It has proved useful to separate the sound recorder from the picture camera. The necessary synchronism is maintained by one of several types of motor systems including a-c interlock,[7] d-c interlock,[8] and synchronous.

(*e*) *Auxiliary Apparatus.*—This includes such necessary elements as volume controls, fixed or variable equalizers, volume indicators, monitoring equipment, power supplies, *etc.*

Subsequently to the necessary processing of the sound negative and the making of positive prints the equipment necessary to reproduce sound from this film in synchronism with the picture, whether for studio purposes or for projection in theaters, is as follows:

(*f*) *Film-Driving Mechanism.*—Moves the sound-track past the reproducing point with the required uniformity of speed and in synchronism with the picture. In most studio processes the sound-track and the picture are on separate films and the sound-reproducing mechanism is driven by a-c interlock motors or by a "dual film attachment"[9] to the picture mechanism, as the requirements dictate. When released in theaters a "composite print" is used in which sound and picture are printed on adjacent areas of the same film. In this case, the sound and picture mechanisms are combined, and synchronism is afforded by locating a given picture frame twenty frames behind the corresponding sound modulation so that they will appear in their respective "gates" of the mechanism simultaneously.

(g) *Optics and Photocell* (*Third Transformation*).*—Produces electrical energy corresponding to the varying optical transmission of the film record. A steady source of light is provided together with an optical system so arranged that light passing through a narrow slit (transversely of the sound-track) reaches the photoelectric cell. As the sound-track moves through the mechanism, the variation in the density or in width of the sound-track causes the required fluctuations in the light falling upon the photoelectric cell.

(h) *Amplifier.*—Increases the electrical energy to useful proportions. The photoelectric-cell output is very feeble under some conditions. In good theater practice the amount of sound-modulated electrical energy required to drive the loud speakers varies from 15 to 100 watts, depending upon the size of the theater, *etc.* Hence theater amplifying systems must have not only considerable gain but also quite high output levels with low distortions.

(i) *Loud Speakers* (*Fourth Transformation*).—In response to the amplified electrical energy, the loud speakers reproduce in the theater sound corresponding to that which originally appeared at the microphone. Simple radio types of loud speakers, even though large in scale, will not serve the requirements adequately. For good results, special high-frequency speakers equipped with multicellular horns are required to minimize high-frequency distortion and to afford uniform distribution of intelligibility throughout the theater. In order to exercise proper judgment in scoring, re-recording, and reviewing operations, similar equipment must be used in the studio.

THE TECHNIQUE OF SOUND PICK-UP

(4) To point a camera at an indoor object, turn on a light, and snap the shutter is one thing. To produce photography having consistent beauty and story-telling power is quite another. It is so with sound. There must be acoustic "lighting" or "conditioning" to obtain the best results. Microphone "placement," like camera "angle," must be carefully worked out.

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* The transformations referred to are those mentioned at the beginning as being unique to sound recording and sound reproduction, as distinct from picture photography; hence the film-processing transformations are not numbered among them.

Consider first the problem of intelligibility *vs.* angle, as the actor is photographed from various angles in a given scene. The voice is directional in its frequency characteristic. Forward from the face it is much more brilliant acoustically and carries more intelligibility than toward the rear. Hence if two actors face each other and the camera shoots over the shoulder of one into the face of the other, and if the microphone takes the same view of the situation as the camera, then the face-on voice will be good but the other will have a muffled yet rather roomy or reverberant quality. Unfortunately, the microphone exaggerates the effect over that observed by human ears in the same location. But even in the absence of such exaggeration, the effect would still be unwanted. A digression is in order to point out why.

It is not the purpose of alternate angle shots over one shoulder of one actor into the face of a second actor, and *vice versa,* to give an audience the sensation of having been swung back and forth through space to have a look first at one actor and then the other, nor yet that the *terra firma* that supports the actors is performing similar gyrations. On the contrary, if such a scene is well done in all technical respects, the audience should experience no such gyratory effect, but only a snapping of attention from one actor to the other at the instants of greatest interest or of greatest pertinence to the story. The same considerations govern sound recording for such a scene, and accordingly the microphone, though necessarily above the camera angle, should always be in front of and facing the person speaking. This requires extreme mobility of the microphone—mobility available on the instant and accomplished without making noise, without appearing in or casting a shadow on the scene. This demand has led to the development of very excellent microphone booms which afford great freedom of microphone movement and direction, controllable from positions outside the camera angle. By their use the microphone is manipulated into correct position from instant to instant by the "boom" operator under the occasional guidance of the chief sound man or "production sound mixer," who is also controlling other portions of the system and observing the sound quality produced as discussed later.

The type of scene just described consumes a lot of Hollywood film footage each year, but there are, of course, other cases in which the audience should experience special orientation with respect to the scene or should be made aware of such acoustic qualities of the scene as the reverberation of a cathedral, the hollowness of a cave, *etc.* In other words, the character of the sound sought for by the mixer is always governed by "good theater."

Such effects are rather easier to obtain when wanted than avoided in scenes where they are inappropriate. The microphone is a "one-eared" device, and tends to exaggerate the reflections from walls and other surfaces that give rise to room effects so that the mixer's constant struggle is to reduce them.

The case of strong short-path reflections encountered during close-ups such as at lunch-counters or in other confined spaces is so typical of the mixer's acoustic problems that a close look at this case will illustrate the tools and techniques employed by the mixer for nearly all other cases as well.

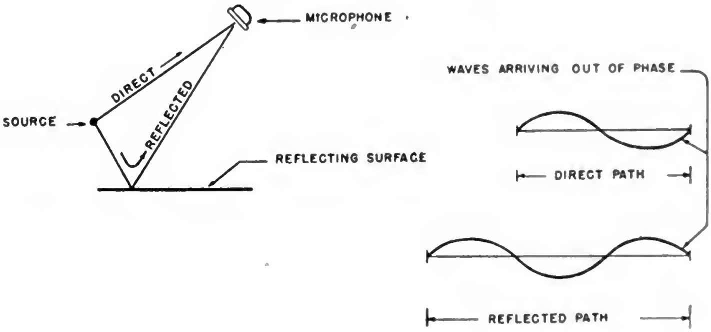


FIG. 2. Interference due to short-path reflections.

The objectionable character of these short-path reflections lies in the fact that they may arrive at the microphone with such strength, due to their shortness of path, that they may nearly cancel the direct sound at certain frequencies or objectionably overemphasize it at other frequencies. As illustrated in Fig. 2, this is determined by the relation of wavelength to difference of path between the direct and the reflected portions.

Such reflections may be reduced during rehearsals by carefully probing the available microphone space to find the spot least affected by the reflections without suffering too much loss of voice brilliance due to unfavorable angle as discussed earlier. The properties of certain recently developed directional microphones[1,2] may also be employed to discriminate somewhat in favor of the direct as against the reflected sounds but with rather less benefit than might be expected. Fig. 3 illustrates a microphone whose directional properties (see Fig. 4) are adjustable to embrace practically every directional characteristic now attainable. A pressure-responsive unit which is essentially non-directional (see Fig. 4*D*) is mounted in close association with a velocity-responsive element whose polar directional diagram is a pair of circles (see Fig. 4*R*) indicating full response in one axis and zero response at right angles thereto. As may be seen in the intermediate diagrams, these elements may be combined in varying degrees to give a variety of response patterns of the general type known as "cardioid."

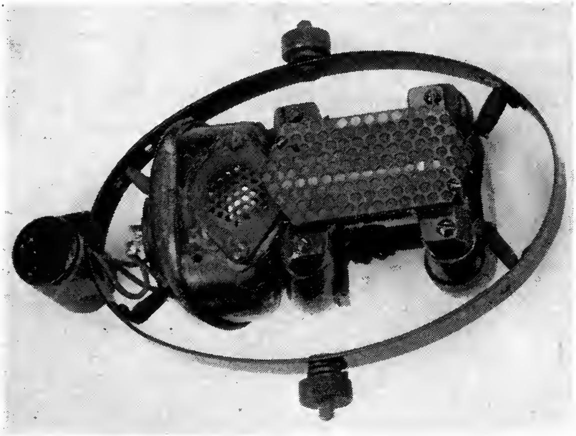
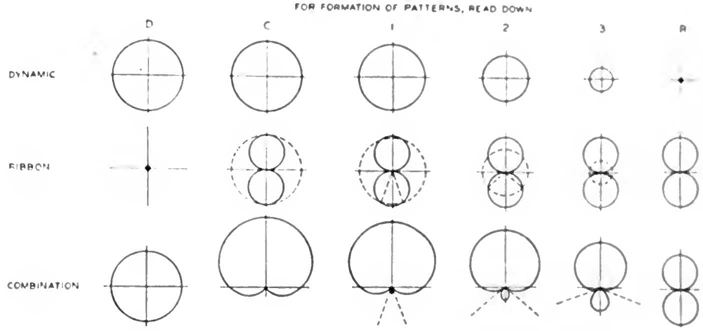


FIG. 3. Unidirectional microphone.

If now the mixer attempts to use any one of these patterns to discriminate between two sounds differing in angle by as little as thirty-five degrees, as in the example of Fig. 2, then he must choose between having the direct sound arrive at an angle of nearly maximum sensitivity and let the reflected sound be scarcely attenuated, or let the reflected sound arrive at an angle of nearly zero pick-up, which will give excellent discrimination but will always find the direct sound arriving at a point of much less than maximum sensitivity. In the latter case, the major pick-up axis may enhance set noises or smaller reflections from other surfaces to such an extent that these become limiting factors.

The advantages of such microphones are not gained without some penalty. Nearly all microphones are sufficiently bulky and heavy to impair their mobility when swung at a radius of ten to eighteen feet on the modern microphone boom. These "unidirectional" or multi-duty microphones, consisting as they do of a pressure and a velocity microphone combined in one case, always have greater weight and bulk than other microphones of comparable sensitivity.



DYNAMIC (D) IN %	100	50	46	39	25	0
RIBBON (R) IN %	0	50	54	61	75	100
INDEX I	1	1/3	1/3.2	1/3.6	1/4	1/3
INDEX J	1	1/7	1/9	1/13.7	1/7	1

FIG. 4. Formation of directivity patterns by combinations of ribbon and dynamic microphone elements.

$$\left(\begin{array}{c}\text{Directivity}\\ \text{Index}\end{array}\right) I = \frac{\text{efficiency for sound of random incidence}}{\text{efficiency for sound of normal incidence}}$$

$$J = \frac{\begin{array}{c}\text{average efficiency for all angles of sound}\\ \text{incidence in rear hemisphere}\end{array}}{\begin{array}{c}\text{average efficiency for all angles of sound}\\ \text{incidence in front hemisphere}\end{array}}$$

It happens that the strong short-path reflections are most obvious to the ear at frequencies below 1000 cycles. If the mixer has done his best, with the coöperation of the boom operator, to locate a favorable position and orientation for the microphone and still finds himself having reflection troubles, he may be able to effect an improvement by adjusting his low-frequency equalizer or suppressor. If not, he may be able to find a spot favorable to reducing the low-frequency reflections at the cost of some brilliance, but he may be able to restore some of the latter with his high-frequency equalizer. Sometimes, though seldom in this type of problem, he can introduce acoustic absorbing material that will help.[10]

After fighting one of these "lunch-counter" reflections for half a day while the boy and girl finish their coffee and doughnuts, quarrel, kiss and make up, and exhaust the sound crew's patience, the crew usually go home resolved that if they ever become writers or producers or executives, there will be no more lunch counter scenes!

The chances are that next day they may work in a well furnished living-room set that gives no trouble at all; or in a bare tenement bedroom having plenty of "cistern" effect but in which by laying a rug on the floor (out of the camera angle) or by hanging a blanket or two in some area that will not interfere with the lighting, the mixer can get the "feel" of the set about right in his monitor. In general the considerations of time-lag and intensity of reflection in the larger spaces make proper sound pick-up a simpler problem. Of course, when a large "exterior" set must be constructed inside a stage, the stage-wall reflections must be held abnormally low if naturalness is to be achieved. Most sound stages are treated on the inside with two inches of rock wool furred out two or more inches from the solid construction, with the result that the reflections[11] are not objectionable except in the case of exterior scenes. In such cases the sound man is in contact with the job days in advance, learning the camera angles to be used, studying the acoustic problems to be met, planning the treatments necessary, *etc.* Nor does the sound department neglect to develop the coöperation of the art department in shaping structures or choosing material that will minimize the sound-reflection problem.[10]

We have seen then that the mixer's "acoustic lighting" problem is primarily one of avoiding excessive reflections of three distinct types:

(*a*) Confined space or "barrel" reflections.
(*b*) Medium space or "roominess" reflections.
(*c*) Large space or "reverberant" reflections.

To any one of these reflection problems he may apply one or all of the following controls:

(*a*) Proper choice of materials or designs, through coöperation with the art department.
(*b*) Microphone placement.
(*c*) Microphone directional properties.
(*d*) Blanketing to absorb reflections.

Noises occurring within the motion picture set are objectionable except in rare instances when they are in keeping with the character of the action. This is particularly true of such modern noises as traffic and machinery sounds when the scene being photographed belongs to an earlier period in history. To reduce the penetration of traffic and other external noises, stage walls are heavily insulated,[11] some having attenuations as high as 70 db. Mechanical noises arising within the stage from cameras, wind machines, *etc.*, are reduced by careful design, by elimination of gears, and by the provision of good insulating housings where necessary.[12,13,14] The relative effect of the noises that remain, as compared to the wanted sounds arising from the action, may be further reduced by taking advantage of the directional properties of microphones. Refer again to Fig. 4 for the effectiveness of such microphones in reducing noises of random incidence as compared to direct sounds.

ADDITIONAL QUALITY CONTROL MEASURES

(5) While acoustic considerations and microphone characteristics are of utmost importance to successful sound recording for theater projection, there must also be adequate control of volume. In this respect also it is "good theater" that governs. In actual life a dance band will produce more than ten million times the sound energy of a quiet scene in a murder mystery. This is a 70-db difference, but if the murder scene were recorded 70 db lower in level than a properly chosen dance band level, the dialog would be completely inaudible in the theater. We must, instead, enable the persons in the back row of the theater to hear the quiet scene distinctly, even though softly, and for this purpose the original 70-db difference in level must be reduced to about 25 db. Hence the mixer must be constantly alert to make the proper volume adjustments of the material he is recording. To this end he is provided with a "unit volume control" for each microphone (normally one to as many as four) plus an inclusive or master volume control. To help him gauge the correct level, he is provided with a volume-indicator meter whose deflections are an indication of the modulation reaching the film. He is provided also with an audible monitoring system, usually a headset of high quality,[15] which enables him to listen critically to the overall result of his work and to apply the judgment that his task demands.

It is true that in the re-recording process some opportunity is afforded for the refinement of the production mixer's work. However, the signal-to-noise ratio of the film (of the order of 55 db) becomes a limiting factor. If the production mixer records a "quiet" original scene about 15 db lower than he should, then in attempting to correct this error during re-recording, a very objectionable amount of film-surface noise would be introduced. If, on the other hand, a dance band were recorded 10 db too loud, the result would be severe distortions in the recording which could never be corrected. Hence, it is necessary that the production mixer come as nearly as possible to the correct level in the original recording.

Experience has indicated that there must also be considerable adjustment of frequency characteristic[16] to secure proper theater presentation. In some studios this step is reserved solely for the re-recording process. In others, the production mixer makes a first-order correction, leaving refinement to the re-recording mixer.

Having used the foregoing tools and methods in the control of sound and quality to the best of his ability, the production sound mixer must exercise the further control of suggestion and rejection. The most successful mixers develop a high degree of tact and good judgment, knowing just when a word of suggestion to the actor or director will secure a more effective sound recording, and just when sound imperfections are of such importance that he must request additional takes which may cost anywhere from fifty to several hundred dollars.

TECHNIQUE OF FILM RECORDING

(*6*) In the editing of a motion picture, great advantage is had if the sound record is on a strip of film separate from the picture. It is of further advantage if the sound-recording machine is separate from the picture camera—a practice followed without exception in Hollywood. These two mechanisms must run in synchronism. In "process" photography shots, a predetermined phase relationship between the camera and the process projector is also involved, and for such shots all studios use some form of a-c interlocking motor system.[7] Several studios use this system for all studio operations and in some cases even for location shooting. Other studios substitute salient-pole synchronous motors for all production shooting except process photography scenes. Neither of these systems is very economical of electrical power and in location work, power-supply takes on considerable importance. For this reason, most studios employ some form of d-c interlock for location work and especially for super-portables.[8]

The sound-film recorder, like the motion picture camera, is a highly specialized and very precise piece of mechanism. The design requirements to secure the necessary uniformity of film motion are adequately discussed in the literature;[5, 6] so also are the requirements and characteristics of the modulators by means of which exposure of the film is produced corresponding to the sound impinging upon the microphone.[3,4] One such system is introduced schematically into Fig. 5 to afford some idea of the operational problems involved.

In this illustration, the pole-pieces of the electromagnetic yoke are cut away and the light-valve ribbons are much enlarged so that their position and action may be clearly seen. Light from the lamp on the left is spread quite uniformly over the slit between the light-valve ribbons by setting the condenser lens in a slightly out-of-focus position. When a current passes through the ribbons from *a* to *b*, the ribbons will separate allowing more light to pass between them, and *vice versa*. The objective lens focuses this light into a thin, sharp line on the motion picture film. If the film were at rest, the intensity of this line would remain constant, but its thickness would vary exactly in accordance with the spacing of the light-valve ribbons; but since the film is moving at a uniform speed of 90 feet per minute, the effect is to vary the exposure lengthwise of the film and hence produce variable-density sound-track. The drum that carries the film is mechanically filtered from the rest of the driving mechanism. Great

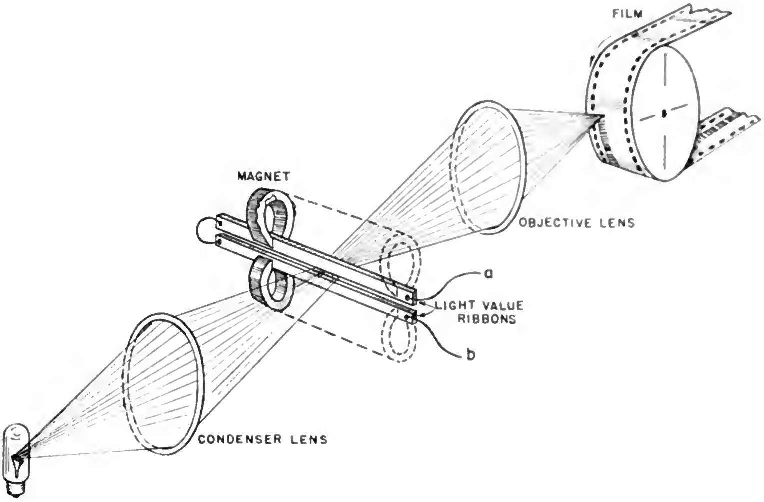


FIG. 5. Light-valve modulator system.

care is taken in the design of the mechanical filter, and in some types the variation of speed or "flutter" is held to less than 0.05 per cent of the designated uniform speed.

The light-valve ribbons weigh only two millionths of an ounce each, are about six mils wide and half a mil thick, and must be spaced about a mil apart and accurately parallel. The stringing and adjusting is ordinarily done by a specialist, who also takes care of certain other equipment requiring precise adjustment. In some studios, however, each recordist (recording machine operator) strings and adjusts his own light-valves as required.

During operation, these ribbons are "biased" electrically to a spacing of about $^1/_{10}$ of a mil to effect reduction of film grain-noise by reducing the light reaching the negative. This results in darker exposure of the positive, and hence less reproduced noise during intervals of silence or of low sound level at the microphone.[17, 18, 19] To make the biasing adjustment properly, the recordist must carefully determine the sensitivity of the valve and then adjust the biasing current to the proper amount. The accuracy required is approximately ten millionths of an inch.

In the galvanometer type of modulator, comparable considerations apply, except that in "type *B*" variable-area recording, as practiced at one studio, no noise-reduction amplifiers are involved.

There are many other adjustments of the recording machine and associated equipment that the recordist must make. In addition, he usually starts and stops the entire system on signal from the stage and applies "end strip" exposures for processing control, *etc.*

The sound department must participate actively in the establishment of processing control limits and in the interpretation of the daily results, and must provide the laboratory with most of the specially exposed "strips" that are required. Sound quality controls for processing of variable-density recordings always include sensitometer strips for control of processing gamma. In the case of fine-grain films, which afford considerable improvement in grain-noise and distortion,[20] it is also necessary to make occasional light-valve gamma strips because of the failure of the photographic reciprocity law and the fact that this failure is not uniform with conditions. Most studios also use the newly developed technique of inter-modulation measurement. This method affords a useful means of establishing correct print density for given negative processing conditions.

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PRESCORING AND SCORING*

BERNARD B. BROWN**

Summary.—*A brief description of the procedure followed in the Hollywood studios in scoring and prescoring motion picture productions. Scoring is the addition of music and effects after the finish of the photographing; prescoring is the preparation of musical or dance numbers before the photographing.*

PRESCORING

The recording of music for motion pictures is divided into two categories: prescoring and scoring. As the name implies, prescoring means the recording of musical or dance numbers *before* the numbers themselves are actually photographed. At first thought, the idea of recording a sequence prior to photographing it may seem strange; but in actuality there are two very logical reasons for the sound director to do just that: (*1*) We prefer to make these recordings on a stage that has been acoustically treated to make it as perfect as possible for music recording. (*2*) By so doing, we are able to achieve not only fidelity of tone, but also of tempo.

Our first reason is self-explanatory; our second is quickly explained. If we were to record a musical number as the director photographs it, we should be dealing with small sections of music, which when assembled would not be smooth, for the director breaks the sequence up into its component photographic parts, such as long shots, medium shots, close-ups, and various camera angles. It is obviously impossible to play the music at exactly the same tempo each time these short scenes are photographed. Therefore, to do the job correctly the musical number is first recorded on film and on a record, thus insuring that an even tempo will be maintained. It is well to point out that the artist, when making this recording, is free to make all the grimaces and contortions he feels may be necessary to reach

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** Universal Pictures Company, Inc., Universal City, Calif.

the high notes and pronounce the words clearly, as he is not being photographed while singing for this recording.

The record is then taken to the sound stage and played back to the artist. Here the artist must look his (or her) best, which now is possible because he does not have to think of the singing but only of looking well and synchronizing the lip movement to the record that has already been made. He only has to appear as if he were singing, as the prescored record is used for the final film.

On the scoring stage is a small room, 10 × 10 × 10 feet in size, in which the artist sings. A large window in one of the walls faces the orchestra so that the artist and the musical director can see each other. The singer can hear just enough of the orchestra to assist in singing in tune, but the sound of the singer's voice does not penetrate through to the stage, so the director uses ear-phones bridged into the vocal channel. As soon as a piece has been sufficiently rehearsed, all is ready for a take. The "quiet" signal is given, the stage man signals the recordist to start his machine, the red light flashes, the orchestra plays, the singer sings, and "Take Number One" is made.

The musical number is recorded on two or more separate films and on a wax record which is played back so that the artist and others may hear and criticize the recording. If everyone is satisfied, the "take" is finished; if not, repeat recordings are made until a good one results or until there are enough good parts of several takes to cut together and make one good complete take.

The orchestra and artist may then be dismissed. If after assembling the good parts of several takes the result is not entirely satisfactory, the singer is called back to the scoring stage to re-make all or part of the number. This is done by having the artist sing while listening on a pair of headphones to the orchestra track that has already been recorded. This process saves the studio thousands of dollars a year, since the orchestra is not required for retakes.

When photographing dance numbers the recording that has been pre-scored is played back and the dancers perform to it. If the number is a tap dance the taps are recorded later on a special dance floor on the recording stage. The dancers are brought in and the picture of the dance that has been photographed is projected. The performers then dance while listening to the music through headphones, and the taps are recorded. The picture has been cut exactly the way it appears in the theater, and the taps match the picture exactly.

SCORING

Scoring is sometimes called "underscoring," which means adding music to the picture after it has been finished. The musical director and his associates view the finished picture with the producer or director, and decide where music can most effectively be used. While the musical director is composing the themes his assistant is timing the scenes, so as to know how much music to write and at what points it must synchronize with the action.

Where it is necessary to time the music to several definite cues, a "click track" is made, which when reproduced sounds like a metronome. The "clicks" or beats range from one every sixteen frames to as many as one to every four frames. The tempo is determined by the tempo of the scene, and is produced by making a scratch or punching a hole in a piece of blank film at the points where the beats are to occur.

The film is then run on a moviola, and along with the picture, and on it are marked the cues in the picture to which the music must be made to fit.

Now that the composer has the length of the scenes and the timing, he composes the music for the picture. The compositions then must be arranged, sometimes by the composer himself and sometimes by professional "arrangers." The arrangement is checked by a musician called a proof-reader, who corrects any mistakes made by the composer or arranger, and the score is given to copyists who copy on separate sheets the music for the different instruments in the orchestra. The proof-reader again checks what the copyists have done, and all is now ready for recording.

The orchestra is seated in a semicircle in front of the director, who stands upon a platform facing the screen and the musicians. The orchestra is arranged in sections with a microphone in each section, as follows, beginning at the left of the director: violins first, then violas and cellos, woodwinds, piano, bass, guitar, and harp, with the brass and the percussion instruments up in back on a separate platform. There are two principal reasons for using this arrangement: One is to provide good compositions and variety in the integrated sounds, just as the cameraman in photographing resorts to long shots, medium shots, and close-ups. The microphones used in the various sections pick up sound from both sides. They are tilted so as to have a close pick-up on one side and a long pick-up on the other side, and thus give good definition, room tone, and scope to the orchestra.

The other reason for using a microphone in each section is to permit the sound director to control the volume from each section by dials on his mixing panel in the monitoring booth. The volume of any section can be increased or decreased, so that if a section is too loud or too soft corrections can be made during the recording and a retake avoided. This saves much time, and time means money in the studio.

The musical director now rehearses the orchestra and at the same time the sound director adjusts his levels on the mixing panel in the monitor booth. When all is ready the recording room is signalled, the picture is flashed on the screen, the orchestra plays, and the director conducts the orchestra while listening to the click track or dialog on a pair of headphones and looking at the picture on the screen behind the orchestra. The process is repeated for each section of music to be used with the picture.

This describes briefly the general processes of prescoring and scoring. A thousand details have been omitted, and it must be emphasized that the processes are not matters of simple routine. Each take has its own problems, and experience and experimentation are as much parts of the work as the general routine that has been described.

A STUDY OF FLICKER IN 16-MM PICTURE PROJECTION*

E. E. MASTERSON AND E. W. KELLOGG**

Summary.—*It seems to be generally accepted opinion that three-blade shutters must be employed to control flicker properly in the projection of 16-mm pictures, even though the machine is not required to operate at less than 24 pictures per second. There is little complaint of the flicker in theater projection, where two-blade shutters are practically universal. Why then should it be necessary to make a large sacrifice in screen brightness by using three-blade shutters when projecting 16-mm pictures? Less control of the conditions of projection is probably the most important of the valid objections. However, the opinion that two-blade shutters are not to be considered is based in part upon misleading tests, and the writers hold that for many applications single-speed machines should be given the benefit of the greater luminous efficiency possible with two-blade shutters.*

The paper discusses the various factors that bear on flicker, and reports a number of experimental studies.

The Problem.—For many years it has been the practice to project 35-mm pictures in theaters at 24 frames per second with two 90-degree shutter blades, giving a 48-cycle flicker with equal dark and light intervals. It is customary, on the other hand, to equip 16-mm projectors with three-blade shutters, and this is at serious cost in screen brightness. The gain in light from substituting a two-blade for a three-blade shutter is shown in Table I. The gain depends upon the blade width, which in turn depends upon the pull-down time of the intermittent movement.

TABLE I

Shutter Blade	Light on Screen		Ratio
	3 Blade	2 Blade	
45°	0.652	0.75	1.20
50°	0.585	0.72	1.22
60°	0.50	0.67	1.33
75°	0.375	0.585	1.56
90°	0.25	0.50	2.00

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* Presented at the 1942 Spring Meeting at Hollywood, Calif.; received May 4, 1942.

** RCA Manufacturing Co., Indianapolis, Ind.

The requirement that the flicker rate be 72 cycles per second for 16-mm projection, whereas 48 cycles is considered satisfactory in theaters, is the more surprising when we consider that in the projection of 16-mm pictures it has been common to use a pull-down that operates over a smaller fraction of the picture cycle; for example, about 60 degrees instead of the 90 degrees which is necessary with the Geneva motion generally employed in 35-mm machines. It is well known that the smaller the fraction of time that the screen is dark, the less noticeable is the flicker. Thus, flicker would be less with two 60-degree blades than with 90-degree blades. Therefore 48-cycle flicker should be less noticeable in 16-mm pictures than in 35-mm pictures.

The obvious explanation of the prevalence of three-blade shutters in 16-mm projectors is that the machines are designed for projecting pictures at either 16 or 24 frames per second. In view of the vast number of silent 16-mm films, made at 16 frames per second, it seems clear that general-purpose projectors for a long time to come will have to meet this requirement and there seems to be no satisfactory solution to the flicker problem at this picture frequency except to use three blades. On the other hand, the increasing use of sound pictures is unquestionably bringing a market for projectors that will have to operate at only one speed. Under these conditions it becomes a question of considerable importance whether it is necessary to provide these projectors with three-blade shutters. The loss of between a quarter and a third of the available light is serious if it is not necessary. Tests have been made from time to time under varying conditions, with the usual verdict that the 48-cycle flicker is noticeable, whereas the three-blade shutter does away with flicker entirely. The result has been the continued use of the three-blade shutter. The anomaly that a projector with 48-cycle flicker is good enough for a theater, even the best, but not for 16-mm projection, has been a puzzle of long standing. The reluctance of many engineers to accept this conclusion (which seems so illogical) appeared to the writers to warrant a survey of the considerations applying to the problem, and experimental checks of some of the factors.

Tests Using Screen without Picture or with Abnormally Bright Pictures.—The first question that arises in attempting to make comparisons between flicker under 35-mm and 16-mm projection conditions is, "What is the screen brightness at which the observations were made?" The relations between screen brightness and flicker rate are shown in Fig. 1 which is reproduced from a paper by E. W. Engstrom on television image characteristics.[1]

Screen brightness of the order of 10 foot-lamberts[2] (without picture but with shutter running) is recommended for satisfactory picture projection, and is readily obtained with 16-mm projectors, provided the screen size is not abnormally large. When the question of flicker is brought up the most natural way to make an observation is simply to run the machine without a picture and decide whether there is too much flicker. The result of such a test is almost invariably that the 48-cycle flicker would be objectionable, but the test is by no means a fair one. Theater practice is not based upon such a test but upon the very practical test of experience while viewing the

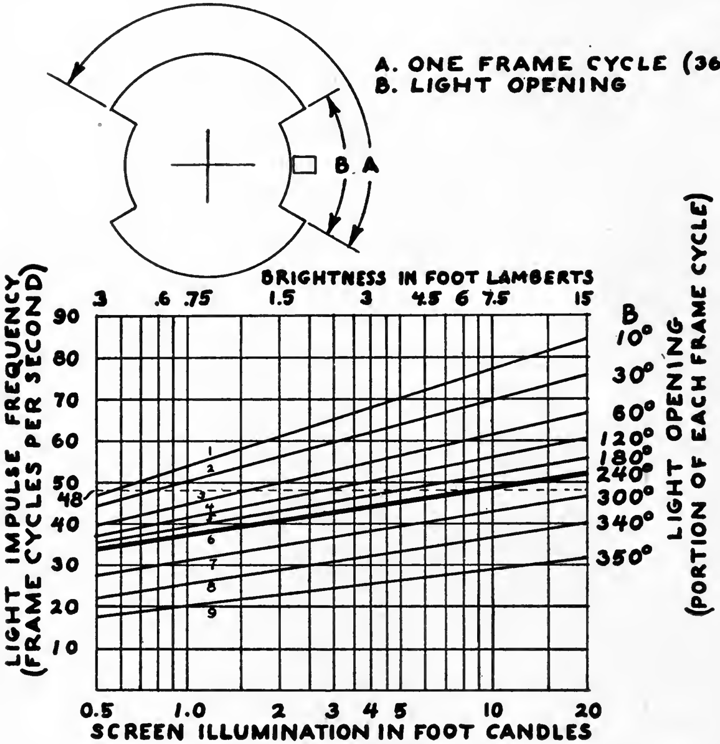

FIG. 1. Relations between screen illumination, flicker frequency, and blade angle for threshold flicker. (Curve *5* corresponds to two 90-degree blades; Curve *6* to two 60-degree blades.)

pictures. When a picture is being projected the evidence of the flicker is very much reduced by several causes. Measurements with a number of typical pictures, including outdoor scenes, indicated average or integrated screen brightnesses ranging from 8 to 28 per cent of that of the blank screen, with an average of about 10 per cent; and highlight or white object brightness ranging from 50 to 70 per cent. It might be thought that the tolerance for flicker would be determined entirely by the highlight intensity, but tests indicate that the area of the bright parts of the picture is also an important factor. Fig. 2 shows the results of a number of observations of the effect of viewing distance upon the value of screen brightness for just-perceptible flicker, using a blank screen. The farther the observer is from the screen, and therefore the smaller the angle subtended by the screen from his viewpoint, the greater is the flicker intensity that can be tolerated. It is a decidedly exceptional picture in which a bright highlight occupies $^1/_4$ of the screen area. Where large areas of sky are shown, artistic photography would almost invariably resort to breaking up the expanse of clear sky with clouds, which means considerable darkening of much of the sky area.

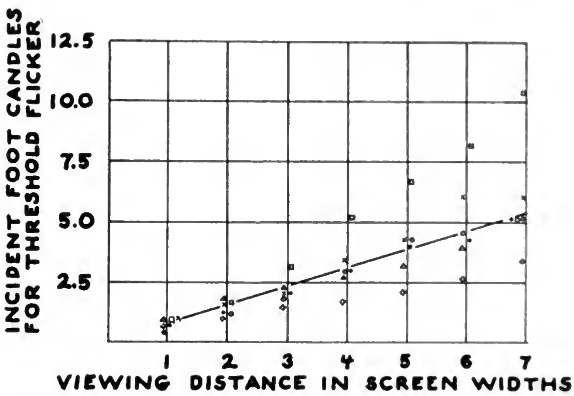

FIG. 2. Effect of angle subtended by illuminated area upon flicker threshold (each form of symbol is for one observer).

Another effect of the presence of the picture is that attention tends to be directed toward some center of interest. In viewing a blank screen the eyes wander from one part of the area to another. Flicker is much more noticeable with the eyes in motion than when the observer looks steadily at one part of the area (see Table II).

In addition to the effects of the picture just mentioned, we must recognize that picture jump is not completely eliminated, that there is jerkiness in all motion, and that these and other imperfections tend to mask what might otherwise be a perceptible flicker.

Part of our recent study was an effort to make a rough determination of the relation of flicker thresholds with and without pictures. Two projectors were arranged side by side, one with a shutter having three 70-degree blades and one with two 70-degree blades. Removal of the reflector from the 48-cycle machine gave substantial screen brightness balance. Loops of film showing the same subject were put into the machines and a number of observers were asked to say whether they saw any more flicker in one than in the other, after as many switchings back and forth as they wanted. The distance of the screen from the projector was varied until the minimum distance (maximum brightness) was found at which the observer found no appreciable preference for the 72-cycle picture. The film was then removed from the projector and the screen illumination measured. Since the observer sat close beside the projectors, the angle subtended by the picture was not altered by distance.

TABLE II

Effect of Picture upon Flicker Tolerance (Foot-Candles for Unobjectionable Flicker)

Observer	Still Picture Color*	Moving Picture*	Blank Screen	
			Eyes Fixed at Center	Eyes Moving
RLH	11	10.5	2.0	1.5
LTS	9	13	4.8	2.0
EWK	10	10.5	3	2.0
HER	9	12	2.5	1.3
CC	14	8	4.2	2.0
HH	10	12	2.0	1.2

* Illumination adjusted for satisfactory flicker with picture in place and measured with picture removed. Screen reflectivity about 90 per cent. The angle subtended by the picture width was 18 degrees for still pictures, and 22 degrees for the motion pictures and blank screen tests, corresponding to observer distances of 3.1 and 2.6 screen widths, respectively.

In another test a slide-projector was used with a shutter interrupting the light-beam. The shutter had two 60-degree blades, giving 48-cycle flicker. Numerous slides (in color) were introduced and the distance of the screen from the projector changed until the point was found at which flicker was not noticeable with the brightest pictures. For comparison the screen illumination at which flicker practically disappeared was measured with no picture, first with the gaze directed continuously at the center of the screen and then with the eyes moving. Table II shows the results of these tests.

The mean density of the slides was measured, using the Weston illumination meter and a *K-2* Wratten filter to simulate roughly the color-sensitivity characteristic of the eye. These measurements indicated about the same average or integrated light transmission as the black-and-white 16-mm subjects, namely 28 per cent as a maximum, with most of the subjects in the region of 10 per cent.

The Committee on Non-Theatrical Equipment in its July, 1941, report[2] recognized the effect of the picture in reducing flicker, in specifying 3 foot-lamberts for bare-screen flicker tests, whereas they recommended 10 foot-lamberts as the desirable screen brightness for picture projection conditions but with no film in the machine.

We have spoken of the misleading results of tests and demonstrations with the bare screen, without making due allowance for the effect of the picture. It is also easily possible for persons not too well acquainted with projection problems to be mislead by observations with excessively bright pictures, especially if viewed from nearby. Such excessive brightness is easily possible in individual tests by projecting very small pictures. Beaded and metallized screens[3] may give bright spots having many times the luminous intensity shown by a good matte screen. If the actual service for which a projector is intended includes use with directive screens, a three-blade shutter is obviously in order. Our purpose here is simply to mention the fallacy of drawing conclusions from tests with directive screens and applying these conclusions to the case of matte screens.

Effect of Color of Light—Since theater pictures are projected with arc lamps, and 16-mm pictures for the most part with incandescent lamps, it occurred to the writers that the eye might be more sensitive to flicker near the red end of the spectrum than near the blue end. The relations between color, brightness, and flicker have been the subject of many investigations[4, 5, 6, 7] but not being completely satisfied that the tests reported in the literature applied exactly to the problem under consideration here, the authors carried out a series of tests. In order to make any comparison it would be necessary to establish the fact that the screen brightness was equal for the two colors being compared. It was obviously not appropriate to make the measurement of brightness with a photocell or photronic measuring device unless the spectral-sensitivity curve of the instrument was the same as that of the eye. To test the relative flicker sensitivity to lights of different color it was necessary, after selecting the desired color-separation filters, to rate the light projected through them in terms of its utility for visual purposes. In order that the eye adaptation[5, 6] might be representative of conditions during the viewing of motion pictures, a small spot of colored light was projected on a test-object in the center of a rectangle which was illuminated from the rear, to about normal screen brightness. The first determinations of the illumination value of the light passing the several filters were made by measuring the light-flux on a Weston photronic cell required for bare visibility of a dark test-object of low contrast. We then decided that it would be a better test of the general utility of the light to bring up the intensity until a test-object of extremely low contrast was just discernible. These readings gave the ratio between the light as measured by the photronic cell and its utility to the eye for visual purposes. The screen illumination at which flicker became just discernible also was determined for the same observers, and the ratio of measured illumination for threshold flicker and threshold visibility was compared for the several colors. The conclusion from these tests was that the sensitivity to flicker is in direct proportion to the brightness which makes for visibility and low-contrast discrimination. Since the photronic-meter measurement was in each case used for comparing two effects of the light of each color, the spectral sensitivity of the cell cancels out. As a

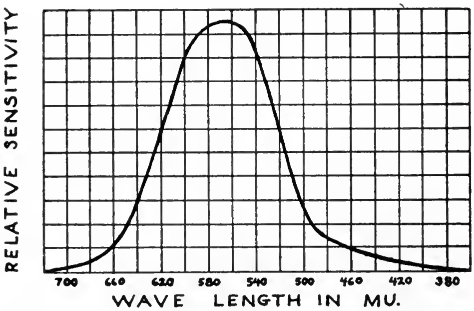

FIG. 3. Relative response of the eye to light of various colors.

check, the visual density of the several color-filters was measured on a Capstaff densitometer. The work just described checks the conclusions of various previous investigations. The well known flicker-photometer, for example, evaluates lights of different color in terms of the amount of flicker that they produce. Thus, when the flicker of a green light cancels that of a red light they are regarded as equal. In numerous investigations the results of flicker-photometer measurements have been compared with those of other types of photometer and the agreement has been found to be excellent. The well known eye-sensitivity curve (Fig. 3) has been checked by the three fundamental methods, judgment of brightness, flicker, and visibility, with substantially identical results.[4,5,6,7]

From the foregoing it is evident that if two screens are equally satisfactorily illuminated but by light of slightly different color, flicker will be no more noticeable in one than in the other. There is, however, an error that may easily be made in comparing theater screen brightness with 16-mm screen brightness. Although foot-candle meters are designed to approximate eye-sensitivity, many of them are relatively more sensitive to blue light than the eye. If such a meter indicates an illumination of 10 foot-candles on a theater screen and 10 foot-candles on a 16-mm screen, the latter would actually look brighter to the eye. It is thus improper to compare the flicker on the basis of equally measured screen brightness unless the meter is corrected to match closely the spectral sensitivity of the eye.

A psychological factor may enter into the judgment of screen brigthness as seen in theaters and in 16-mm projection. We associate high-intensity light-sources with very white or bluish light, and may thus be inclined to estimate the brightness of an arc-lighted screen as higher than that of an incandescent-lighted screen having the same useful brightness. In addition to this, the better suppression of stray light in the theater, of course, makes a given screen intensity seem greater than it would in the presence of more stray light.

Effect of A-C Ripple.—During tests of the effect of speed of cutting we were interested in the actual "wave-shape" of the illumination curve. A cathode-ray tube was connected to the output of a photocell. This showed that, in addition to the effects of the shutter, the 120-cycle ripple in the lamp brightness was contributing to flicker effects. We estimated that the light from the 750-watt projection lamp fluctuated through a total range of about 5 per cent. E. E. Masterson devised the method shown in Fig. 4 of illustrating the effect of this upon flicker. In each $^1/_{24}$ second there are five periods of higher and five of lower lamp brightness. The effect of cutting off certain fractions of the cycle by the shutter-blades may result in an unbalance which produces a small component of 24-cycle flicker. The tolerance for flicker of this frequency is, of course, very small. It appears also that there are certain blade-widths that are better than others in reducing the 24-cycle component to a minimum.

Effect of Blade Angle.—Fig. 1 summarizes in useful form the relation between flicker frequency, screen illumination for flicker threshold, and ratio of bright to dark time. Screen illumination was measured with the shutter running. The reflectivity of the test-screen was given as 75 per cent, whence the brightness in foot-lamberts would be 0.75 of the foot-candles read on the vertical scale. It will be noted that narrowing the shutter-blades makes it possible to work with greater screen brightness without observable flicker. The increased efficiency may be used in part for increasing screen brightness and partly for reducing lamp wattage or simplifying the optics. From Fig. 1 it is clear that we can not classify flickers in terms of the frequency only but must specify the bright to dark ratio, or blade-width, in addition to the number of blades and the mean screen brightness. With two 60-degree blades, Fig. 1 indicates that 10 foot-candles, or 7.5 foot-lamberts would give threshold flicker on a

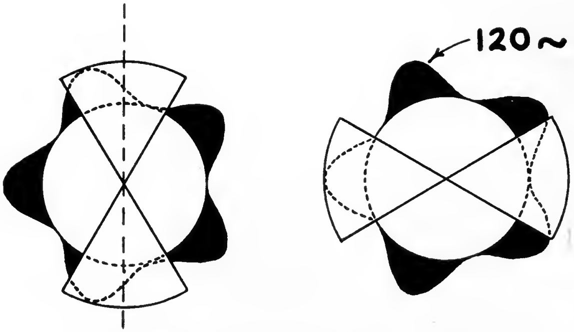

FIG. 4. Unbalance of 120-cycle fluctuation in lamp brightness, produced by shutter blades.

bare screen at 48 cycles. The observations upon which these curves were based were with a 14 × 16-inch bare screen six feet from the observer.

Effects of Speed Of Cutting.—It seems reasonable to expect that a shutter system that maintained full brightness up to the last possible instant, and then cut off quickly, would give less flicker than one with which the screen was at its maximum brightness only during the middle of the bright period. To test this, a projection system was arranged with a large-diameter shutter that could be placed at chosen positions in the light-beam and could be used either with its axis fairly close to the optical axis or farther away, so that the blade edges were moving faster. The light-beam was about 1 inch in diameter at the largest and about $^3/_8$ inch in diameter at the smallest, and the 24-rps shutter was used with from 2 to 4-inch active radius. Within the range of these tests no noticeable difference was found in the screen brightness for threshold. We do not consider that this proves that the wave-form of the screen-brightness curve is immaterial, but it is safe to say that it does not affect the flicker radically and there is every practical reason for maintaining the screen brightness at full possible value for the longest possible time. It is of course of even greater importance to cut the light off completely during the time that the film is in motion.

Since the light-beam is at its smallest cross-section close to the picture aperture, quick cutting is promoted by placing the shutter close to the aperture. The gain, however, may not be quite in proportion to the reduction in distance across the light-beam. With a focal-plane shutter the entire picture is not obscured at the same instant, and any portion that is not covered while the film is moving is on the screen at full brilliance. The avoidance of travel-ghost may therefore require more complete fulfillment of the requirement of complete coverage during motion than seems to be necessary with the shutter farther away where it acts to fade the entire picture in and out.

Tests were made to determine whether there is any difference in noticeable flicker with a focal-plane shutter as compared with a lens-aperture shutter, the blade size being identical. No difference could be noticed.

Shutters with Unequal Blades.—Trials have been made from time to time of shutters with various arrangements of unequal blades in the hope of finding an arrangement that would permit the necessary blade-width to prevent travel-ghost and not intercept so much light while the picture is stationary as the usual full-width extra blades. In 1938 R. O. Drew conducted a series of experiments using a shutter with one full-width and two narrower blades. The narrow blades could be shifted in position. The optimal position was found (within the limits of observations) to be that at which the shutter is also mechanically balanced. If the light-intensity is plotted as a wave, a Fourier analysis shows that the abovementioned condition results in the fundamental component's becoming zero. In other words there is no 24-cycle component of flicker. However, it is not beyond possibility that the eye response is of such nature that the actual optic nerve stimulation would have a component of fundamental frequency even though the external stimulus did not have it. This would be analogous to the well known reconstruction of fundamental frequency due to the non-linear character of the ear. In these tests, which were made with a blank screen, the observers judged the flicker produced by the shutter with the three unequal blades to be about as objectionable as the 48-cycle flicker from a balanced two-blade shutter. In recent tests, however, the conclusions from a fairly large number of observations was that when a picture is being shown the flicker from the unequal-blade shutter can, if the shutter is properly designed, be substantially less than with a two-blade shutter. The unbalanced shutter therefore represents a compromise between the two- and three-blade shutters, and evidently has a place in picture projection.

Conclusions.—Omitting from consideration the obvious necessity of using a three-blade shutter if the same machine must also project pictures at 16 pictures per second, the widely held opinion that three-blade shutters are needed for 16-mm picture projection (at 24 frames per second) whereas the two-blade shutters apparently give satisfaction in theaters may be attributed to the following:

(*1*) Many of the comparisons have been made with no picture in the machine, or with the screen so close to the machine that the picture was much brighter than that corresponding to ordinary projection.

(*2*) In comparing theater conditions with 16-mm projection conditions, it may frequently have been considered that the screen brightnesses were equal, because so indicated by a foot-candle meter, whereas from the visual standpoint the 16-mm film was actually brighter. The better freedom from stray light and the whiter character of the screen illumination probably gives theater patrons an impression of abundant brightness whereas the same actual screen illumination under 16-mm projector conditions would seem to be less bright.

(*3*) Although the only logical way of measuring screen brightness is in terms of the reflected light (foot-lamberts), measurements of the incident light are common. The reflectivity of theater screens is cut down slightly by the perforations. Therefore the actual brightness tends to be less, for the same illumination, in a theater than in a 16-mm projecting system, assuming the screens to be of equal quality.

(*4*) The 120-cycle fluctuation in lamp brightness may under some conditions increase the flicker effect.

(*5*) The eye is more sensitive to flicker at the beginning of a period of watching motion pictures than after a few minutes of continuous viewing. Therefore practically all tests for flicker threshold (and this includes our own tests recorded here) give lower values of brightness for threshold flicker than those that would correspond to freedom from noticeable flicker during most of the duration of a film showing. The subject of flicker fatigue and adjustment to flicker was interestingly discussed by P. A. Snell,[8] in the May, 1933, JOURNAL.

(*6*) It is more than likely that if a comparison were arranged under theater conditions with a two-blade shutter in one machine and a three-blade shutter in the other and with the screen brightness equalized to normal level, the observers would see a perceptible difference. In other words we probably tolerate perceptible flicker in theaters. Owing to the ease with which tests and comparisons can be made, we have become more critical in the 16-mm field.

(*7*) Screen brightness in the theater and viewing distances are the same from day to day. The inability to control or predict conditions of use constitutes a valid reason for providing against more severe conditions of showing in the case of the 16-mm projectors.

The following items of interest in connection with flicker studies have been brought out in our recent tests:

(*1*) Tolerance for flicker increases in marked degree after the first few minutes of continuous viewing. Some of the tolerance is probably developed within a few seconds, as is evidenced by the reduced sensitivity to flicker when the eyes do not move.

(*2*) Color of the light may be a factor in creating a subjective impression (probably based upon association) of differences in screen brightness, but in terms of visual utility the flicker threshold and useful brightness go together independently of the color of the light.

(*3*) When a picture is being projected the average screen brightness is a small fraction of that of a blank screen, and even the bright portions are likely to be little more than half the maximum possible brightness. This means that picture projection will be satisfactory even though the illumination of the bare screen may be three or four times flicker threshold.

(*4*) It is permissible to allow the screen brightness in small areas of the projected picture to exceed considerably the blank-screen flicker threshold. This is because the viewing angle subtended by the bright area is a large factor.

(5) When viewing a large area, the sensitivity to flicker is much increased by the motion of the eye.

(*6*) The magnitude of the flicker is not materially affected by the location of the shutter or the velocity of the edge of the blade, but the blade-width is important, and the narrower the blade the better.

(7) The value of high blade-speed (or large radius) is that it will permit the use of a narrower blade without travel-ghost.

The general conclusion from our studies is that the decision to employ three-blade shutters for general-purpose 16-mm projectors where the conditions of use can not be predicted, is entirely justified. Projectors with three-blade shutters and with incandescent lamps can, if provided with efficient optical systems, illuminate a 3 × 4-foot screen with 10 foot-candles. Hence with screens of this size or smaller, two-blade shutters can not be recommended as giving any better picture. On the other hand, projectors that are designed to be used for showings to fairly large audiences, where screens 5 feet or more wide are desirable in order to make the picture easily seen from the remote seats, should (if they are not equipped with arc lamps) preferably have two-blade shutters in order to obtain the benefit of the brighter picture. Unless the screen brightness (with no picture in the machine) considerably exceeds 10 foot-lamberts, flicker should be no worse than it is in practically all theaters.

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[6] SOUTHALL, J. P. C.: "Physiological Optics," *Oxford University Press*, Chapt. X, p. 372.

[7] IVES, H. E.: "Spectral Luminosity Curves by the Method of Critical Frequency," *Phil. Mag.*, **24** (1912), p. 352.

[8] SNELL, P. A.: "An Introduction to the Experimental Study of Visual Fatigue," *J. Soc. Mot. Pict. Eng.*, **XX** (May, 1933), p. 367.

DEVELOPMENTS IN TIME-SAVING PROCESS PROJECTION EQUIPMENT*

R. W. HENDERSON**

Summary.—*The projection of a motion picture on a translucent screen for background purposes has become increasingly important in studio operations during the past ten years. Many shots now made through the use of this process would have been extremely costly and perhaps impossible if attempted by direct filming of the complete action.*

The sharp rise in production costs during the past few years, coupled with the curtailment of foreign markets, demanded that every effort be expended to simplify production methods.

With this in view, Paramount Pictures embarked upon a complete modernization program of the Transparency department production equipment early in 1940. New compact projection units, bases for the projectors, rewind tables, screen frames, screen handling equipment, and light-bridges were designed and built. This equipment has immeasurably simplified operations as well as improved quality beyond levels heretofore achieved.

Descriptions of this equipment are presented, with emphasis upon a comparison of the new with the old. The success of the equipment can be attributed largely to standardization of component parts. Complete interchangeability of essential units, coupled with easy access to critical points, has gone far toward eliminating lost time and motion in meeting unexpected emergencies.

The projection of a motion picture upon a translucent screen for background purposes has become increasingly important in studio operations during the past ten years. Directors and producers have come to accept these backgrounds with confidence in the appearance of the finished photographic illusion, where they once insisted upon location shots. Through the coöperation of these men and the efforts of the Transparency Division of Paramount's special photographic department, headed by Mr. Farciot Edouart, techniques have been developed that permit the making of certain types of scenes that would have been impossible without the use of projected backgrounds. The importance of this work is more evident now

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*Presented at the 1942 Spring Meeting at Hollywood, Calif.; received April 13, 1942.

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

than ever before, because of the increased costs entailed in sending a shooting company on location.

One of the greatest advantages of background projection is that of providing "cover" for a company that might otherwise be delayed by some unforeseen difficulty that may arise in spite of careful planning. The most common of these is that of a company finishing a day's scheduled shooting early in the afternoon, in which case the cast would have to be dismissed on pay if it were not possible to move into a transparency scene. Realizing this, the production department attempts to maintain at least one transparency set as "cover" for every shooting company.

The "stand-by" function of background projection set-ups demands that all the equipment used be of a standardized, interchangeable nature; flexible, efficient, easily handled by a minimum of operating personnel; and so arranged that it can be assembled and put into action in a few minutes.

With this aim in view, the Paramount Engineering department, following a preliminary investigation period, commenced design work early in 1940 on a complete modernization program embracing the following major equipment used by the transparency department, which will be described in the order named.

(*1*) Projection units
(*2*) Projector bases
    (*A*) Single
    (*B*) Triple
(*3*) Rewind tables
(*4*) Screen equipment
    (*A*) Screen frames
    (*B*) Screen jacks
(*5*) Light bridges

(1) PROJECTION UNITS

Customary studio practice during the last ten years has been to have the projection machine permanently housed in a large, cumbersome, heavy booth which was awkward to move in and out of restricted stage space. In addition, the extreme heat from the arc lamp, cramped working space, excessive noise, and limited ventilation provided poor operating conditions for the projectionist.

Another objection to the booth was the difficulty of making high shots. To accomplish such shots, the booth had to be taken to a large hydraulic hoist on the lot, lifted, rolled off onto a caster base parallel, and pushed back upon the stage. This was not only time-consuming but hazardous when negotiating the ramps outside the stage doors.

To eliminate these objections, Paramount followed the lead set by Selznick International Pictures in 1939 and embarked upon the design of a comparatively light-weight, silent, projection unit that could be used without a booth. In general, the specifications as drawn up by the Process Projection Equipment Committee of the Research Council of the Academy of Motion Picture Arts & Sciences were adopted.

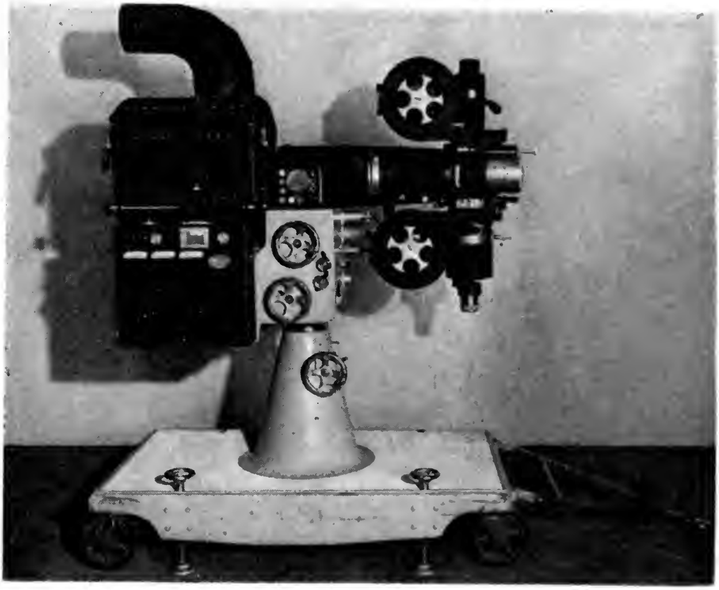

FIG. 1. New type silent projector; operator's side.

To increase flexibility further, the projector was designed as a complete unit in itself, comprised of a projection head, light-tube, optical relay condenser system, lamp house, self-contained cooling system, and a support housing that tied all these various elements together into one completely independent assembly that could readily be lifted on or off a separate base, as shown in Fig. 1.

The projection head was designed and built by the Mitchell Camera Corporation in accordance with the suggestions of the Research Council. To date eight of these heads have been built: one for Selznick International Pictures, Inc., three for RKO, and four for Paramount.

The projection-head mechanism is driven by a 1440-rpm distributor controlled, a-c interlock motor which is normally tied in with a camera and a recording machine. To provide for all "sync" shots, *i. e.*, shots made without recording sound, a special variable-speed d-c driving motor was built into the top of the projection-head. When in use, this motor is connected through a magnetic clutch to the head mechanism and to the rotor of the interlock motor. By applying three-phase power from a common source to the stator windings of both the interlock motor and the camera motor, the interlock motor becomes in effect a distributor interlocking the camera to the projector.

For standard speed work the d-c motor operates at 1440 rpm, controlled by a centrifugal governor. The variable-speed feature was designed to provide for under- and over-cranking between the limits of 12 and 36 frames per second.

This system eliminates the necessity of having a sound crew standing by for the single purpose of operating the distributor in the recording building, or the equally objectionable practice of having a local distributor either on or just outside the stage. Another great advantage of the reversible d-c drive system is that it provides a rapid method of rewinding, particularly during line-up.

The light-tube serves as a support for the projection-head and also as a housing for the relay condenser elements and fire-shutter. It consists of cylindrical Mehanite casting to the outer end of which the projection-head is fastened by a large-diameter clamping ring. This ring is fitted with a tangent-screw adjustment which permits rotation of the head about the optical axis for line-up purposes and special effects. This feature is a particularly important time-saver during the registration of superimposed pictures from several machines in multiple-head projection. The lamp house is a Mole-Richardson type *250* designed in accordance with recommendations of the Research Council.

The cooling unit consists of a motor, centrifugal pump, squirrel-cage blower, and radiator, mounted on rubber as an isolated unit under the lamp house. Its function is to supply cooling water to the carbon-holding jaws in the lamp house and to the jacket surrounding the distilled water in the water-cell of the optical system.

To increase the efficiency of the projection unit further, a talk-back amplifier system was added, terminating with the cameraman on the set in the form of a small combination microphone-speaker. Paralleling this system is another combination microphone-speaker mounted on a small portable desk just off the set which is normally tended by the assistant cameraman whose duty it is to keep the shooting log and print records. The desk is equipped with a remote-control panel, making it possible to operate the projector from that point for special shots. It also contains a group of signal push-buttons for transmitting instructions to the projectionist without the aid of the talk-back system.

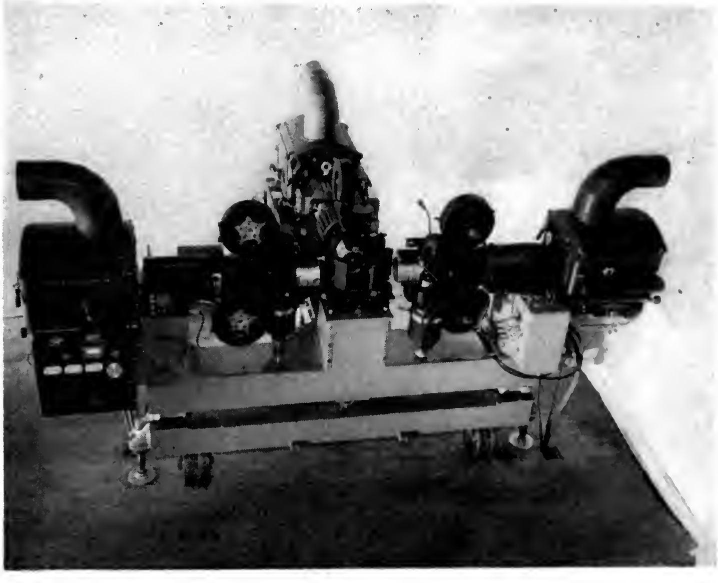

FIG. 2. Triple-head projection unit; top view.

High shots with the new equipment are normally made from parallels. For certain shots, however, where restricted stage space and the ability to make quick moves are the governing factors, the equipment may be rolled onto the platform of a compact motor-driven industrial stacker or telescoping elevator, the floor-space required by the stacker being only slightly greater than that of the projector and its associated equipment.

The performance of the unit can best be judged by the relatively high average light output level of about 42,000 lumens, which has been boosted to better than 50,000 lumens at times through careful regulation and operation.

(2) PROJECTOR BASES

(*A*) *Single Projector Base.*—The single projector base serves as a mount for the projection unit and is a complete piece of equipment in itself. Into it is built a panning mechanism permitting a 360-degree rotation about a vertical axis, a tilt-mechanism allowing a ±20-degree tilt from the horizontal, and an elevating mechanism capable of placing the optical axis anywhere between 4 feet 9 inches and 6 feet 8 inches above the floor. The single bases built to date are completely interchangeable with any of the four projection units, thereby eliminating unnecessary confusion and delays that might otherwise affect set-up time.

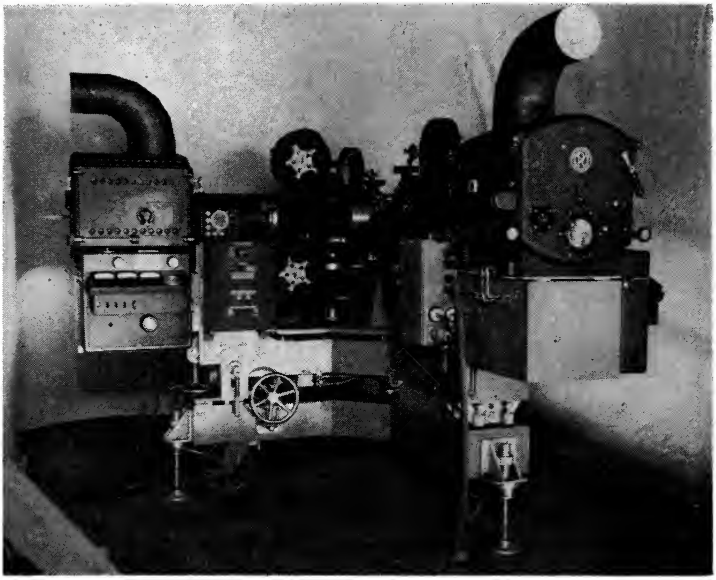

FIG. 3. Key operator's station, triple-head projection unit.

(*B*) *Triple Projector Base.*—With the advent of large-screen color shots, the industry turned to multiple-head projection and superimposed pictures to increase the screen illumination. To provide for this type of work, a base was designed upon which any three of the four projectors could be mounted in approximately 45 minutes, including the time required to collect and lift them from their individual bases (Figs. 2 and 3). Built-in mechanisms in the base provide for ±5-degree pan and tilt with the possibility of increasing this range through the auxiliary jacks used to tie off the base to the floor. This new equipment has an average total light output level of about 126,000 lumens, replacing the old triple booth which had a total light output of slightly less than one of the new single-projection units.

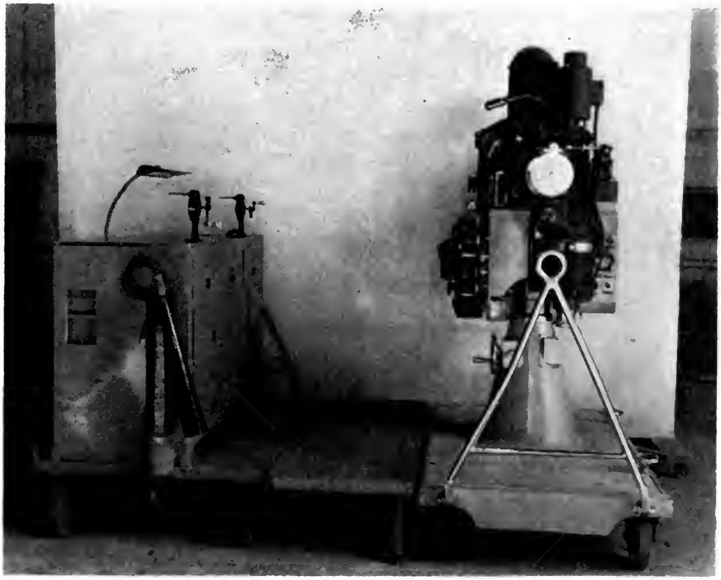

FIG. 4. New type projection unit, rewind stand, and working platform; front view.

Most of Paramount's large-screen shots are made in an outdoor diffused area approximately 62 feet wide by 300 feet long. To increase further the flexibility of the triple-head unit in this location, the machine is placed on the floor of a semiportable elevator permitting a maximum optical axis height of 19 feet 6 inches above the floor. If the unit is required on any other stage, it can be rolled off the elevator, transported on its own wheels, and set up on its jacks wherever desired.

The synchronized control of the triple-head motor system, necessary for superposition of pictures, is accomplished through a central control-panel permanently mounted on the base which gives the key operator control of all three machines when running in interlock. However, the individual projectionists can at will drop off the line and run independently for line-up and rewind if they so desire. The built-in talk-back system mentioned above as a part of the projection unit serves in the same capacity in the triple set-up.

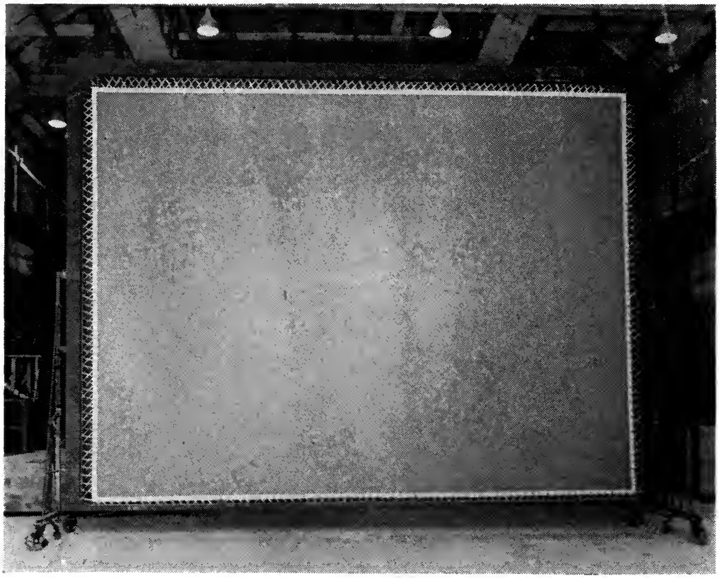

FIG. 5. New type 18′ × 24′ stressed-skin metal screen frame.

(3) REWIND TABLE

A necessary auxiliary to the projector is the rewind table, which serves the dual purpose of a storage cabinet for film, lenses, and operating equipment, as well as a work table for rewinding, cleaning, and examining the film (Fig. 4).

This unit is of all steel construction and is normally mounted on a rubber-tired caster-equipped dolly having a built-on folding work-platform on which the projectionist stands. The work-platform, floor of the projector base, and floor of the rewind dolly are all at the same level, thereby producing an unobstructed working area from which the projectionist can reach either the table or the projector controls merely by turning around.

The table top is equipped with standard manually operated rewinds, a flush-surface opal-glass panel illuminated by fluorescent light for scanning the film as it is rewound, and a folding-type fluorescent reflector for general illumination of the working area.

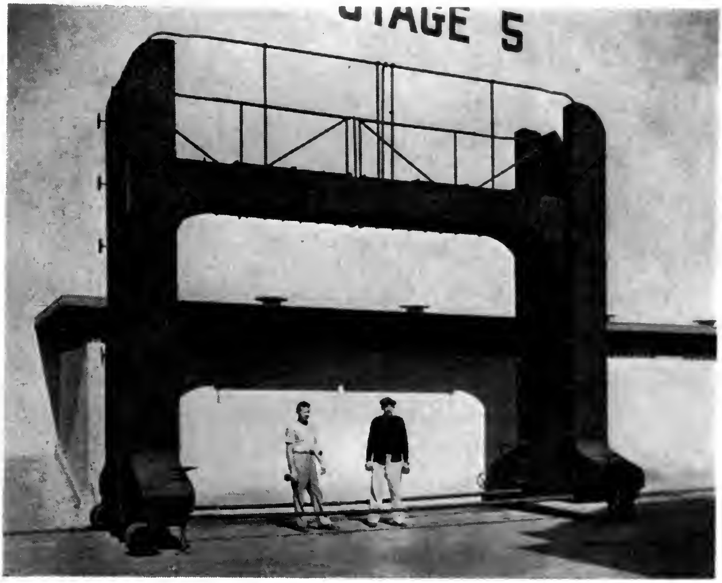

FIG. 6. New metal light-bridge; minimum span and height.

When it is necessary to operate the projector from high parallels or on the elevator it would often be inconvenient to leave the rewind table mounted on its dolly. For shots of this type the table is normally lifted off the dolly and used without the convenience of the work platform.

With this new equipment, the operator has pleasant surroundings, compact, orderly arrangement of all accessories, and no appreciable mechanical noise, all of which is in marked contrast to the old system.

(4) SCREEN EQUIPMENT

The primary objection to the conventional transparency-screen frame and supporting structure has been its great bulk. Customary practice has been to have the screen frame permanently hung inside a portable bridge which served as a catwalk for the mounting of top lights. This procedure necessitated moving the large units on and off stages continually and was often complicated by the arrangement of sets on the stage. In some cases the day's work on one stage would require two or perhaps three screen sizes, which meant that either a great deal of stage space was taken up by the units not in use or the sets had to be so arranged as to leave easy access to the door to permit exchanging the screens.

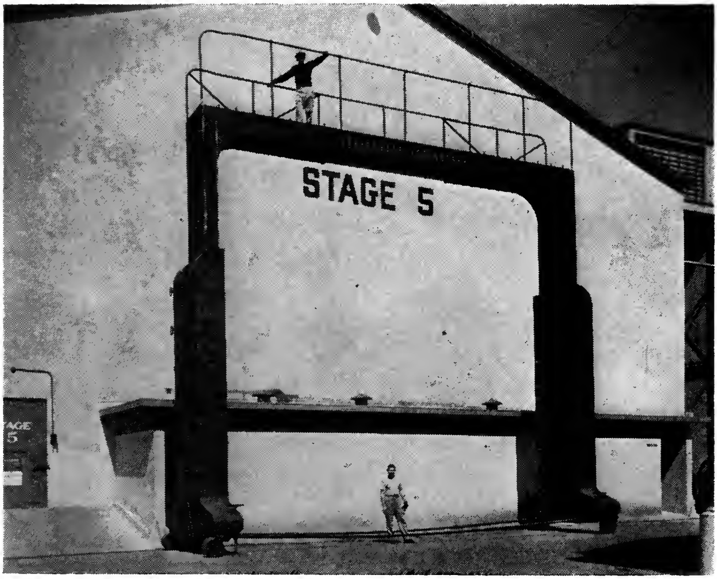

FIG. 7. New metal light-bridge; maximum span and height.

To minimize the handling problem, a system was devised that incorporates a very light stressed-skin steel frame in which the screen is mounted, portable elevating-type jacks which can be readily attached to the ends of these frames for handling, and an independent light-bridge of semistressed-skin construction from which the screen frame can be hung if desired.

(*A*) *Screen Frames.*—Four standard-size screen frames were designed using steel stressed-skin or the full Monocoque principle, as it is sometimes called. In this type of construction, the loads applied to the structure are carried principally by the thin sheet-metal covering, eliminating the necessity of having a relatively heavy internal structural framework, and thereby reducing the overall weight of the unit. To date the studio has acquired four 11 feet × 14 feet, two 14 feet × 18 feet, two 16 feet × 21 feet, and four 18 feet × 24 feet screens (Fig. 5). The frames are remarkably light and rigid, and can be used either on their own detachable jack supports or can be hung from the light-bridge structure.

One important feature of the frames is the minimum screen height, which places the lower edge of the working area within three to four inches of the floor. This feature permits building directly on the floor certain sets that previously had to be built on parallels.

Some transparency shots can be made without heavy top-lighting, so for these shots the light-bridge previously mentioned can be dispensed with entirely. In the event that a small amount of overhead lighting is required, but not enough to warrant the use of a light-bridge, sockets have been provided along the top of the screen frames to take the spindles of the light-bails. For protection of the screen material during handling, light-weight plywood cover-panels of sectionalized design are hung from the top of the frame. One man can handle the largest panels, although two men usually work together.

An enclosed, moderately dust-tight storage shed with an overhead monorail system was built for the protection of the screens and other equipment when not in use. The monorail system makes it a simple matter for the operating personnel to select any of the twelve screens and move it out of the building. From that point it is transported on its own jacks to any stage on the lot, the entire procedure requiring only a few minutes.

(*B*) *Screen Jacks.*—The screen jacks are compact, easily handled, caster-equipped elevators which engage built-in lugs on the ends of the screen-frame. They are provided with a tow-bar, diagonal tie-rods for bracing to the screen frame, and a folding leg with third wheel for stabilizing the jack when not attached to the screen-frame. The jacks have a maximum lift of six feet, permitting the making of high shots without the expense of building special parallels for supporting the screens.

When in the high position, the wheel-base of the jacks can be increased by a built-in feature to provide all the necessary stability for safe operation.

(5) LIGHT-BRIDGES

The light-bridge illustrated in Figs. 6 and 7 is of semistressed-skin construction which gives it great load-carrying capacity in proportion to its weight. The bridge structure is designed to telescope in both directions. In the most compact position it has a net clear rectangular opening of 13 feet 3 inches × 18 feet 3 inches, which can be extended 13 feet 4 inches vertically and 10 feet 0 inches horizontally to a maximum opening of 26 feet 7 inches × 28 feet 3 inches. This extended opening permits hanging an 18 feet × 24 feet screen six feet in the air. All smaller screens can be hung wherever desired in the bridge opening. This construction is particularly useful when the arrangement of the props might require a bridge that could completely straddle the set.

The first of three of these light-bridges has recently been put into use. When the other two are completed it is planned to assign each to a group of about four stages among which it can be shuttled as required. This procedure should help considerably in minimizing handling and set-up time.

The two remaining items included in the modernization program are the construction of a stereopticon projector, the design of which is substantially complete, and the design and construction of a high-speed motion picture background projector.

The base for the high-speed projector will be identical to the other four single-bases, and the general appearance of the projection unit will be similar to that of the standard-speed machines. The difference will be mainly in the design of the motor system and the projection-head, which has been delayed by the war. It is intended that this unit be capable of overcranking as high as 120 frames per second, or five times normal speed, which is desirable for many types of miniature work.

In addition to its primary high-speed function, it will be possible to operate the unit at 24 frames per second, thereby giving the studio a fifth-standard-speed projector if required during heavy shooting schedules.

Stereo-projection is a potential source of considerable savings, both in the shooting of the original plates as well as in processing.

The plates can be taken by a still photographer working without the assistance of a staff of technicians, as contrasted to the procedure necessary when shooting motion picture backgrounds. Here it is necessary to send out a cameraman, an assistant, perhaps a camera mechanic, and a considerable amount of miscellaneous operating equipment that is particularly objectionable when travelling by air. In addition, there is the cost of the negative, processing, and print which must be met before the picture can be used. The resulting cost differential makes it desirable to use still backgrounds wherever possible.

Paramount has used the process frequently but has been limited in recent years by design improvements and a higher standard of quality that outmoded the equipment available. It is believed that the new stereopticon that is about to be constructed will broaden the field of application for this type of equipment and permit considerable reductions in costs for still background work.

With the completion of this new equipment, it is felt that Paramount will be well equipped to cope with the changing production technique and operating conditions that will inevitably follow as an aftermath of the present world-wide conflict.

CURRENT LITERATURE OF INTEREST TO THE MOTION PICTURE ENGINEER

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

American Cinematographer

23 (Aug., 1942), No. 8

"Pre-Photographing" in 16-Mm as a Means of Conserving Film (pp. 342–343, 382)	L. GARMES
Animated Cartoon Production Today. Pt. V (pp. 344–346, 380–382)	C. FALLBERG
Make 16-Mm Business Movies That Help the War Effort (pp. 347, 379–380)	W. G. BOSCO
Controlling Color in Lighting 16-Mm Kodachrome for Professional Pictures (pp. 348–349, 377–379)	J. A. LARSEN, JR.
Diopters—for Distortion (pp. 358, 370–371)	J. WALKER
Explaining "Montage" (pp. 359, 364–366)	L. G. DUNN
Making Movies under Water (pp. 360, 370)	T. TUTWILER
Why Not Try Making Third-Dimensional Movies? (pp. 362–363, 366–368)	P. TANNURA

Institute of Radio Engineers, Proceedings

30 (Aug., 1942), No. 8

Recording and Reproducing Standards (pp. 355–356)	L. C. SMEBY
The Zero-Beat Method of Frequency Discrimination (pp. 365–367)	C. F. SHEAFFER
Transients in Frequency Modulation (pp. 378–383)	H. SALINGER

Motion Picture Herald (Better Theaters Section)

148 (July 25, 1942), No. 4

Simple Method of Testing and Correcting the Projection Light System (pp. 7–9, 19–20)	C. E. SHULTZ
Luminous Screen Frame (pp. 10–11, 20)	B. SCHLANGER

FIFTY-SECOND SEMI-ANNUAL MEETING

OF THE

SOCIETY OF MOTION PICTURE ENGINEERS

HOTEL PENNSYLVANIA, NEW YORK, N. Y.
OCTOBER 27th–29th, INCLUSIVE

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HOTEL RESERVATIONS AND RATES

Hotel Rates.—The Hotel Pennsylvania extends to SMPE delegates and guests the following special *per diem* rates, European plan:

Room with bath, one person	$3.85–$7.70
Room with bath, two persons, double bed	$5.50–$8.80
Room with bath, two persons, twin beds	$6.60–$9.90
Parlor suites: living room, bedroom, and bath	$10.00, 11.00, 13.00, and 18.00

Reservations.—Early in September room-reservation cards were mailed to the members of the Society. These cards should be returned to the hotel as promptly as possible to be assured of desirable accommodations. Reservations are subject to cancellation if it is later found impossible to attend the meeting.

Registration.—The registration headquarters will be located on the 18th floor of the Hotel at the entrance of the *Salle Moderne*, where most of the technical

sessions will be held. All members and guests attending the meeting are expected to register and receive their badges and identification cards required for admission to all sessions.

TECHNICAL SESSIONS

Technical sessions will be held as indicated on the next page. The Papers Committee is assembling an attractive program of technical papers and presentations, the details of which will be given in a Tentative Program to be mailed to the members of the Society about October 10th.

FIFTY-SECOND SEMI-ANNUAL BANQUET AND INFORMAL GET-TOGETHER LUNCHEON

The usual Informal Get-Together Luncheon for members, their families, and guests will be held in the Roof Garden of the Hotel on Tuesday, October 27th, at 12:30 P. M.

The Fifty-Second Semi-Annual Banquet and dance will be held in the Georgian Room of the Hotel on Wednesday evening, October 28th, at 8:00 P. M. Presentation of the Progress Medal and Journal Award will be made at the banquet, and the officers-elect for 1943 will be introduced. The evening will conclude with dancing.

LADIES' PROGRAM

Mrs. D. E. Hyndman, Hostess, and members of her Committee promise an interesting program of entertainment for the ladies attending the meeting, the details of which will be announced later. A reception parlor will be provided for the Committee where all should register and receive their programs, badges, and identification cards.

MISCELLANEOUS

Motion Pictures.—The identification cards issued at the time of registering will be honored at the Paramount Theater, the Roxy Theater, the Capitol Theater, and Radio City Music Hall. Many entertainment attractions are available in New York to out-of-town delegates and guests, information concerning which may be obtained at the Hotel information desk or at the registration headquarters.

Parking.—Parking accommodations will be available to those motoring to the meeting at the Hotel garage, at the rate of $1.25 for 24 hours, and in the open lot at 75 cents for day parking. These rates include car pick-up and delivery at the door of the Hotel.

Golf.—Arrangements may be made at the registration desk for golfing at several country clubs in the New York area.

Note: The dates of the 1942 Fall Meeting immediately precede those of the meeting of the Optical Society of America at the Hotel Pennsylvania, New York, N. Y., to be held on October 30th and 31st.

The Convention is subject to cancellation if later deemed advisable in the national interest.

TENTATIVE PROGRAM

Tuesday, Oct. 27

9:00 a.m. *Hotel Roof;* Registration.
10:00 a.m. *Salle Moderne;* Business and Technical Session.
12:30 p.m. *Roof Garden;* SMPE Get-Together Luncheon for members, their families, and guests. Introduction of officers-elect for 1943 and addresses by prominent members of the motion picture industry
2:00 p.m. *Radio City Music Hall Studio;* Technical Session.
8:00 p.m. *Museum of Modern Art Film Library;* Technical Session.

Wednesday, Oct. 28

9:00 a.m. *Hotel Roof;* Registration.
9:30 a.m. *Salle Moderne;* Technical sessions.
12:30 p.m. Luncheon Period.
2:00 p.m. *Salle Moderne;* Technical session.
8:00 p.m. *Georgian Room;* Fifty-Second Semi-Annual Banquet and Dance.

Thursday, Oct. 29

9:00 a.m. *Hotel Roof;* Registration.
10:00 a.m. *Salle Moderne;* Technical Session.
12:30 p.m. Luncheon Period.
2:00 p.m. *Salle Moderne;* Technical Session.
8:00 p.m. *Salle Moderne;* Technical Session and Convention adjournment.

Note: Any changes in the location of the technical sessions and schedules of the meeting will be announced in later bulletins and in the final program.

W. C. KUNZMANN,
Convention Vice-President

IMPORTANT

Hotel room reservation cards must be returned immediately; otherwise the Hotel Pennsylvania can not guarentee satisfactory accommodations on account of the recent large influx of visitors to New York.

ABSTRACTS OF PAPERS

FOR THE

FIFTY-SECOND SEMI-ANNUAL MEETING

HOTEL PENNSYLVANIA
NEW YORK, N. Y.
OCTOBER 27-29, 1942

The Papers Committee submits for the consideration of the membership abstracts of papers to be presented at the Fall Meeting that have been received thus far. It is hoped that the publication of these abstracts will encourage attendance at the meeting and facilitate discussion. The papers presented at Meetings constitute the bulk of the material published in the Journal. The abstracts may therefore be used as convenient reference until the papers are published.

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Recent Laboratory Studies of Optical Reduction Printing; R. O. Drew and L. T. Sachtleben, *RCA Manufacturing Co.*, Indianapolis, Ind.

This paper reports recent laboratory work that has resulted in marked improvements over previous 16-mm reduction print quality. Improvements in image quality accrue from exposure of the print with ultraviolet light, and from the use of reflection-reducing coatings on the lens surfaces, while speed variations are reduced by increasing printer speed to as much as twice the normal film speed. These improvements involve only relatively simple changes in commercial reduction printers.

Precision Recording Instrument for Measuring Film Width; S. C. Coroniti and H. S. Baldwin, *Agfa Ansco*, Binghamton, N. Y.

The film passes through a film gauge, one member of which is fixed and the other movable. The latter is attached to one plate of an electrical condenser. Changes of film width are translated into changes of capacitance. The electrical condenser is connected to a parallel tuned circuit which acts as a load in the screen-grid circuit of a crystal oscillator. A 0—1 dc milliammeter is connected in series with the screen grid. The circuit is tuned to some point off resonance. The dc screen-grid current corresponding to this point operation is balanced out. Therefore, any changes of capacitance will vary the screen-grid current. For a width variation of 0.250 mm the relationship between screen-grid current and film width is linear.

A continuous recording milliammeter is connected in the meter circuit. Its chart velocity and film velocity are maintained at a fixed ratio. The accuracy of the instrument is ±0.002 mm.

Some Characteristics of Ammonium Thiosulfate Fixing Baths; DONALD B. ALNUTT, *Mallinckrodt Chemical Works*, St. Louis, Mo.

A brief description of the history and nature of ammonium thiosulfate is given. Several practical formulas employing this agent are presented and their advantages discussed. Some of the differences in characteristics between the ammonium thiosulfate and sodium thiosulfate fixing baths are pointed out.

An explanation is offered to account for the apparent discrepancies in the effects of concentration on clearing time reported by previous investigators. The speed of fixation of ammonium thiosulfate is shown to be greater than that of sodium or lithium thiosulfates and greater than that of mixtures of ammonium chloride and sodium thiosulfate.

Motion Pictures in Aircraft Production; NORMAN MATHEWS, *Bell Aircraft Corp.*, Buffalo, N. Y.

The great numbers of aircraft needed in this war posed new problems in the training of maintenance personnel in sufficient numbers; every plane in the air requires that there be three to twelve men on the ground for servicing. Each branch of our armed forces was faced with the big job of training many men rapidly, not only in the maintenance of aircraft, but in every phase of modern warfare. A great share of this training job could be done by means of motion pictures.

Although the U. S. Army was producing an extensive series of training films dealing with aircraft maintenance, the Bell Aircraft Corporation believed that it, too, could help in this respect. Its service department had been in the field close to the problems of maintaining one particular type of aircraft and it was from their experience that material could be drawn for the production of training films dealing with servicing the *P-39*, the Army Airacobra.

In April of this year the motion picture division of this company was organized and production was begun on an extensive series of films, each dealing with a specific service operation. All work was to be done in 16-mm and, with the exception of the laboratory, all phases of motion picture production were handled in the division. Working closely with the service department, the details of the various operations were carefully checked for accuracy and instructional value. The small staff was organized into two crews, each alternating weekly in the writing and shooting of scripts. All phases of production on a number of films were kept moving simultaneously, with the added advantage from a working point of view of having one crew follow a picture through from the initial script stage to the final release.

Aside from being used by the Army these films were to be used by the company's service department to train a rapidly expanding personnel and to help with service training in the field. Service representatives throughout districts in the various war-fronts were equipped with small sound projectors and complete sets of these films. A broader distribution was to be effected by the Army itself, which is placing these films in all bases where these planes are in service. The success of the films in aiding the training program is evidenced by their designation as official Army training films, and further by the results of a questionnaire aimed at an evaluation of them.

Pilot training is another subject being treated in film to tie in with the Army's recently organized safety campaign. It is planned also that soon the work of the motion picture division will be expanded to include industrial training, for which there is an urgent need today in the aircraft industry with its rapid expansion and the introduction of new methods of fabrication.

The Practical Side of Direct 16-Mm Laboratory Work; LLOYD THOMPSON, *The Calvin Company*, Kansas City, Mo.

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

Direct 16-mm production calls for the reversal type of processing, the negative-positive method, and color developing. Some producers own laboratories for doing the first two, but color is processed by the manufacturer. However, independent laboratories are printing color. It is the purpose of this paper to explain how some of these processes are used in direct 16-mm production, especially when the methods differ from conventional 35-mm practices. Some of the subjects discussed are: processing originals, work prints, reversal printing, dupe negatives, color printing, control methods, special laboratory equipment, *etc.*

Sixteen-Mm Editing and Photographic Embellishment; LARRY SHERWOOD, *The Calvin Company*, Kansas City, Mo.

The paper will first discuss the essential equipment necessary to the editing of 16-mm film, with a detailed analysis of the types of commercial equipment available. Also will be included certain equipment that has been developed outside the commercial field.

The second section will concern itself with the technique and methods that have been developed and proved to be applicable to the editing of 16-mm film. This section will take up the methods of identifying film; of synchronization; of matching work print with original, both sound and photography, without edge-numbering; and the technique of preparing film for the laboratory, with particular regard to the methods employed in laying in mattes to produce dissolves, double exposures, trick effects, *etc.*

The third section will concern itself with the importance of trick effects in industrial and educational motion pictures; how trick effects might be utilized as an integral part of the educational process; and examples will be given to show how trick effects might be employed to eliminate footage, so essential to the production of this type of film.

Carbon Arc Projection of 16-Mm Film; W. C. KALB, *National Carbon Co.*, Cleveland, Ohio.

This paper summarizes the characteristics of the high-intensity carbon arc as applied to the projection of 16-mm film. It includes a description of the carbon trim, color quality of the light, magnification, optical speed, and power requirements of the projection lamp. Intensity and distribution of screen light are discussed in relation to the operating characteristics of projectors commercially available and the transmission characteristics of heat filters, shutters, and available types of lenses. Resulting screen illumination is interpreted in terms of screen dimensions and audience capacity under conditions conforming to recommended projection standards.

Laboratory Practice in Direct 16-Mm Sound-Film Production; W. H. OFFENHAUSER, JR., Washington, D. C.

In a paper such as this, it is not uncommon to find minute detail of machinery design and operation that is of little interest to any other than those who use the machinery or its product. If, however, a motion picture film laboratory is defined as but one of a series of tools necessary to accomplish the effective transmission of intelligence by means of the 16-mm sound motion picture as a communication medium, the laboratory takes on a new aspect—that of function. It is with function that this paper deals, together with its inescapable results in machinery and machinery operation.

Before our entry into the present World War, 16-mm films had been widely used for advertising and ballyhoo purposes; advertising seemed best able to supply the largest sums for 16-mm production budgets. With our entry into the war, the voices that had cried in the wilderness a decade ago for instructional and training uses of film were finally heard; the death knell for the ballyhoo film occurred "for the duration," and training films marched in to displace and overrun them. This limitation of function was a blessing in disguise; the industry was permitted for the first time to clear decks of non-essential frills and strip for action.

Direct 16-mm sound-films are generally of two kinds: black-and-white, and color (usually Kodachrome). In both cases the original picture is developed by the film manufacturer or his agents; the cost of development is included in the price paid for the film.

The sound used is scored as a sound negative after the picture is edited; it is from this stage onward that the commercial laboratory enters. In the case of black-and-white, a fine-grain duplicate (intermediate) negative is made of the picture, release prints being made from the original sound negative and the intermediate picture negative. In Kodachrome, a black-and-white fine-grain positive print is made of the sound, the Kodachrome duplicates being made from the original Kodachrome picture and the black-and-white fine-grain sound-track print.

The paper deals with procedures, and presents some of the highlights of equipment and operational techniques used in the volume production of high-quality copies.

Film Distortions and Their Effect on Projection Quality; E. K. CARVER, R. H. TALBOT, AND H. A. LOOMIS, *Eastman Kodak Co.*, Rochester, N. Y.

The three main types of film distortion are (*1*) Embossing due to differential shrinkage or hardening of the emulsion caused by local absorption of heat in the dense portions of the picture; (*2*) Fluted edges due either to stretching of the edges or shrinkage of the center; (*3*) Short edges or buckle due to shrinkage of the edges while in the roll.

Careful tests have failed to show any effect on the screen, such as in- and out-of-focus effects, due to image embossing. Measurements of the magnitude of the distortions show that these are ordinarily much less than the depth of focus of the lens. Laboratory tests as well as field experience indicate that fluted edges very rarely cause distortion of the image on the screen.

Short edges, however, produce a type of buckle which often shows in- and out-of-focus effects. This is due to the fact that short edges leave a fullness in the center similar to the bottom of an oil can. Under some circumstances this fullness causes a movement back and forth in the projector gate causing in- and out-of-focus movement. Short edges are commonly caused by loss of moisture from the edges of the film when wound up in a roll immediately after processing. When such films are placed in tin cans, the rate of loss is reduced so that moisture has time to diffuse from the center of the film to the edges and permit uniform shrinkage. A scarcity of tin and substitution of cardboard boxes makes it desirable to dry the film more thoroughly on the processing machines so as to avoid this quick loss of moisture during the storage period before projection. Trouble can be avoided also by wrapping the film in moisture-vaporproof envelopes before packing in cardboard boxes or by the use of cardboard boxes of a highly impermeable type.

Effect of High Gate Temperatures on 35-Mm Film Projection; E. K. CARVER, R. H. TALBOT, AND H. A. LOOMIS, *Eastman Kodak Co.*, Rochester, N. Y.

In a study of the effects of high temperature arcs on 35-mm motion picture film in the projector gate, high-speed Cine Kodak pictures (1400–1500 frames per second) were taken of the image of the 35-mm film on the projection screen. In making these pictures an *E*-7 projector with a Macauley Hy-candescent lamp was used and the image was sharply focused on the projection screen. A portion of this image was used as a target for the high-speed Cine Kodak so that when this Cine Kodak picture was projected one could observe the appearance of the 35-mm image during various portions of each frame. The shutters of the 35-mm projector were thrown slightly out of synchronism so that the appearance of the image as it came to rest in the gate could be determined. When the high-speed 16-mm pictures were projected, it was observed that the 35-mm image was in sharp focus during only a small part of its stay on the projection screen. After the pull-down, the film comes into the gate out of focus, and slowly moves into focus. As it moves into focus it always moves toward the lamp, as if the emulsion were expanding, thus causing the film to curl away from the emulsion. In some cases it does not come into sharp focus until after the flicker blade has passed. The above phenomena occur during all normal projections but are more prominent at higher temperatures. The 35-mm projected pictures appear to be perfectly sharp, even though the high-speed analysis shows them to be out of focus during a large fraction of their stay on the screen. If the image is in focus during the last fraction of a second before the next pull-down, it appears sharp to the eye regardless of the fact that it was out of focus during the first part of its stay on the screen.

Under certain definite circumstances, however, in- and out-of-focus effects are observed on the 35-mm screen. When these are observed, the high-speed movies indicate that the film comes into the gate out of focus, moves toward the lamp and, therefore, toward sharp focus, but before it reaches sharp focus a sudden drift toward the lens occurs. Thus the film never reaches its position for sharp focus and gives the in- and out-of-focus effect.

A further study of these effects was made by cutting away part of the projector gate so that a high-speed Cine Kodak can be focused directly onto the film in the gate. This study showed exactly the same effects as described above but, in some respects, made them clearer.

The Use of High-Speed Photography in Analyzing Fast Action; E. M. WATSON, *Capt., Ordnance Dept., Watervliet Arsenal,* Watervliet, N. Y.

Various methods and devices may be used in studying action that is too fast for unaided visual observation. In almost every set-up the following points must be considered: (1) Means must be devised for placing the image (with necessary sharpness and steadiness) on the medium where the exposure is to take place; (2) Arrangements must be made for starting and stopping the exposure; (3) Means must be devised for placing the subsequent exposures on recording material at the proper time and location to obtain the desired results.

The principal methods for studying high-speed action are the *shutter method* and the *stroboscopic method.* The former is used where subjects radiate light of themselves or reflect utility light not used to determine exposure time; exposure time is determined by the shutter. The stroboscope is used where other light does not materially interfere with stroboscopic light; exposure time is determined by the stroboscopic flash.

Whenever the subject being investigated does not repeat its motion at all or not often enough to use a stroboscopic device, it is necessary to use some form of photography for quickly recording the action for later study; when complications are not great, still cameras can be used. When a single picture is insufficient and the motion occupies approximately the same area, causing multiple images to overlap and be confused, one must resort to motion pictures. Motion pictures taken at speeds moderately in excess of the regular projection speed can be taken with an intermittent camera. When the film speeds up to about ninety miles per hour it is necessary to use some kind of device for placing the image on the film while the film is moving at a constant linear speed. If these additions are to be exceeded it is then necessary mechanically to support the film in motion or allow it to remain stationary and move the light which affects the exposure.

In any kind of high-speed photography, all the limitations of ordinary photography are encountered plus some special restrictions imposed by the high speed. As types of cameras are changed to obtain increased speed, compromises in image quality and exposure must be made.

There is opportunity in high-speed photography for anyone having only modest equipment, but many of the applications require very expensive equipment which has little versatility.

Effect of Composition of Processing Solutions on Removal of Silver from Photographic Materials; J. I. CRABTREE, G. T. EATON, AND L. E. MUEHLER, *Eastman Kodak Co.*, Rochester, N. Y.

To insure the permanence of the photographic negative or print it is necessary to remove all residual hypo and silver. The effect of composition of the processing solutions on hypo removal has been discussed in a previous paper. The factors which govern the removal of residual silver are considered in the present paper.

The retention of silver in the photographic material gives rise to a yellowing of the non-image area of the negative or print under adverse storage conditions, the stain consisting of silver sulfide produced either by decomposition of complex silver thiosulfates or the action of hydrogen sulfide present in the atmosphere on the residual silver salts.

Present practice of using a single fixing bath to exhaustion except in those cases where the concentration of silver is kept at a minimum by electrolysis does not insure the complete removal of residual silver. With films the use of two fixing baths is necessary but with prints intended for archival purposes three fixing baths are required; preferably with a water rinse between baths. Two fixing baths are sufficient for the normal processing of prints. Data on the limiting concentrations of silver in the fixing baths and the photographic materials are given.

The following factors affect the rate of removal of silver: (*a*) the *p*H of the fixing baths and the wash water, (*b*) the nature of the hardener employed in the fixing bath, and (*c*) the temperature of the wash water. Practical recommendations are given for the removal of silver to produce photographic negatives and prints for (*a*) archival storage, and (*b*) normal keeping periods.

Copper and Sulfide in Developers; R. M. EVANS, W. T. HANSON, JR., AND P. K. GLASOE, *Eastman Kodak Co.*, Rochester, N. Y.

The formation of excessive fog by a developer containing copper or sulfide is well known. However, no quantitative method for determining the concentration of either copper or sulfide in a developer appears to have been published. In this paper, polarographic methods of analysis for these substances are given together with photographic determinations of the effect of concentration on fog, thus demonstrating that the analyses are capable of determining the minimum amount of copper or sulfide required to cause fog under the conditions used.

The fogging action of a developer which has accumulated sulfide by bacterial action is shown to be the same as that produced by a fresh developer containing the equivalent quantity of sodium sulfide.

Factors Affecting the Accumulation of Iodide in Used Photographic Developers; R. M. EVANS, W. T. HANSON, JR., AND P. K. GLASOE, *Eastman Kodak Co.*, Rochester, N. Y.

Development of uniformly flashed motion picture film has been carried out in developers of varying composition and the amount of iodide, which remains in the developer, determined by analysis. The amount of iodide in the developer was found to increase under the following conditions:

(*1*) Development to a higher density.
(*2*) Increasing the footage of film for a given volume of developer.
(*3*) Increasing the time of development for the same density.
(*4*) Increasing the strength of the developer.
(*5*) Increasing the proportion of the surface covered by image.

These results are explained by a kinetic equilibrium between the rate of release of iodide from the developing portion of the emulsion and the rate of removal of iodide from the developer by the undeveloped silver halide.

BACK NUMBERS OF THE TRANSACTIONS AND JOURNALS

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

	No.	Price		No.	Price		No.	Price
1924	19	$1.25	1926	25	$1.25	1928	33	$2.50
	20	1.25		26	1.25		34	2.50
1925	21	1.25		27	1.25		35	2.50
	22	1.25		28	1.25		36	2.50
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	24	1.25		32	1.25		38	3.00

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

SOCIETY SUPPLIES

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

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

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

S. M. P. E. TEST-FILMS

These films have been prepared under the supervision of the Projection Practice Committee of the Society of Motion Picture Engineers, and are designed to be used in theaters, review rooms, exchanges, laboratories, factories, and the like for testing the performance of projectors.

Only complete reels, as described below, are available (no short sections or single frequencies). The prices given include shipping charges to all points within the United States; shipping charges to other countries are additional.

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Approximately 500 feet long, consisting of special targets with the aid of which travel-ghost, marginal and radial lens aberrations, definition, picture jump, and film weave may be detected and corrected.

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SYLVAN HARRIS, EDITOR

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RE-RECORDING SOUND MOTION PICTURES*

L. T. GOLDSMITH**

Summary.—*The nature of re-recording as it applies to motion picture production is described in some detail by showing what happens to a typical picture in the re-recording department after shooting on the set has been completed and the picture has been edited to the satisfaction of the producer.*

Sound is added to those portions of the picture that have been photographed silent because of the difficulty or impossibility of recording the corresponding sound at that time, as for example, credit titles, montages, miniatures, stock shots, and scenes photographed silent to playbacks of pre-recorded sound. Music that has been especially scored and recorded for the picture together with appropriate sound-effects is added to heighten its dramatic presentation.

Improvements in dialog quality are made if required by employing electrical equalizers, although distortion is often purposely introduced where telephone, dictaphone, radio, and similar types of quality must be simulated as required by the picture.

Proper balance of the relative volume of the dialog and accompanying music and sound-effects is determined to the satisfaction of the re-recording supervisor. All the sounds from as many as a dozen or more different sources are re-recorded to a single composite sound-track which is afterward printed with the picture to make up the final print to be projected in the theater.

The organization of the re-recording department is discussed and the duties of various members of the personnel are outlined. Crews are so made up that an average of from three to six pictures are in work at the same time.

A division of the sound department of every major film-producing studio is known as the re-recording department, sometimes called the dupe or dubbing department. In the days before sound pictures it was common practice in the laboratory, to make duplicate picture prints or "dupes," as they were called. Also, the special picture-effects department would often add foregrounds or backgrounds to a picture, a process termed "dubbing in" or "dubbing." So, in general, the duplicating process, with the finishing touches added, became known as duping or dubbing.

The sound-duplicating process, especially since it is not photographic but electrical duplicating, is more properly known as re-

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* Presented at the 1942 Spring Meeting at Hollywood, Calif.; received May 10, 1942.

** Warner Bros. Pictures, Inc., Burbank, Calif.

recording. As the name implies, sound originally recorded on film in synchronism with the picture being shot on the set, is recorded again from that film along with added sound-effects and music recordings to a second film. This film is a composite of all the desired sounds required for the picture. The composite sound-track is then printed on the same film as the corresponding picture and projected in the theaters.

Suppose we take a typical picture as an example, and follow its progress through the re-recording department. After the shooting of the picture on the set has been finished, the picture editor assembles the daily prints of picture and sound-track in proper timing and continuity. These two prints are known as the cutting picture and cutting track. The producer who is responsible for this particular production runs the picture in this form with the editor, and indicates what changes he wishes made. When the picture is complete and the corresponding original dialog sound-track is approved, the editor delivers the picture to the re-recording supervisor.

The film is received as separate picture and sound-track reels, which are close to 1000 feet long. The sound-track consists almost entirely of dialog and any sound-effects that may have happened to be recorded at the same time. The supervisor assigns the picture to one of the re-recording crews who check it reel by reel.

The re-recording crew usually is made up of a re-recording mixer who acts as the crew chief, two sound-track editors who edit the music and further edit the dialog track, a sound-effects editor who prepares appropriate sound-effects for the picture, and a projectionist. The sound-track editors usually split up the reels between them, each man taking every other reel. They check the reels for synchronism and for words of the dialog that may have been cut off because of picture cuts. These will require an overlapping of two sound-tracks in re-recording.

As the reels are run one by one, the sound-effects editor makes notes as to what kinds of sound-effects are required and where they should go into the picture. Some sound-effects are recorded especially for the scene at the time the picture is shot. When such effects are made, the production mixer sends a memorandum to the re-recording department identifying by scene and take number, the effects that have been recorded and noting where in the picture they are to be used.

The sound-track editors then run the sound-track and picture in a moviola and make notes in ink on the sound-track film, indicating for the laboratory negative cutters which scenes are to be extended, and what scenes and effects are to be removed. Additional prints of the required scenes are ordered from the laboratory, which are assembled into a secondary dialog track to allow some of the dialog sentences to overlap when it is re-recorded. At the same time, the sound-effects editor orders the required number of sound-effects prints from the laboratory, both those made at the time the picture was shot and those made from sound-effects negatives kept in the sound-effects library.

The picture and sound-track are then sent to the laboratory, where two composite sound-and-picture dupe prints are made. One of these dupe prints is sent to the music department, where it is used for checking the picture to determine where music must be scored. The other dupe print is sent to the re-recording department. The laboratory then cuts the original sound-track negative in accordance with the edge-numbers and inked instructions on the cutting sound-track, and makes a print. This may be called a primary dialog print, and is the print used in the re-recording. It is necessary to re-record from this new primary dialog track rather than from the original cutting track because in the new track certain dialog sequences have been extended or removed at the laboratory to take care of overlaps. Furthermore, the original track has become scratched from the many runnings in the picture editor's moviola, and the new track has been blooped at all splices. When the laboratory delivers to the re-recording department the new primary dialog track, the additional prints of portions of the dialog, the prints of sound-effects, the composite dupe print, and the original picture and sound-track prints, the sound-editors begin to prepare the reels for re-recording.

The sound-track editors, using the original cutting picture and cutting track as guides, prepare the secondary dialog track which will cover the overlaps in conjunction with the primary dialog track. At the same time, the sound-effects editor, using the dupe-picture print as a guide, cuts his sound-effects prints into reels to match the picture action. He may have the sound-effects on several reels because often more than one effect is required at one time. In addition, there are usually several loops of sound-effects which run all the time during the re-recording of the reel and can be mixed in as required. The loops are numbered and catalogued and consist of the more frequently used sound-effects such as laughter, applause, crowd noise, street noise, *etc.*

If the music recordings or "takes" are now available, the sound-track editor prepares the music tracks for re-recording, using the cutting-picture as a guide and following the footage notes prepared for him by the music department as to what the music selections are and where they go into the reel. Several music tracks are often required, and here again additional prints may have to be ordered to take care of overlaps in the music. As soon as a reel has been prepared either with or without all the music and effects tracks, it is run once to check for synchronism, overlaps, effects, *etc.* If no music has been received for that particular reel, the sound-track editors then set it aside and prepare another reel.

The sound-track editors prepare a cue sheet for the re-recording mixer to use during the re-recording of each reel to indicate to him where the secondary dialog and music tracks come in and go out. A similar cue sheet is prepared by the sound-effects editor for his own use when he assists the mixer in re-recording the reel. These cue sheets must be corrected as changes are made during re-recording rehearsals, so that after the re-recording is made and the sheets are filed, they will be accurate if at some later time they are used again.

When all the tracks are prepared, the re-recording mixer and the sound-effects editor, acting as an assistant mixer, proceed to rehearse the reel for re-recording. The mixer usually handles the dialog and music, and the assistant mixer handles the effects tracks. All the tracks, usually eight to twelve in number, are threaded on re-recording machines by machine-room attendants, and the speech circuits patched to the desired mixer controls on the mixer console. The projectionist who has the cutting or dupe picture to project on the screen as a guide to the mixer threads his print on a silent projector. In addition to the picture screen for watching the action, the mixers have an illuminated footage indicator similar to a veedor counter, which is used with the picture for cueing the various sound-tracks. A peak-reading neon volume indicator and theater-type loud speaker behind the screen serve as guides to the mixers as to the volume and balance of the dialog, music, and sound-effects tracks.

After a number of rehearsals, depending upon the complexity of the reel, the re-recording supervisor is asked to approve a rehearsal. If he approves, a recording or "take" is made of the combined tracks on a film-recording machine. The film is sent to the laboratory as the re-recording crew proceeds to the next reel. (It might be mentioned here that a picture is not always re-recorded reel by reel consecutively, because some reels may take longer to prepare for duping than others.)

The following morning a checking print made from the sound negative is delivered by the laboratory to the sound department. This is run by the sound director in a review room with the cutting picture. It is carefully checked for synchronism, volume, quality, balance of sounds, and quietness. If the re-recording is judged faulty in some respect, the entire reel or part of it is ordered re-recorded again. Usually the reel is satisfactory and the laboratory is notified that a composite picture and sound print of it can now be made. The laboratory first cuts the original picture negative in accordance with the cutting picture print edge-numbers, and then makes the composite print from this and the re-recorded sound negative. When all the reels have been re-recorded and a composite print made of each, the picture is previewed in a neighboring theater.

If there are changes to be made after the preview, the picture editor makes the required changes in the cutting picture and sound-track, and again delivers the affected reels to the re-recording department. Sometimes the changes are such that the previously re-recorded sound-track negative need only be cut to match the picture cut, but more often a re-recording has to be made of the sections affected, usually one or more small sections of reels, sometimes entire reels. A checking print of the new sections or reels is approved by the sound director, and the picture is either previewed a second time or is approved for making composite release prints.

In the meantime, the re-recording crew has usually received another picture and begun its preparation for re-recording in the same way. The re-recording department has several such crews so that a number of pictures can be in various stages of re-recording at any one time.

In addition to the re-recording crews that work directly on the picture there are the machine-room personnel who thread up the re-recording machines, and a man who is responsible for the recording and operation of the recording machines. Often several machine-room men and a single recordist are sufficient to handle the equipment for three or four re-recording crews. A transmission engineer, or maintenance man who sometimes is also the recordist, maintains all the electrical equipment. The mechanical equipment is usually maintained by men who care for the rest of the equipment in the sound department as well. A representative of the music department is often assigned permanently to the re-recording department who is responsible for the music cutting, and acts as contact between the two departments. A film clerk receives all incoming and outgoing film and acts as general secretary to the department.

In connection with the re-recording of a picture the re-recording department is called upon for a variety of duties other than those mentioned. Pre-recordings may be required for timing the photographed action on the set to a previously recorded song or dance number. Frequently the music recording for this has been made in sections. Perhaps a separate choir track of voices, an orchestra track, or even added tracks of trumpets, drum beats, or other effects may be needed. To permit the chorus and dancers to perform in proper tempo while they are being photographed without sound, a composite sound-track is played back to them on the set through loud speakers for timing. This track is made in the re-recording department by editing the various music tracks or parts of tracks, and re-recording them to the playback film or disk.

Timing or "tick" disks are similarly prepared for the use of the orchestra in music scoring. The ticks are made in a special machine and so spaced that when played back to the members of the orchestra through headphones the musicians will be in tempo with each other and with the action of the picture.

The re-recording department is equipped to record acetate disks at either $33^1/_3$ or 78 rpm, as in some cases songs and musical numbers are re-recorded from film to disk for talent rehearsals at home or for music-publisher auditions. Microphone pick-up facilities are available for recording sound-effects and wild lines of dialog. These can be timed by watching the picture on a screen or by following the dialog played back through headphones.

Many kinds of circuit equalizers are used to distort the quality of speech or music purposely to simulate radio, telephone, dictophone, or other types of sounds. An "echo chamber" is available to simulate voice sounds in large halls, caves, *etc.*, and to add reverberation and life to some kinds of music. Sound-tracks are often run at variable speeds to achieve special effects, particularly in cartoons.

No description has been given of the actual equipment, both electrical and mechanical, that is used in re-recording. There are many kinds of machines used for special purposes, and an adequate description of them would cover many pages. For this reason, the reader is referred to the following bibliography, which lists publications describing the equipment.

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THE CUTTING AND EDITING OF MOTION PICTURES*

FREDRICK Y. SMITH**

The Physical Aspect

Summary.—*The first part of this paper deals with the physical aspect of cutting and editing motion pictures—that is, the manner in which the film is physically handled in the process of assembling the various "dailies," "rushes," and other forms of film up to the time of release.*

The second part of the paper deals with the editorial aspect—that is, the assembling of the various shots of the picture and the importance of the proper arrangement of these shots in producing the desired dramatic effects.

Questions usually asked by visitors to a studio Cutting Room are, "What is a film editor?" "What does he do?" "Is a cutter a film editor?" In fact, questions like these are asked not only by laymen, but also quite often by workers of other crafts in the industry. No one thinks of asking, "What is a director, a cameraman, or a writer?" Their professions were known before motion pictures existed. Therefore, it seems to follow that whatever the skills and artistic accomplishments of the film editor—or cutter—they are specific for this medium of expression, and have grown out of motion pictures.

Webster's New International Dictionary gives the following definitions:

> *Cutter:* One who cuts; as a stone cutter; specif.: (1) one who cuts out garments; (2) one whose work it is to cut a (specified) thing (in a specified way), as in: *amethyst cutter, machine cutter, disc cutter, gravestone cutter, timber cutter, film cutter.*
>
> *Editor:* One who produces or exhibits. One who prepares the work of another for publication; one who revises, corrects, arranges, or annotates a text, document, or book.

Substituting the word *exhibition* for *publication*, and *film* for *text, document, or book*, we have a fairly simple yet accurate definition of a *Film Editor*.

This title appearing on the technical credit card of most motion pictures produced today refers to the person who assembles the scenes

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* Presented at the 1942 Spring Meeting at Hollywood, Calif.; received May 30, 1942.

** Metro-Goldwyn-Mayer Studios, Culver City, Calif; President, Society of Motion Picture Film Editors, 1941–42.

after they are photographed and who is invariably referred to in the industry as the *cutter*. Whereas the term film editor is more indicative of the creative nature of the work, the term *cutter* seems to imply that the process is the work of a technician who performs his duties according to the standards and regulations of this profession.

This creator-technician position, as we know it now, was a child of necessity. Mass production of motion pictures demanded a person who would keep the film assembled so that when the last scenes of the picture were photographed the producer could expect an early projection of the final total results.

With the advent of sound, film cutting became a much more involved process than it was in the era of silent pictures. In those days it may have been possible to edit a picture with a work-bench, a set of rewinds, a pair of scissors, film cement, a viewing device, and a receptacle for the film.

Since the introduction of sound, film cutting has become much more technical; and before considering the artistic phase of editing, we must first become acquainted with the mechanical side of the business. This necessitates a description of the materials with which the editor works, the tools at his disposal, and the application of these tools to the materials at hand. The tools of the cutting room consist of reels, rewinds, flanges, synchronizers, scissors, film cans, bins, racks, a splicing machine and a viewing machine (moviola).

When the positive film comes from the laboratory to the cutting room, the first operation, unless it has been done already in the laboratory, is the synchronizing of the "rushes," or "dailies," which are the terms given to the scenes taken by a producing unit the previous day. A set of synchronizing leaders is prepared, and attached to the right-hand rewind apparatus. Identification marks are placed on these "sync" leaders, giving the number of the reel and stating whether it is picture or sound-track. These sync leaders are 16 feet long, the first four feet being required for threading the projector, and the next 12 feet being necessary to permit the projector to get up to full speed before showing the picture on the screen and reproducing the sound. Four feet from the beginning of each leader a frame is marked off on both picture and sound-track for the "starting mark." The frames thus marked are placed directly opposite each other on the wheels of the synchronizer and locked in position. The cutter then now winds through the remaining 12 feet of leader, and marks off both pieces on the frame line of the synchronizer.

The closing of the "clappers" on the picture film and the sharp modulations on the sound-track recording the noise of the clappers provide the synchronizing cue. The picture reel is unrolled to the point of the first scene, where the synchronizing clappers are seen to come together, and the frame is marked. The point of the corresponding modulation on the sound-track film is also marked, and the two films are then placed in synchronism on the synchronizer and wound back to the start of the scene, where the films are cut. They are then fastened, by means of paper clips, to the leaders and wound on to their respective reels. The markings are made on the emulsion side of the film with red grease pencil, which can be easily wiped off with a clean, dry cloth without damaging the film. The use of carbon tetrachloride will greatly help the cleaning.

Sometimes the clapper marks occur at the end of the scene, usually under the following circumstances:

(*1*) When the position of the camera on the opening shot is such that it would be inconvenient to use the clappers.

(*2*) When it is necessary to avoid frightening the subject or impairing his acting ability by any sudden shock or noise (*e. g.*, an infant, or an animal).

The synchronizing of scenes when the clappers occur at the end is accomplished in the same way as described before. The clapper marks are framed; a foot of identifying slate footage is retained after the marked frame; and then the scene is wound back to the beginning of the scene and cut at the light flash. Where an interlocked start is used, or a synchronized fog mark is made, the procedure is the same, the fog marks being substituted for the clapper marks.

When all the scenes of one day's shooting have been thus synchronized and all the splices have been made, the "dailies" are projected for the approval of the producer, director, cameraman, and editor, after which they are sent to the numbering room. Here the film is put through a numbering machine similar to the machine that prints the key numbers on the negative. The sound-track and picture films are threaded on machines so that the number *000* will be printed at the "start" marks and every foot of film is thereafter numbered consecutively. The numbers are printed along the clear edge of the film on the side opposite the negative key numbers.

After the film has been numbered it is delivered to the continuity room where typists make up the continuity sheets giving scene number, description of angle and action, and the exact dialog. From the continuity department the "dailies" are returned to the cutting room, where the first and last negative key numbers of each scene, both picture and track, are written on cards which are later filed in index form. This procedure enables the assistant editor promptly to locate the trims of scenes after they are cut and filed away.

The "dailies" are now ready to be broken down. This process is accomplished with the aid of a disk or flange. The disk is placed on the rewind to the right of the operator, while the reel of action or sound to be broken down is placed on the left rewind. A ground-glass plate lighted from below is between the rewinds, so that the film may be viewed easily. The film is broken at the end of the scene, and the roll of film that has been wound upon the disk is removed from the spindle.

The film is now ready for cutting by the film editor, or it may be filed away in tins, marked with the scene number in racks or in lockers until such time as a sequence is completed and ready for a first assembly.

Omitting the editorial functions, we come to the final mechanical stages of cutting, which include the preparation and synchronization of music and additional sound-effects. These multiple sound-tracks consist of off-scene dialog, dictaphone dialog, echo or reverberant dialog, *etc.*, sounds of water lapping on a shore, croaking of frogs, chirping of crickets, motorboat sounds, *etc.* These must all be in synchronism with the picture, and built for the purpose of "dubbing" or re-recording. The splices in the sound-track are painted over with photoblack or covered with scotch tape in the form of triangles or crescents, to eliminate the noise that would otherwise occur when the sound-track is reproduced in the theater.

When the picture has been finally re-recorded and is ready for negative cutting, it is necessary for the Editor, or his assistant, to make a final check of the film, attach new standard leaders, fill in the picture with black frames and mark all negative jump-cuts unless specifically desired, and check the synchronizing numbers of each scene to the sprocket-hole code number opposite code number. All cuts not clearly obvious to the negative cutters are plainly marked, either by pen and ink, or by scratching the film with a stylus.

This, in brief, constitutes the physical handling of film, but obviously has omitted the creative aspect of the film editing.

The Editorial Aspect

Paul Rotha says, in part, "From the first days of film production until the present, most story-film technique to have emanated from Western studios has been based upon the fact that the camera could reproduce phenomena photographically onto sensitized celluloid, and that from the resulting negative a print could be taken and thrown in enlarged size by a projector onto a screen. In consequence, we find that more consideration is accorded the actors, scenery, and plot than the method by which they are given *screen presence*, a system of manufacture that admirably suits the departmental organization of the modern film studio. Thus the products of the scenario, together with the accommodating movements of the camera and microphone, are numerous lengths of celluloid, which merely require trimming and joining in correct sequence, according to the original scenario, for the result to be something in the nature of a film. Occasionally, where words and sounds fail to give the required lapses of time and changes of scene, ingenious camera and sound devices are introduced. It is not, of course, quite so simple as this but, in essentials, the completed film is believed to assume life and breath and meaning by the transference of acting to the screen and words to the loud speaker.

"The skill of the artist, therefore, lies in the treatment of the story, the guidance of the actors in speech and gesture, the composition of the separate scenes within the picture-frame, movements of the cameras, and the suitability of the settings; in all of which he is assisted by dialog-writers, cameramen, art-directors, make-up experts, sound-recordists, and the actors themselves, while the finished scenes are assembled in their correct order by the editing department.

"Within these limits, the story-film has followed closely in the theatrical tradition for its subject-matter; converting, as time went on, *stage* forms into *film* forms, and *stage* acting into *film* acting, according to the exacting demands of the reproducing camera and microphone.

"The opposite group of thought, however, while accepting the same elementary functions of the camera, microphone, and projector, proceeds from the belief that nothing photographed, or recorded on celluloid has meaning until it comes to the cutting bench; that the primary task of film creation lies in the physical and mental stimuli that can be produced by the factor of editing. The way in which the camera is used, its many movements and angles of vision in relation to the objects being photographed, the speed with which it reproduces actions, and the very appearance of persons and things before it are governed by the manner in which the editing is fulfilled."

To understand these words fully, let us go back to the beginning of the motion picture. Edwin S. Porter was working for the Edison Company in 1896 when that concern imported some pictures made by George Melies, a Frenchman. Porter studied these pictures very carefully and became aware of the tremendous effect such simple pictures had upon audiences. As a result an idea came to Porter that contained all the elements of motion picture making as we know it today, an idea that created a new art-form, a new mode of expression, working with new tools. It was the first process of using mechanical means to create emotional values. The idea was to try to tell a story with the new film medium by combining several shots or scenes in successive order, the story to be told not only through the action in a given scene, but also by the relation of that scene to the preceding and the following scenes, thus giving a coherent meaning to the whole.

Porter's first motion picture telling a story was *The Life of an American Fireman.* He found some stock material about fires and fire brigades and then staged such additional scenes as his plot demanded. These scenes, together with the stock shots, he assembled into a dramatic continuity that has become the pattern for all motion picture action stories since.

The very same method which Porter used in his *The Life of an American Fireman* is frequently used today. It is not uncommon for a studio having a good deal of stock material of some exciting event to assign a producer, writer, and film editor to build a story around this material. This pertains particularly to the cheaper action pictures. A picture was released last year that contained about 3000 feet of stock scenes, and the entire length was only 7200 feet.

Exactly what did Porter achieve? He discovered that real occurrences can be made dramatic by means of editing, that the art of the motion picture depends not upon the shots alone, but upon the continuity of shots. He discovered that the combination of shots into scenes gives a meaning that is not in the individual shots; and that a scene need not be taken in one shot. A long period of time in actual life can be shown on the screen in a short period of time, and *vice versa.*

The Life of an American Fireman contained a very significant innovation, namely, the close-up. The second scene of the picture is a close-up of a New York fire-alarm box. This was at least five years before D. W. Griffith established the close-up as an integral part of motion picture technique. Porter discovered that a film story can be made from the sum of a number of individual scenes, but D. W. Griffith developed the new technique and applied it not only to story, but also to sequence, scene, and individual shot. He found that editing enables the dramatization of the moment, that it gives perspective and interpretation. He became aware of the fact that mood and tempo could be created by the proper arrangement of scenes. He found a new technique by composing his scenes with a number of shots, each shot and scene being kept on the screen only long enough to portray the essential piece of business in its dramatic height. Without waiting for the end of a scene, he cut to the next, thus giving the whole a continuous flow and rhythm. The result, to quote from Lewis Jacobs, is that, "Not connected by time, separated in space, shots are now unified if affected by the theme. The basis of film expression has become editing, the unit of editing the shot and not the scene."

Thus the invention of editing had a great effect upon story content. The world was open, the sky the limit. Events of the moment could be put into relation to the dim past. The hero of the drama could travel to China and to the North Pole. New themes rapidly found their way onto the screen.

In *The Thread of Destiny* Griffith found another use for shots. For the first time he shot scenes not called for in the script, scenes without action, to give atmosphere and background, thus underlining the narrative and action of the story and establishing mood and motive. He introduced the extreme long shot, giving the feeling of wide space and, when the story required it, he cut to an extreme close-up, achieving a singular dramatic effect by the contrast.

In the final analysis, motion pictures are movement. Story, drama, moods, and thoughts are expressed in movement. The action is movement, the camera moves. Cutting is movement, forcing the eye of the spectator to move from one scene, one object, from one angle to another. In cutting shorter and shorter, trimming the individual shots down to the last of one essential fact, the rhythm of the movement is accelerated and the tension is led to its highest point.

To sum up Griffith's contribution to the making of motion pictures and thus to editing, Lewis Jacobs may again be quoted: "It is that the primary tools of the screen medium are the camera and the film, rather than the actor; that the subject matter must be conceived in terms of the camera's eye and film cutting; that the unit of the film art is the shot; that manipulation of the shots builds the scene; that the continuity of scenes builds the sequence; and that the progression of sequences composes the totality of the production. Upon the composition of this interplay of shots, scenes, and sequences depend the clarity and vigor of the story." Pudovkin, the famous Russian director, states: "Editing is the foundation of film art, the process of physical integration of scenes and sequences by which the film becomes a unified entity." It follows therefore that editing becomes all important. The camera, in spite of its obvious importance, becomes subordinate to the cutting process. If necessary, a film can be made from still pictures transposed to film and assembled in changing rhythm.

The camera now has the function of an observer; an observer, however, who can see an object or an occurrence from all and every side, angle, and distance. The aim of the editing is to show the development of the scene, drawing the attention of the spectator to the details and occurrences that best represent and form the meaning one wishes to give to the scene. In doing this, the dramatic tensions are created, reinforced, or re-directed. One might compare the process to the job of an announcer at a football game. He observes the game from the most advantageous point. He does not give a detailed account of all the things happening on the field; or rather, he chooses those events that give meaning to the occasion. If the action is fast and exciting, he will hurry in his commentary, speaking in fast, short sentences that give close-up impressions. If the game is slow and uneventful, he will describe the general atmosphere, giving long-shot impressions. Just as a good announcer, by selecting the outstanding happenings—the highlights of the event—can give his listeners the impression of the entire game, so the film editor, by proper choice of his material, by using the right angles for the right piece of action, will convey to his audience the strongest dramatic interpretation of the material.

This leads to the subject of rhythm. It has been said that rhythm is the skeleton of the motion picture art, to be filled out with the flesh of content. How is rhythm built in a picture? The tempo of the action can be accelerated or slowed down in the camera, and camera movements can have rhythmic values that become apparent after editing. The rhythmic effect is formed either by the footage—that is, by the number of frames of each shot in a sequence; by the sequence or changes of angle; by the changes in direction of movement—left to right against right to left, top to bottom against bottom to top, *etc.*, by the changes of size—long shot against close shot, *etc.;* or finally by any combination of these devices.

Ten years ago the Russian technique of cutting influenced motion picture production and turned attention to the importance of form and structure through editing. Directors, writers, and producers became montage-conscious—it was recognized that certain very strong dramatic effects could be achieved through editing and through montages. What is montage?

Montage, as the term is used in Hollywood, is a condensation of all the various ways of cutting, as mentioned before. The cutting is done partly or entirely in the optical printer, making it possible to show several scenes simultaneously. Condensation is here used not only in the technical, but also in the dramatic sense. A montage is a sequence in the abstract. It is the strongest form of dramatic expression motion pictures can give. It should, therefore, be used only when the dramatic content of the story demands it, and not, as unfortunately is often the case, when the writer does not know how to get over a lapse of time in the story.

Another important discovery was that editing releases the latent suggestive powers of an audience, thus making a series of pictures impressive, eloquent, and significant. In 1921, Kuleschov, a Soviet film director, proved this point with the following experiment. He took a medium close shot of a young man who was looking down at something. He intercut this shot once with a scene of a plate of food. While running this little sequence it was quite obvious that the young man was hungry. Then Kuleschov intercut the same scene with a shot of a dead man. Now our young man appeared afraid and seemed to have a guilty conscience. The audience was convinced that he had killed the man. Finally, the scene of the young man was intercut with a shot of a nude woman lying on a bed. Now it became apparent that the young man had strictly dishonorable intentions. The very same shot, used in three different ways, had three different meanings—a practical film demonstration of the power of suggestion.

By the same manner of suggestion, motion pictures actually have created their own symbolism and sign language, a language as vivid and changing as slang. The funnel of an ocean liner and the wake of a boat are sufficient to tell that the hero has crossed the ocean; the gavel of the judge indicates that the court is in session; a few shots of a radio tower convince us that the news has spread to the four corners of the universe.

And now a few words about the relationship of the editor to the members of the other crafts in the industry. In the early days the editing was done by the cameraman, the director, writer, or supervisor, or any combination of them. Next to the director, and often more than he, the writer took the most prominent part in the cutting of a picture. The reason for this is quite easy to understand if one remembers that titles had to be composed to fit the material and that they had to be spaced correctly.

As pictures became longer and more elaborate, as more separate angles were shot, and as camera technique and optics improved, film editing became a specialized job. First, the cutter merely relieved the director of the tiresome job of sorting out and splicing film. But the front office soon wanted to see the assembled picture as quickly as possible. The cutter was entrusted with the first rough cut. It was soon recognized that the editor's ability to evaluate a scene was an important faculty that directors often lacked.

Eventually the editor gave the picture its final form, strengthening continuity, progression, and logic; tightening story and plot; covering up technical mistakes and bad acting. The technical knowledge of what actually can be done by arranging various pieces of film developed into a creative ability. In the old days, a personal creative relationship existed between editor and director and writer, but as the process of motion picture making became industrialized, this relationship disintegrated. Today, in most cases, a director seldom chooses his own film editor and the editor has scant opportunity to confer with the director and practically no chance to discuss story points with the writer.

In conclusion, it will be appropriate to quote from Frank Capra, one of the foremost directors of the present time and former President of the Screen Directors Guild: "The motion picture, as a creative art, peculiarly has need for many contributors, of whom the film editor is of foremost importance. Without his sympathetic understanding of theme, his sensitive appreciation for mood, his instinct for dramatic effect, and his sense of *timing* for comedy, every motion picture would suffer immeasurably."

The writer wishes to thank two members of the Society of Motion Picture Film Editors, Herman J. Kleinhenz and Walter Stern, for their coöperation and for their permission to use some of their material in this paper.

PROGRESS IN MOTION PICTURE INDUSTRY*

REPORT OF THE PROGRESS COMMITTEE, 1940–41

Summary.—*No report of the Progress Committee has been presented to the Society since that covering the year 1939, which was published in the* JOURNAL *in May, 1940. Accordingly, the present report covers the years 1940–41. This report, like previous ones, includes the following classifications: (I) Cinematography: (A) Professional, (B) Substandard; (II) Sound Recording; (III) Sound and Picture Reproduction; (IV) Television; (V) Publications and New Books.*

The period covered by this report ends with the entrance of the United States into World War II, and during these two years the facilities of the equipment manufacturers have been gradually turned to production for the war effort. As a result there is little to report in the way of new equipment. Specialized instruments and methods developed for war photography in England have been the subject of a number of papers, particularly in the *Photographic Journal*, and a list of these is included in the final section of this report.

The Committee wishes to acknowledge especially the contributions of the following individuals and organizations: Drs. W. B. Rayton and A. F. Turner of the Bausch & Lomb Optical Company, Robert E. Shelby of the National Broadcasting Co., Inc., H. Barnett of the International Projector Corp., and Charles W. Handley of the National Carbon Co. Because of the war there have been no reports available from members abroad.

G. A. CHAMBERS, *Chairman*

F. T. BOWDITCH
G. L. DIMMICK
J. A. DUBRAY
M. S. LESHING
G. E. MATTHEWS
D. R. WHITE

SUBJECT CLASSIFICATION

(*I*) *Cinematography*

- (*A*) *Professional*
  - (*1*) Emulsions
  - (*2*) Cameras and Accessories
  - (*3*) Lenses and Surface Treatments
  - (*4*) Studio Lighting
  - (*5*) Color

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* Received August 15, 1941.

- (*B*) *Substandard*
  - (*1*) Films
  - (*2*) Cameras and Accessories
  - (*3*) Projectors and Accessories
- **(*II*) *Sound Recording***
  - (*1*) General
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- **(*III*) *Sound and Picture Reproduction***
- **(*IV*) *Television***
- **(*V*) *Publications and New Books***

(I) CINEMATOGRAPHY

(*A*) *Professional*

A short time prior to the last Progress Report the advances in motion picture films had been chiefly in the field of negative emulsions where increased speed had been combined with suitable contrast and grain characteristics. Minor additional changes and adjustments have been made in this field during the past two years but the main progress has been in the realm of positive materials which had been essentially unchanged for a considerable period of time.

(*1*) *Emulsions*.—Progress in this field started in sound recording work where fine-grain stocks were tested experimentally. Pictorial tests were made with some of these stocks which showed that the field of their usefulness was not limited to sound recording but that they could be used also for release work with an overall improvement of quality. The status of the work in this field is summarized to the fall of 1939 in a paper by Daily published in the JOURNAL in January, 1940.[1]

Following these first steps, improvements were made and new fine-grain sound and positive stocks were introduced both by DuPont and Eastman. The DuPont Company introduced the *226* type which was first used for background projection work and sound recording, and then, as further advances were possible, introduced the *225* type, fine-grain release positive, and the *230* type, a low-contrast fine-grain sound recording stock particularly designed for variable-density recording. The *228* type, master positive, carried these emulsions into this field of work. The Eastman fine-grain release positive, type *1302*, was introduced in the fall of 1940, being followed by a fine-grain sound negative for variable-density recording, carrying the code number *1370*. This latter film was first marketed in May, 1941.

The speed of these new fine-grain release positive films is about one-quarter that of the older type of positive. The new emulsions are characterized by high resolving power and image sharpness. Processing techniques and conditions have been discussed by Shaner[2] and by Wilkinson and Eich.[3] Daily and Chambers[4] have discussed the application of fine-grain films to variable-density recording.

An advance in the coating of a protective layer over the emulsion following the normal photographic processing operations was outlined by Talbot.[5] Unlike earlier coatings, this particular one is removable in an alkaline solution and the film can then be recoated, thus greatly extending the life of the film during which the emulsion itself can be kept free from scratches and abrasions.

(*2*) *Cameras and Accessories.*—Additional units of the Twentieth Century camera described in earlier reports have been manufactured and are in use. Details regarding the camera are given in the JOURNAL by Clarke and Laube.[6]

Several new, very compact slating devices have been described. These units, usually attached to the camera, provide translucent data which are photographed through the camera lens. The Twentieth Century camera includes such a device, and another has been described by Gilbert.[7]

A novel method of obtaining great depth of field has been proposed by Goldsmith.[8] In this increased range (*IR*) system a method of regional lighting of the set in synchronism with differential focusing during each frame exposure is employed. Another attack on this same problem is made in the Electroplane camera[9] which incorporates an oscillating element in the lens. This element is driven electrically over a total distance of 0.3 mm many times during the exposure of each frame.

(*3*) *Lenses.*—The use of surface-treated lenses to increase speed and contrast has become rather widespread in the two-year period, 1940–41. Firms that have either announced the provision of surface treatment in certain optics of their own manufacture, or have solicited work to be surface-treated are the following: Bausch & Lomb Optical Co., Rochester, N. Y.; General Electric Co., Schenectady, N. Y.; National Research Corp., Brookline, Mass.; RCA Manufacturing Co., Indianapolis, Ind.; Vard Mechanical Laboratories, Pasadena, Calif.

The surface treatment of lenses is carried out commercially in one of the following ways: (*a*) by chemical means in which some constituents of the glass are leached out to a certain depth below the surface, and (*b*) by physically applying a film of material of low refractive index to the glass surface. Frank L. Jones[10] describes chemical methods for optical glasses and F. H. Nicoll[11] announces a new chemical method using hydrofluoric acid. In the second method (*b*) films are applied in high vacuum, for instance, as described in U. S. Patent 2,207,656 (July 9, 1940). Both W. C. Miller[12] and RCA claim improvements in the evaporation process to increase the durability of the films. The method of surface treatment using films built up of monomolecular layers of metallic soaps described by K. B. Blodgett[13] does not appear to have been adopted commercially.

The action of films in increasing transmission by reducing surface reflection loss is discussed popularly by A. F. Turner.[14] W. B. Rayton[15] describes the application of films in projection optics and C. H. Cartwright[16] gives data on a treated camera objective. Charles G. Clarke[17] and Gregg Toland[18] relate experiences in shooting with treated camera optics.

(*4*) *Studio Lighting.*—The high-intensity carbon arc continues to be the principal light-source for color photography[19] and is being used also to an increasing degree in monochrome, where it is reported to bring out textural values and to permit the use of smaller apertures as required by increased-depth technique.[20] A number of refinements in the design of the carbon arc lamps used for set illumination have been made during the period under review, although none involves basic changes in the nature of this equipment. An important advance in this connection is the elimination of objectionable lamp noise through rubber mounting of the feed-motors, the use of an improved negative carbon, and a sound-proofing treatment of the lamphouse.[21] The use of a triple-head projector[22] has expanded the scope of background process photography for both color and black-and-white, and a new 16-mm super-high-intensity studio positive carbon capable of burning at currents as high as 225 amperes is finding considerable use in this type of work.[23] New lamp equipment[19] for use with process projection makes possible the transition from one carbon size to another with only momentary delay, as positive carbons are positioned through an automatic photronic control. This lamp will accommodate carbons from 13.6 to 16 and 18 mm in diameter with their various negative carbons. The positive feed is water-cooled. An increased amount of process slide projection is being done with the larger size biplane filament tungsten lamps made available for this purpose.[19, 23]

A trend is also reported toward the increased use of properly corrected incandescent lighting for color photography where smaller units are required, on certain types of close-ups and on small sets.[20] Daylight fluorescent lamps were also introduced to studio technique[21] where the high diffusion and freedom from glare is suited to general lighting not requiring projection.

An item of particular interest in special fields of photographic illumination is the use of the Edgerton high-speed mercury lamp,[19] which is capable of photographing a single frame in a time-interval of only $^1/_{130,000}$ second and is thus adapted to "slow-motion" photography at a frame rate determined primarily by the mechanical limitations of film movement.

(*5*) *Color.*—Experimental work looking toward the use of a 35-mm monopack-type film for original exposure has been in progress. That considerable success is being achieved was demonstrated by results shown at the Spring meeting of the Society in 1942 by the Technicolor Motion Picture Corporation.

Considerable work has been done also on the problem of producing 35-mm three-color prints from 16-mm Kodachrome originals. Several shorts produced by this method using Technicolor for the 35-mm imbibition prints have been released by Warner Bros.

(*B*) *Substandard*

(*1*) *Films.*—Agfa introduced two new emulsions in this field during the period—a 16-mm high-resolving sound recording film and twin-8-mm Triple-*S* Pan. The 16-mm sound recording film was designed primarily to improve the available quality of variable-area records but, of course, can be used for other purposes by proper selection of processing conditions. The twin-8-mm Triple-*S* Pan is a high-speed film for use in black-and-white photography in the 8-mm field.

In 1940 DuPont improved the 16-mm films that it sold by the introduction of the *321*-type which continued to carry the name of regular panchromatic reversal, and the *302*-type superior panchromatic reversal.

In 1941 the advances which had been made in fine-grain positive stocks were made available in the 16-mm field by the introduction of the *605*-type, fine-grain positive by DuPont and type *5302* fine-grain positive by Eastman.

The quality of Kodachrome images was improved by a new method of processing, as reported by Mees at the 1940 Christmas Lectures at the Franklin Institute (Philadelphia). The older method required three separate color developments on three machines, with a drying after each development. Continuous processing on one machine is possible by the improved procedure. The assigning of the three dyes to their correct layers depends upon the sensitivity of the three emulsions rather than the position of the layers in the depth of the film.

The sequence of the processing operations is as follows: (*1*) development to a negative; (*2*) exposure through the base side to red light; (*3*) development of a cyan image in the lower emulsion layer; (*4*) exposure from the top side to blue light; (*5*) development of a yellow dye image in the top emulsion layer; (*6*) development of a magenta dye image in the middle layer; (*7*) removal of the silver from all three layers; (*8*) fix; (*9*) wash; (*10*) dry.

Two sizes of color prints ($2x$ and $5x$) from miniature Kodachrome transparencies were announced in August, 1941. These were made on an opaque safety support and were exposed and processed by the Eastman Kodak Company. Commercial color enlargements for advertising or lobby display purposes were introduced at the same time. A similar type of support was used but improved color correction resulted from the use of a special black-and-white mask printed on panchromatic film from the original sheet Kodachrome. These enlargements, known as Kotavachrome, were supplied in several sizes to a maximum of 30 × 40 inches.

A new still process of color photography was announced in December, 1941, under the name "Kodacolor." It uses roll film which is exposed in the camera in the usual way. After development by the manufacturer, negatives are produced which have colors complementary to those of the original subject, and from these negatives, color prints are made on paper. The film has three light-sensitive layers, in each of which are suspended minute particles of organic compounds in which the couplers are dissolved. After exposure, the film is developed and the oxidation product of the developer penetrates the particles and reacts with the couplers, each in its own layer, to form a dye image. The printing material is coated with a similar set of emulsions. Prints are made by projection and are of the same width, $2^7/_8$ inches, regardless of the size of film used.[24]

(*2*) *Cameras and Accessories.*—The magazine-loading principle was extended to the 8-mm camera field in the Ciné-Kodak Eight, model *90*, announced in July, 1940. The magazine contains 16-mm film which is slit after processing. The magazine is suitably marked so that the user can expose it properly, running the film through the camera once, reversing the magazine in the camera, and subsequently exposing the second side.

A professional type 16-mm camera incorporating pilot-pin registration was produced by Bell & Howell.[20] While only one unit was manufactured, it has been used for commercial production. The manufacture of additional units must necessarily await available materials after the war. This camera is in every way a miniature of the well known Bell & Howell 35-mm camera.

A review of the problems related to lens design for sub-standard cameras, together with a description of various commercial lenses available, has been given by Kingslake.[25]

(3) *Projectors and Accessories.*—A non-intermittent 16-mm motion picture projector was designed by F. Ehrenhaft and F. H. Back.[26] Optical compensation is effected by means of a rotating glass prism placed between the film and the projection lens. The prism has twelve faces and the distance between opposite faces is 41.5 mm. The relation between image displacement and rotational angle of the prism is substantially linear. To prevent misalignment of the prism faces with respect to the film frames during the rotation of the prism, it is driven by the film itself.

A new line of 16-mm sound projectors identified as *F, FB, FB-25, FS-10,* and *FB-40* were introduced by Eastman Kodak Company.[27] The first three models operate on alternating or direct current while the last two operate only on a 50 to 60-cycle 100 to 125-volt supply. On all models, a governor of the electrical vibrating-reed type maintains constant sound speed of 24 frames per second. Fast rewind for all sizes of reels up to and including the 1600-ft. is provided on all models through the use of a clutch, rewind lever, and the main drive motor. Uniform speed of the film at the scanning point is assured by the use of a specially designed oil-damped, film-driven flywheel. Models *F, FB,* and *FS-10* provide 10 watts of undistorted power. Model *FB-25* has an output of 25 watts and model *FB-40* provides 40 watts. Projection lamps from 300 up to 750 watts are recommended.

An extensive study has been made of procedure and equipment specifications for 16-mm projection by a Committee of the Society.[28] This Non-Theatrical Equipment Committee recommends that projectors be selected to provide, in conjunction with the screen used, picture brightness not greater than 20 ft-lamberts and not less than 5 ft-lamberts. When screens larger than eight or nine feet wide are used, the incandescent projectors conventionally employed with smaller screens are incapable of furnishing the amount of light recommended and an arc-lamp type of machine should be employed. A new high-intensity carbon trim has been made available for this purpose.[29] The light from this combination of carbons has been modified to give a spectral quality suitable for use with colorfilm processed primarily for projection with incandescent lamps. These carbons, used in lamps especially developed for them, provide approximately three times as much light as was hitherto available for 16-mm projection.

(II) SOUND RECORDING

(*1*) *General.*—During 1940 and 1941 much attention was directed to the problems of recording and printing multiple sound-tracks on film. Control tracks of various types were developed in the laboratories and were tested in the studios under production conditions. Stereophonic recording on film was accomplished and was successfully demonstrated.

The trend toward fine-grain film continued during the past two years. The speed of fine-grain film was increased and the objectionable brown color was eliminated. Although work continued on the high-pressure mercury-vapor lamp for exposing fine-grain film, there was a growing desire to use incandescent lamps for original recording. The increased efficiency obtained by coating the recording optics to reduce reflections greatly relieved the exposure problem.

The effect of ultraviolet light on variable-density recording and printing was studied in the laboratory.[30] An ultraviolet variable-density recording system utilizing quartz lenses[31] was built and tested under studio production conditions. These tests showed an improvement in both wave-shape and frequency response. The noise level from the film was not affected by the wavelength of the exposing light.

A careful study of the noise-reduction amplifier was made,[32, 33] and the desired characteristics were expressed in terms of promptness of opening and closing, peak reading ability, and filtering. Many circuits were analyzed and the requirements for variable-area and variable-density were compared.

(*2*) *Recording Equipment.*—A line-type microphone for speech pick-up was developed by RCA.[34] It has a pick-up angle of approximately 30 degrees at medium and high frequencies and approximately 60 degrees at low frequencies. The frequency response is reasonably flat between 150 and 5000 cps. A model was sent to Hollywood for test.

ERPI developed a multiduty motor system[35] for use in (*1*) original recording on a studio stage, (*2*) original recording on location, (*3*) re-recording, and (*4*) background projection. The new system provides more power for camera motors without increase in size, more accurate interlock, and a number of accessory features which add to the convenience and reliability of operation.

RCA developed a three-layer dichroic reflector for use in photocell monitoring systems.[36] It has a transmission of 95 per cent at 4400*A* and a reflectivity of 65 per cent at 7340*A*. When placed in the light path of a recording optical system the new reflector transmits the actinic rays and reflects the rays to which a caesium photocell is most sensitive.

A new noise-reduction unit designated as *RA-1124* was introduced by ERPI.[37] This unit delivers sufficient bias current to give closure to any Western Electric light-valve circuit and will also operate the Western Electric variable-area shutter. Peak-type operation is employed and the timing is easily changed for standard or push-pull variable-area or variable-density records. (Photo. p. 144, Feb., 1942.)

A precision direct-reading densitometer was developed by Afga Ansco.[38] It utilizes a simple electronic arrangement designed to give a uniform scale over a density range of 0 to 3.0. The color-response represents a compromise between the response of the eye and that of positive film. The scale is calibrated to read visual diffuse density. (Photo. p. 167, Feb., 1942.)

Headphones having high-fidelity characteristics were offered by RCA.[39] These phones combine high sensitivity and low distortion with a good frequency response. They are comfortable to wear and are readily serviced. (Photo. p. 322, Sept., 1941.)

ERPI developed an amplifier (*RA-1111-A*) for the application of stabilized feed-back to the *RA-1061* and other ERPI light-valves.[40] The amplifier is used to obtain controlled damping of the mechanical resonance without distortion and temperature variations inherent in mechanical damping methods. Light-valves that are tuned to 10,000 cps will now produce uniform response from 40 to 8000 cps. (Photo. p. 248, March, 1942.)

The Canady Sound Appliance Company announced a new professional-type 16-mm recorder[41] built to meet the requirements of the commercial producer of 16-mm films. The recorder is provided with a rotary stabilizer of the dry type which is not affected by climatic conditions. A gaseous discharge lamp is used as a light-modulator and the output is focused on the film by an optical unit of high resolving power. Frequencies from 30 to 9000 cps have been recorded on a standard recording emulsion. (Photo. p. 208, Aug., 1940.)

(III) SOUND AND PICTURE REPRODUCTION

(*1*) *General.*—Limitations of the single-channel reproducing system were generally recognized and several methods were developed for increasing the volume range and the acoustic spread of the sound in the theater.[42, 43] Walt Disney's *Fantasia*[44] was an outstanding example of the added realism accomplished through the use of a three-channel reproducing system. This system employed four double-width sound-tracks. Three of these were used for music and dialog and one was a control-track for regulating the volume of each of the three reproducing channels. The special sound reproducer and other units of the equipment were developed by RCA in coöperation with Disney engineers.

The Bell Telephone Laboratories developed a system for stereophonic reproduction[45] from film, and successfully demonstrated it in New York and Hollywood. The system employed four variable-area sound-tracks,[46] one of which was used for controlling the volume from the other three. The three program tracks were separately recorded from three microphones spaced across the stage. Separate reproducing channels carried the output of the sound-tracks to three loud speakers having the same relative positions as the microphones. The frequency response of the complete system extended from 50 to 15,000 cps. By compressing the original recording and expanding it in reproduction, a volume range of 100 db was realized.

A sprocket-hole control-track system was developed by RCA Manufacturing Co., Inc., for switching on additional speakers for music and for regulating the volume from a multiple-speaker reproducing system. One advantage of this system is that the release print is interchangeable with standard release prints. The sprocket-hole control-track also eliminates the necessity for changing existing film standards and the obsolescence of reproducer equipment. Warner

Bros. studio has applied this system to a number of pictures[43] and are testing it in three large theaters.

ERPI developed a reproducing system utilizing a 5-mil control-track located between the sound-track and the picture. One or more variable-frequency tones are recorded on the narrow track for the purpose of regulating the volume of the sound and for switching the side speakers on and off. The advantages of this system are that it can be made to perform several functions, and the control can be operated very fast.

Projection lenses with coated glass surfaces continued to gain in popularity during 1940 and 1941. The increase in light transmission due to the surface treatment varied from 15 to 30 per cent depending upon the number of elements in the lens. Improved contrast appeared to be as important as the gain in light. New coated projection lenses were offered for sale by the Bausch & Lomb Optical Company. Also a service for coating used projection lenses was offered by RCA Manufacturing Co. Inc., Indianapolis; Vard Mechanical Laboratory, Pasadena, Calif.; and the National Research Corporation, Brookline, Mass.

Continued improvement in light-sources for the projection of 35-mm motion picture film was characterized by the appearance of a series of improved carbons giving more and cheaper light, new lamps, particularly in the "One Kilowatt" classification, adapted to supply economical white light to the smaller theaters, and a renewed interest in automatic control mechanisms for accurately maintaining carbon position.

The "One Kilowatt" direct-current lamps employ a 7-mm copper-coated positive carbon burned at 27.5 volts and 40 amperes, the low voltage being made possible through the development of a special negative carbon[47] which permits the use of a very short arc length without the development of the carbide tip obtained when earlier types of negative carbons are so operated. An a-c type of "One Kilowatt" arc also was made available,[48] operating on 96-cycle alternating current delivered by a special generator. The choice of this frequency was determined by the fact that one full cycle occurs during each 90-degree shutter opening of a standard 24-frame-per-second projector, so that the flicker ordinarily considered characteristic of alternating current arcs is eliminated.

A new 8-mm copper-coated positive carbon[49] was introduced, characterized by a 60 per cent increase in crushing strength, giving added resistance to the action of carbon clamping devices, a burning life approximately 20 per cent longer, and an increased current-carrying capacity giving 25 per cent more maximum light than that of its predecessor.

For the inclined-trim condenser-type lamps, a new regular 13.6-mm positive carbon was introduced,[50] having 50 per cent longer life with the same light as the carbon it replaced, plus a higher current capacity resulting in more light at 150 amperes than was available from the old super 13.6-mm carbon at 180 amperes. As an aid to the largest theaters, a new super 13.5-mm carbon for operation at 170 amperes has very recently been introduced,[51] giving almost 25 per cent more light than the old super at 180 amperes, and 15 per cent more than the new regular just described at its maximum current of 150 amperes.

An increased consciousness of the importance of the spectral quality of projector light-sources as they determine the color of the screen image is evidenced by the Society's participation in the activities of the Inter-Society Color Council[52] and by the interest shown in screen light color determinations.[53]

Development work with methods of arc control employing photoelectric cells and bimetallic thermostats[54] has demonstrated that automatic devices of simple construction are capable of maintaining constant the intensity, distribution, and color of the light on the projection screen. The more efficient the optical system becomes, the less the tolerance of the carbon position, so that it is anticipated that the commercial development of control devices of this type will permit a considerable advance in projection efficiency as realized in the average theater.

(*2*) *New Equipment.*—The International Projector Corporation introduced a Simplex double-film attachment.[55] This unit was designed for use with the Simplex *4-Star* sound system where separate picture and sound prints are run for reviewing purposes in studios or for showing pre-release prints in theaters. For double-film operation the lower magazine provides space for three 1000-ft reels. For ordinary sound and picture projection there is ample space in the lower magazine for a 2000-ft reel.

A 35-mm motion picture projector with improved mechanism was offered by the Century Projector Corp.[56] Greater accuracy in projection, increased operating efficiency, low maintainance, and longer life are claimed as the result of accurate design and precision workmanship. Sealed-for-life ball-bearings are used for the high-speed shafts and oil-less sleeve bearings for the low-speed shafts. The projector is equipped with a double-shutter mechanism having 67-degree blades running in opposite directions.

A coin-operated 16-mm sound movie projector was developed for the Mills Novelty Company under the trade name of *Panoram.* In a large cabinet are housed a type *RCA-PG-170* 16-mm sound-picture projector and a 25-watt amplifier which drives six cone speakers. Forced draft ventilation is used for cooling the projector as well as the amplifier. The 16-mm prints, which are treated to prevent sticking, are spliced into an endless loop and are kept in a special continuous-feed type magazine. The picture portion of these prints is obtained by optically reducing 35-mm negatives, whereas the sound-track is contact printed from directly recorded 16-mm sound negatives. Rear projection is used to permit viewing the picture on a translucent screen incorporated in the cabinet.

(IV) TELEVISION

In an order dated May 3, 1941, the Federal Communications Commission authorized commercial television broadcasting to become effective July 1, 1941. On that date one station, *WNBT*, started commercial service in the New York area; a second station, *WCBW*, began regular program service under a commercial construction permit; and several others in various cities inaugurated regular program operation under existing experimental licenses. Subsequently to that date, television broadcast service on either a commercial or experimental basis has been provided in the Philadelphia, Schenectady, Chicago, and Los Angeles areas in addition to New York City. The FCC Rules and Regulations require a minimum of fifteen program hours per week for commercial operation, and specify technical standards essentially as recommended by the National Television Systems Committee, and industry group set up jointly in 1940 by the Radio Manufacturers Association and the Federal Communications Commission to study the problems of technical standards. These standards were given in detail in a report by the Television Committee of the Society in the July, 1941, issue of the JOURNAL.

In spite of the serious handicap caused by shortages of essential materials for both receivers and transmitting equipment, commercial television has made notable progress. It is hoped that it will be able to continue in spite of the war, at least on a modest scale, so that it may be expanded rapidly when the war is over. This is in contrast to the situation in England where television was shut down completely, for the duration, on the first day of the war.

Television broadcasting is aiding in various ways in the nation's civilian defense effort. In New York City, for example, it is being utilized by the police department as a medium for giving official training to the air-raid wardens in that area, as well as to the thousands of persons viewing these official lessons on home receivers. These training programs from station *WBNT* are being re-broadcast by station *WPTZ* in Philadelphia and station *WRGB* in Schenectady for the benefit of air-raid wardens and the public in those areas. Television receivers have been installed in all precinct police stations in New York City for the training of air-raid wardens and police personnel.

At the present time, it is estimated that there are approximately five thousand television receivers in the New York Metropolitan area, four hundred in the Philadelphia area, one hundred in the Chicago area, one hundred fifty in the Schenectady area, and four hundred fifty in the Los Angeles area. Since the last report of this Committee, several notable improvements in television receiver design have been made, including the demonstration of a projection-type receiver for home use producing a picture of good brilliance on a translucent screen, $13^1/_2$ inches × 18 inches. Substantial progress has been made in circuit engineering of receivers, and prices have been reduced from the levels at which receivers were first introduced to the public. Very few receivers have been available for retail sale for six months or more, however.

Progress in television broadcasting has been highlighted by improved studio techniques and facilities and by extension of the scope of outside pick-ups. The latter has been made possible primarily by the development of the orthicon camera for television pick-up under adverse light conditions. With this camera it is possible to televise most public events (boxing and wrestling bouts, baseball games, track meets, *etc.*), using only the lighting provided for the benefit of the spectators who are present, and programs of this sort are now an important part of the regular television schedule. New compact television camera and pick-up equipment has been developed and described in the literature by both the Dumont and RCA Manufacturing Companies, that of the latter company utilizing orthicon camera tubes. New television studio plants have recently been put in operation by the General Electric Company in Schenectady and the Don Lee Company in Los Angeles, and new facilities are under construction by Philco in Philadelphia.

Television network operation has become a reality with the regular re-transmission of programs from the NBC station *WNBT* in New York, by station *WPTZ* of the Philco Radio & Television Corporation in Philadelphia. Earlier experiments in the re-transmission of *WNBT* programs by the General Electric station *WRGB* in Schenectady have also been resumed.

Two developments were announced leading toward possible solutions of the problem of providing a more comprehensive television network service. One of these was the experimental work by the Bell Telephone Laboratories on the transmission of television signals over 800 miles of coaxial cable, looped back and forth between Minneapolis and Stevens Point. The second was the experimentation by RCA Communications on the relaying of television signals by means of 500-megacycle modulated radio repeater stations. For television transmission over shorter distances (within a single city), considerable use is now being made of regular twisted-pair telephone cable circuits with special equalization.

Further progress was made in the development of large-screen television for theater use, and on May 9, 1941, a demonstration was given by RCA in the *New Yorker* Theater in New York to an audience of twelve hundred people. A 15 × 20-ft picture was shown, having a screen brightness within the range considered acceptable by the Society for motion picture theater screens. Commercialization of this development has been halted temporarily, however, by the war.

During the past year and a half there has been considerable increase of interest in color television by the method that employs mechanically rotated color-filters at the transmitter and receiver. Reports on work done by the Columbia Broadcasting System using this method have been made to the Society. Considerable experimentation has been carried on by several organizations in this country and abroad, but it is generally felt that the work on color television has not yet progressed to a point where commercial standards can be recommended.

The standards set up by the FCC on May 3, 1941, allowed for several alternative methods of transmitting synchronizing signals to the receivers, with the stipulation that the various alternatives used must give adequate performance for standard receivers. This was done to allow further study of the several alternative methods before final adoption of a single standard. The National Television System Committee of the Radio Manufacturers' Association accordingly has been carrying on tests and investigations on various proposed methods of synchronization, but at the time of writing of this report, final recommendations have not been announced.

A bibliography of important publications in the field of television during 1940–41 is given in the following section of this report.

(V) PUBLICATIONS AND NEW BOOKS

Shipment of periodicals and books from Europe to this country was slowed up considerably during 1940–41 by the war abroad and ceased entirely with the entry of the United States into the conflict, in December, 1941. Most of the English periodicals continued to be printed with good regularity.

The more notable books which have been published since the April, 1940, report of this Committee are the following:

(*1*) The Cinema Today; D. A. Spencer and H. D. Waley (*Oxford University Press, London*).
(*2*) Motion Picture Projection and Sound Pictures; J. R. Cameron (*Cameron Publishing Co., Woodmont, Conn.*), 8th ed.
(*3*) Chemistry for Photographers; A. R. Greenleaf (*American Photographic Publishing Co., Boston*).
(*4*) Movie Making for the Beginner; H. C. McKay (*Ziff-Davis Publishing Co., Chicago*).
(*5*) Color Movies for the Beginner; H. B. Tuttle (*Ziff-Davis Publishing Co., Chicago*).
(*6*) How to Make Good Movies (*Eastman Kodak Co., Rochester, N. Y.*).
(*7*) Kodachrome and How to Use It; I. Dmitri (*Simon and Schuster, New York*).
(*8*) Photographing in Color; P. Outerbridge (*Random House, New York*).

Yearbooks were issued by the following publishers:

Quigley Publishing Co., New York.
Film Daily, New York.
Kinematograph Publications, Ltd., London.
Amateur Cinema League, New York.

Abridgments, dictionaries, and compilations were issued as follows:

Abridged Scientific Publications of the Kodak Research Laboratories, **21** (1939), and **22** (1940) (*Eastman Kodak Company, Rochester, N. Y.*).
A Dictionary of Applied Chemistry; T. E. Thorpe and M. A. Whitely, 4th ed., **2** (1938) (*Longmans, Green, Ltd., London*). Contains a section on Film Manufacture by W. Clark under "Cellulose."

The Complete Photographer; edited by W. D. Morgan (*National Educational Alliance, Inc., Chicago*). A photographic encyclopedia containing about two thousand articles by authorities in various fields of photography, including motion pictures. Ten volumes, or about four thousand pages, when completely issued.

Fortschritte der Photographie, **2**; E. Stenger and H. Staude (*Akad. Verlag., Leipzig*).

American Cinematographer Handbook and Reference Guide; J. J. Rose (*American Society of Cinematographers, Hollywood*), 4th ed.

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(*1*) Streiby, M. E., and Wentz., J. F.: "Television Transmission Over Wire Lines," *Bell Syst. Tech. J.*, **20** (Jan., 1941), p. 62.

(*2*) "Groundwork Laid for Commercial Television," *Electronics*, **14** (April, 1941), p. 66.

(*3*) "NTSC Proposes Television Standards," *Electronics*, **14** (April, 1941), p. 18.

(*4*) Fink, D. C.: "Photographic Analysis of Television Images," *Electronics*, **15** (Aug., 1941), p. 24.

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Duncan, C. J., "Cine Camera Guns in Service with the R.A.F."
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Matthews, Glenn E.: "Photographic Progress during 1940."

Cartwright, H. Mills: "Photo-Engraving in 1940."
Saunders, John E.: "Progress in Apparatus."
Yule, W. H. Drury: "Colour Photography in 1940."
Cricks, R. Howard: "Technical Progress in Kinematography."
Sewell, G. H.: "Sub-Standard Kinematography in 1940."

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Mortimer, F. J.: "More about Photography's Part in the War."
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THE PHOTOGRAPHING OF 16-MM KODACHROME SHORT SUBJECTS FOR MAJOR STUDIO RELEASE*

L. WILLIAM O'CONNELL**

Summary.—*A method is described of photographing professional short subject pictures on 16-mm Kodachrome film having edge numbers and enlarging on standard 35-mm black-and-white film for the purpose of cutting, editing, and viewing in standard 35-mm studio equipment. The edited black-and-white film is used as a pilot film for cutting the original 16-mm Kodachrome for color separation negatives and the subsequent 35-mm Technicolor release prints.*

In practically all recent photographic publications whose readers are either professional or amateur, there have been many articles showing increasing interest in the possibilities of 16-mm Kodachrome film with regard to its application and success in making pictures comparable to those made on 35-mm film. Proof that comparable pictures can be produced lies in the fact that some major producing companies have already accepted a number of such short subjects made in 16-mm for release in 35-mm.

Progress in any field of endeavor, whether in sports, entertainment, manufacturing of automobiles, aeroplanes, radios, or motion pictures, is based upon the research experimentation, and achievements in the various parts of the field, which, when brought together, establish the present state of the art.

Thanks to manufacturers of 16-mm equipment and film, light weight, portable, and dependable equipment has done much toward producing 35-mm color shorts on reasonable budgets.

In the search for enhancement of the black-and-white short subject release, especially "Sport Shorts," an attempt was made to produce them in color, using the familiar bipack 35-mm camera and two-color release prints. As this added considerable additional cost, it was decided to attempt to use 16-mm Kodachrome, which since has proved highly satisfactory both as to color rendition and

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* Presented at the 1942 Spring Meeting at Hollywood, Calif.; received May 4, 1942.

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

as to cost. Furthermore, it provided for the professional cameraman and director great advantages in portability, and flexibility in making angle shots—in fact, angles that are impracticable with standard 35-mm equipment can be made with this lighter equipment, helping to remove some of the restrictions under which the picture director works in planning his angle shots.

The following describes the procedure originated by Del Frazier, of the Warner Brothers Studios, for using camera equipment and Kodachrome film in the production of short subject features to be released as standard 35-mm Technicolor prints

The *Cine Kodak Special,* equipped with 15-mm, 25-mm, and 50-mm lenses has served every purpose required and has not been found lacking in any respect. A large field professional viewfinder has been added to the left side of the camera, giving more speed and accuracy of operation and eliminating horizontal parallax.

A normal camera speed of 24 frames per second is used when recording sound in synchronism with the photography. A speed of 32 frames per second is used for photographing sport action shots to be presented with narration. For slow-motion or shots of prolonged interest, such as fast swimming, diving, and golf action, etc., a Bell & Howell *Golf Speed* camera operating at 128 frames per second is used. A third camera is carried as a cover for action while reloading magazines; an Eastman Model *K* camera with a 15-mm fixed-focus lens carried in a convenient side pocket. Precautions should be taken in selecting group cameras with regard to the relation between sprocket-holes and frame lines, which should be held to close tolerances so as to avoid frame shift when splicing and during subsequent projection.

A sturdy tripod should aways be used whenever possible, but in many instances work can be accomplished without one, giving more freedom of action. This is especially true in shots close to the ground or taken from tree-tops, or perhaps from a step-ladder. Scenes taken from fast-moving cars or motorboats can be completed in the length of time it would take to fasten down a bulky 35-mm camera. But then again one must be very careful, always holding the camera firmly against the body, and breathing very lightly.

As in all other operations pertaining to the photography of 16-mm pictures, great attention must be given to exposure, for the reason that an under- or overexposure shifts the color of the scene. In addition, it is possible that a slight loss in rendition might occur in the Technicolor print as compared to the original Kodachrome, but this is negligible inasmuch as an audience is not in a position to make a direct comparison. A Weston reading of 8 is used in most instances, but wherever there is a great percentage of deep colors, blue sky, or heavy shadows, a slight overexposure (Weston 6) gives more latitude in making separations.

An important lesson that we learned was not to work with the 16-mm film immediately after processing. When the soft-surfaced emulsion is enlarged to 35-mm size and then enlarged further to the size of a theater screen, all the scratches and finger marks become sadly obvious.

The principal advantages of editing a 16-mm film enlarged to 35-mm black-and-white are, first, the original Kodachrome needs no handling other than that required in printing the 35-mm negative and in cutting to match the 35-mm black-and-white pilot print. Second, the editor can work much faster, and with the same confidence as in regular 35-mm production; the projection of his work can be seen in any available viewing room. To cut the original Kodachrome in the orthodox manner would entail endless splicing troubles, and the required handling of the film would ruin its value for reproduction.

The enlargement of the 16-mm Kodachrome to 35-mm black-and-white is accomplished in a specially constructed optical printer in which a Bell & Howell movement is modified to take the 16-mm film, and the aperture is opened on the edge-numbered side to include the full edge figures. The image is projected through a 3-inch copying lens to the modified aperture of a Mitchell camera which gives a picture size of approximately 0.600 × 0.825 inch, comparable to the sound-film projector aperture. The edge-numbers are approximately in the position of the normal sound-track, and, of course, are not projected. The Hanovia type *AH*4 mercury-sodium lamp is used as a printing light, and the 35-mm negative is produced on Eastman Background *X* negative stock and developed to a gamma of 0.6. Subsequent prints are remarkably free from graininess and possess a very high fidelity to the original Kodachrome pictures, having been mistaken at times, for *original* black-and-white productions.

ELIMINATION OF RELATIVE SPECTRAL ENERGY DISTORTION IN ELECTRONIC COMPRESSORS*

BURTON F. MILLER**

***Summary.**—The exaggeration of sibilant speech-sounds produced when electronic volume compression is employed in sound-recording channels is shown to be a form of amplitude-selective frequency distortion, which is generated by virtue of the normal mode of operation of the compressor. The practical elimination of this form of distortion is accomplished by equalization of the compressor control-rectifier input circuit, the amount of equalization employed being proportional to the inverse average relationship between rms speech-pressure per cycle and speech component frequency.*

Prior to the development of sound systems capable of faithfully recording and reproducing signals having a volume range in excess of 35 or 40 db, it was rather generally believed that the dramatic value of sound pictures was definitely limited by the restricted volume range of the recording medium. Later, following the development of systems inherently capable of recording and satisfactorily reproducing a range of signal intensity comparable with that of dramatic dialog, it was discovered that theater reaction to such recordings was, in general, surprisingly unfavorable.

The results of a study made to determine the cause of this situation have been previously reported in this JOURNAL by W. A. Mueller,[1] in which it was concluded that the general theater auditorium noise level sets a definite lower sound level limit for the intelligible reproduction of sound, while the comfort of the theater patron appears to establish a corresponding upper sound level limit. The normal acceptable range of reproduced sound intensity levels for general dialog recording has, by these studies, been set at approximately 25 db.

In general, two basically different methods may be employed to limit satisfactorily the volume range of dialog recordings. The first of these depends upon manually controlling the relative signal levels

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** Warner Bros. Pictures, Inc., Burbank, Calif.

during recording and re-recording of the sound-track to a suitable overall volume range. The second method, which provides almost instantaneous control of signal levels and repeatedly duplicates its action on signals of equivalent energy levels, is provided by the electronic type of compressor-amplifier. A third method is obviously afforded by combining the two basic forms of control, and represents a fair example of modern recording technique.

Following the installation of electronic compressor units in all the recording and re-recording channels at Warner Bros. studios, it was consistently noted that sibilant speech sounds were reproduced with unusual prominence, occasionally being exaggerated to the point of being reproduced as harsh whistling tones when these sounds were stressed in the original speech. For a time this effect was attributed to the residual high-frequency distortion in the recording and reproducing channels, and numerous circuit developments were studied and employed to minimize such distortion. Meanwhile, the process of re-recording was severely hampered, since it was found impossible to remove the objectionable sibilance merely by introducing a suitable value of high-frequency equalization in the re-recording channel without, at the same time, producing a finished sound-track that was definitely lacking in high-frequency signal energy content.

It was found necessary, therefore, to reduce the energy content of the numerous exaggerated sibilants in each reel of sound-track prior to re-recording by manually applying a layer of semi-opaque ink over each of the offending sections of the record. This process, needless to say, was both time-consuming and costly, since it was necessary to reproduce each reel of the master re-recording print several times to permit locating the objectionable sibilants with reference to the sound-start mark, and then to "paint-out" manually the corresponding sections of track. On the average, from thirty to fifty such spots would appear in each reel of dialog track, requiring approximately two hours of work for the location and "painting-out" of these sections.

It soon became evident that all attempts to reduce the excessive prominence of recorded sibilants through reduction of high-frequency channel distortion were accomplishing almost nothing, and that the cause of the difficulty being experienced was likely due to some factor that had thus far been completely ignored.

In consequence of the above conclusion, attention was directed to the results of the several statistical studies of the spectral distribution of speech energy. Notable among these is the paper by Dunn and White,[2] outlining the results of recent studies on this subject at the Bell Telephone Laboratories. The curves and data presented in the Dunn and White paper indicate that while no single curve can be taken as universally representative of the distribution of speech energy throughout the audio-frequency band, it is nevertheless possible to arrive at statistical averages of speech-energy distribution that can, in any event, be employed to determine the probable energy relationships existing between different portions of the normal band of speech frequencies.

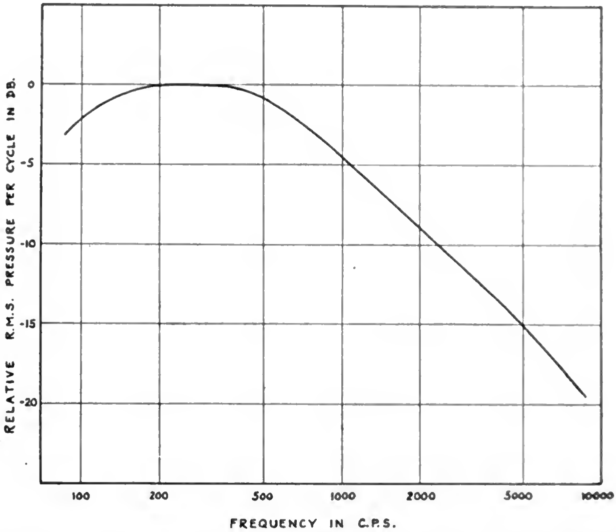

FIG. 1. Average relation between rms speech-pressure per cycle and speech component frequency.

The curve in Fig. 1 represents a "smoothed-over" relationship between root-mean-square speech-pressure per cycle, and frequency, which has been prepared from data taken from the Dunn and White paper. The averaging process employed in obtaining this curve ignores the normal differences in energy distribution between male and female voices, as well as the departures from a smooth curve that actual measurements of speech-energy distribution indicate. In view of the use that is to be made of the above curve, however, this averaging process is believed legitimate.

Assuming this curve to be representative of the relative pressure distribution with frequency for the various frequency components of each spoken work, it may, in general, be observed that the pressures corresponding to the lower-frequency vowel sounds of speech are many times higher than those corresponding to the higher-frequency sibilant sounds. Correspondingly, the low-frequency components of speech signal voltage in the recording channel will normally be many times greater in amplitude than the high-frequency components. If the total amplification of the recording channel is made an inverse function of the instantaneous signal voltage at some point of the recording circuit, as is done when electronic compression is employed, the channel amplification may be expected to be notably higher when speech sibilants are being recorded than when vowel sounds are traversing the recording system. Such a condition gives rise to a form of amplitude-selective frequency distortion, which will be incapable of correction by any straightforward process of signal-frequency equalization during reproduction of the sound record.

This situation may, perhaps, be clarified somewhat by a simple analytical treatment of the several factors involved. In a normal amplifier system the overall amplification may be defined as the ratio of the amplifier output voltage E_o to the amplifier input voltage E_o. This ratio may be a function of signal frequency, but throughout the working range of signal input levels, is independent of signal voltage. Presuming the amplification to be made independent of frequency as well, the ratio of amplifier output to input voltages may be expressed as

$$\frac{E_o}{E_i} = u_a \qquad (1)$$

where u_a is a constant.

In the case of the electronic compressor, however, the amplification obtained is purposely made a function of a tube electrode control-voltage e_c. This control-voltage is normally derived by rectifying a portion of the compressor output voltage, which is then so applied to the amplifier tubes that the expression for amplification through the compressor generally takes the form

$$\frac{E_c}{E_i} = \frac{u_c}{(e_c)^m} = \frac{u_c}{(k_1 E_o)^m} \qquad (2)$$

where u_c and k_1 are constants, and where the exponent m varies from approximately zero at low values of E_o to a positive limiting value approached as E_o assumes progressively higher values.

Solving eq. *2* for the ratio E_o/E_i in terms of the input voltage E_i,

$$\frac{E_o}{E_i} = u_e(E_i)^n \tag{3}$$

where u_e is a constant, and $n = -m/(m + 1)$. A curve showing the actual relationship between compressor amplification and input signal level at constant frequency for the compressors employed at Warner Bros. studio is shown in Fig. 2, the amplification being expressed in decibels rather than in the arithmetical ratio employed in eq. *3*. It will be noted that throughout the greater portion of the compression range of input signal levels, the exponent n employed in eq. *3* would correspond to approximately -0.5.

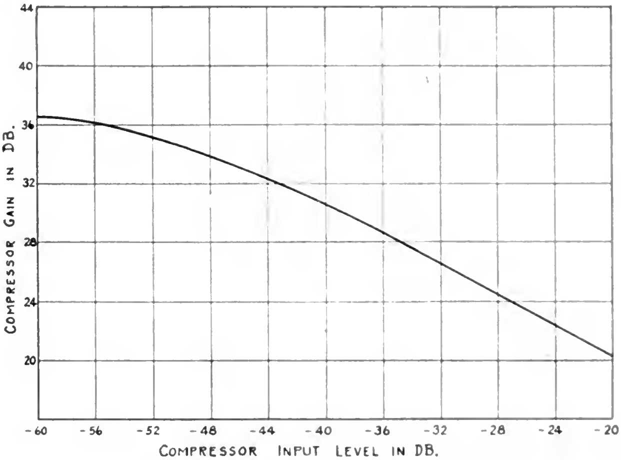

FIG. 2. Relation between compressor amplification and compressor input signal level. Reference level employed is 6 mw.

Returning to consideration of the expression for compressor amplification, let it first be noted that the compressor input voltage corresponding to a speech signal may be written as

$$E_i = A\sigma(f) \tag{4}$$

where A is a constant for any single word, and where the function $\sigma(f)$ expresses the relationship between probable speech-pressure per cycle and frequency as given by the curve of Fig. 1.

Combining eq. *3* and eq. *4*, the compressor output voltage is given by

$$E_o = u_e(E_i)^{n+1} = u_eA^{n+1}[\sigma(f)]^{n+1} \tag{5}$$

In this equation the factor A^{n+1} indicates that the amplitude of the compressor output signal is a non-linear function of the input signal amplitude, and is indicative of the fact that amplitude compression may be obtained. On the other hand, it is also evident that the normal spectral distribution function $\sigma(f)$ has been distorted to the new distribution function $[\sigma(f)]^{n+1}$. It is this latter distortion of the compressed signal that is, in general, responsible for the excessive prominence of speech-signal sibilants in the recorded signal. A simple example may serve to indicate the relative magnitude of this distortion.

Assume that the word *say* is to be recorded. If the predominant frequency[3] of the sibilant *s* is assumed to be approximately 6000 cps, while that of the vowel *ą* is taken as approximately 500 cps, reference to Fig. 1 and eq. *4* indicates that the probable amplitude of the signal delivered to the compressor input terminals which corresponds to the *s* sound will be approximately 15.5 db lower than that corresponding to the *a* sound. Assuming a value $n = -0.5$ for the exponent in the compressor output-voltage equation (eq. *5*), the signal corresponding to the *s* sound at the compressor output terminals will be only 7.75 db lower in amplitude than that corresponding to the *a* sound. In other words, the *s* sound has been exaggerated 7.75 db relative to the *a* sound.

A clue to the method of correcting the distortion just described is offered by the form of eq. *2*. Let it be assumed that before the compressor output voltage is delivered to the compressor control rectifier, the portion of the output voltage employed for control purposes is equalized to the form

$$E_o' = \psi(f)E_o \tag{6}$$

where the form of the function $\psi(f)$ is as yet unspecified. Substituting eq. *6* for E_o in the right-hand member of eq. *2*, and solving for the ratio E_o/E_i, one obtains

$$\frac{E_o}{E_i} = u_e(E_i)^n[\psi(f)]^n \tag{7}$$

Substituting eq. *4* in eq. *7*,

$$\frac{E_o}{E_i} = u_eA^n[\sigma(f)]^n[\psi(f)]^n \tag{8}$$

If, then, we set

$$\psi(f) = \frac{k}{\sigma(f)} \tag{9}$$

k being a constant, the right-hand member of eq. *8* is independent of the normal frequency distribution of speech energy.

Electrically, the correction implied by eq. *9* is obtained by inserting an equalizer between the compressor output terminals and the control-rectifier input circuit, the loss-characteristic of this equalizer being designed to vary with frequency according to the inverse of the pressure-frequency distribution curve of Fig. 1. A schematic diagram of the modified compressor circuit is shown in Fig. 3.

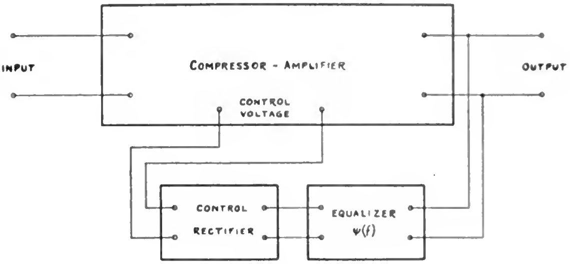

FIG. 3. Schematic diagram of modified compressor circuit.

In conclusion, it may be stated that recordings made with the modified form of compressor are singularly free of any tendency toward exaggerated sibilance, yet exhibit a normal brilliance equivalent to that obtained during reproduction of normal uncompressed recordings.

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CURRENT LITERATURE OF INTEREST TO THE MOTION PICTURE ENGINEER

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

Acoustical Society of America, Journal

14 (July, 1942), No. 1

An Absolute Pressure Generator and Its Application to the Free-Field Calibration of a Microphone (pp. 19–23)	W. J. Kennedy and C. P. Boner
Sound Power Density Fields (pp. 24–31)	J. H. Enns and F. A. Firestone
Perturbation of Sound Waves in Irregular Rooms (pp. 65–73)	R. H. Bolt, H. Feshbach and A. M. Clogston
Experiments with the Noise Analysis Method of Loudspeaker Measurement (pp. 79–83)	B. Olney
American Standard Acoustical Terminology (pp. 84–101)	
American Standard for Noise Measurement (pp. 102–110)	

American Cinematographer

23 (Sept., 1942), No. 9

More Realism from "Rationed" Sets? (pp. 390–391, 430)	P. Ferguson
Sound-Recording Methods for Professional 16-Mm Production (pp. 392–393, 427)	J. A. Larsen, Jr.
Film Conservation and Substandard Film (p. 407)	

23 (Oct., 1942), No. 10

16-Mm Gains in Studio Use (pp. 442–443)	W. Stull
Shooting Action Movies from a Gunstock Mount (pp. 444, 453)	K. O. Hezzelwood

British Kinematograph Society, Journal

5 (July, 1942), No. 3

The Soviet Film in Peace and War (pp. 65–76)	I. Montagu
The Optical Printer and Its Applications (pp. 77–86)	T. Howard

The Combined Services Film Studio (pp. 87–90)	
Educational Screen	
21 (Sept., 1942), No. 7	
Motion Pictures—Not for Theaters (pp. 259–261, 264), Pt. 39	A. E. Krows
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Colour and Stereoscopic Television (pp. 96–97)	
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Amplitude, Frequency and Phase: Modulation Relations (pp. 48–54)	A. Hund
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Communications	
22 (Aug. 1942), No. 8	
Recording Standards (p. 20)	
International Photographer	
14 (Sept., 1942), No. 8	
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Cinecolor Enlargement from 16-Mm Kodachrome (pp. 10–11)	W. T. Crespinel
Conservation of Film (pp. 12, 16, 18)	
International Projectionist	
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Role of Projectionists in the U. S. Navy (pp. 10–11)	
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17 (Sept., 1942), No. 9	
Innovation Ends Buckling of Film (pp. 7–8)	L. Chadbourne
Review of Projection Fundamentals. Pt. V, Necessary Formulas (pp. 11, 18–21)	
Underwriters Code as It Effects Projection Rooms (p. 16), Pt. V	

Motion Picture Herald

148 (Aug. 29, 1942), No. 9

British Educational Film Expanding Despite War (p. 43)	A. FLANAGAN

Motion Picture Herald (Better Theaters Section)

148 (Aug. 22, 1942), No. 8

Simplified Tests for Determining Efficiency of Projector Shutters (pp. 20–23)	C. E. SHULTZ

RCA Review

6 (Apr. 1942), No. 4

Low-Frequency Characteristics of the Coupling Circuits of Single and Multi-Stage Video Amplifiers (pp. 416–433)	H. L. DONLEVY AND D. W. EPSTEIN
A Discussion of Several Factors Contributing to Good Recording (pp. 463–472)	R. A. LYNN

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

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

JOURNAL OF THE SOCIETY OF MOTION PICTURE ENGINEERS

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JOURNAL OF THE SOCIETY OF MOTION PICTURE ENGINEERS

SYLVAN HARRIS, EDITOR

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THE NAVY'S UTILIZATION OF FILM FOR TRAINING PURPOSES*

WILLIAM EXTON, JR**

Summary.—*The use of training films automatically achieves standardization of instruction, and helps to take the place of many men, formerly instructors, who are now needed at sea.*

The production of such training films requires thorough understanding of the subject matter of the films, and its application in practice. Furthermore, one must be acquainted with the kind of men to be taught by the films and the facilities available for teaching them.

The development and use of such films in the Navy has advanced greatly during the past six months, and has covered a vast variety of subjects.

When I had the pleasure of addressing this organization in Hollywood last May, I told you something of the part that the motion picture was beginning to play in the training of men for the navy. The situation at that time was briefly this: The navy was, and still is, faced with an enormous expansion program, requiring that hundreds of thousands of men be converted almost overnight from landlubber civilians to man-o-war's men, mechanics, and technicians, for our rapidly growing fleet, air arm, and other naval activities. A large proportion of these men had to be given special skills so that they can handle the complicated and exacting apparatus and equipment of our modern ships and planes.

All this training must be done when the number of officers and skilled men who are available for instruction purposes is reduced to an absolute minimum by the needs of our fleet for all possible skilled personnel. Further, all this instruction must be carried out as hundreds of separate, individual activities, with consequent danger that the differences in the teaching at each activity may result in

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* Presented at the 1942 Fall Meeting at New York, N. Y.; received October 27, 1942.

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

considerable lack of efficiency when the men are assembled for duty at sea. Adding to these difficulties is the fact that modern war, being almost entirely technological, involves changes and developments in techniques to such an extent that an instructor who may be fully up to date at any given moment is likely to be behind the times shortly thereafter.

The motion picture training film, under these circumstances, offers many of the essential advantages required to solve these problems. The films can be produced under the supervision of experts in each subject, so that the highest and most recent standard of information is included in each film. The use of the same films at all activities concerned automatically effects standardization of instruction. Furthermore, to the extent that these films supplement personal instruction, they take the place of many valuable men, at present instructing, who are required at sea; and the films should thus provide a necessary supplementation for the teaching staff that is available. The training films could be utilized also to keep all techniques up to date, and to correct or adjust techniques as changes are made through experience and development.

You will note that we are concerned with a training program that was and still is an emergency rather than a routine program; and that the training film offers special advantages in the overcoming of the adverse factors of this great emergency.

The last time I spoke to you there was a great deal of excellent work already being done in the use of motion pictures for training purposes. At the beginning comparatively few films had been produced specifically for naval training purposes, and comparatively few training activities had become habituated to the use of motion pictures for training purposes and accustomed to using films in their training.

It is nearly six months since that time. The development and use of motion pictures for training purposes in the navy has advanced mightily during these past six months. I spent a part of this time at sea aboard a destroyer and was myself surprised at the advances made, even though I had participated in planning many of them. Many more films have become available for training purposes. Many training activities, and many officers concerned with training, have become aware of the possibilities in the use of training films and have adapted them to their purposes and needs. I am informed that we now distribute about 2000 separate titles, to more than one thousand activities. It is the rule rather than the exception today that officers given command of ships, not yet in commission, are urgently requesting that they be provided as soon as possible with the training films and projectors with which to prepare their crews for the duties to come. The medium of the motion picture training film has thoroughly sold itself and is well established in its usage in the navy.

Thousands of people are now familiar with the application of motion pictures for training or educational purposes who never dreamed of this until the war brought it into general use. You will recall that I predicted last May that the educational functions of motion pictures would some day exceed in importance and value their entertainment function. I can reiterate that prediction today with a great deal of support; for outstanding educators have said to me earnestly and with an intensity approximating that of the ancient mariner, that the Navy's development of training films will have repercussions in civilian life after the war that no one today can estimate.

Responsible and leading educators predict that the introduction of the motion picture to the extent now achieved will undoubtedly have a profound effect upon education in the future. The Navy is interested, of course, only in developing motion pictures for its own special purposes. The fact that such a development may, however, have its influence upon other developments for other purposes can not be denied, and it is not unfitting that this should be examined at this time.

Some of you may recall that I took considerable pains to point out that the use of the motion picture for training purposes had in common with the use of the motion picture for entertainment purposes only the fact that both are made with cameras, on film; and are projected on screens in the same manner. I am firmly of the opinion that the *arbitrary* introduction into the training film of the paraphernalia of the entertainment motion picture—such as the use of introductory and incidental music and other entertainment devices—results in distraction and frustrates the purpose of the training film. This has all too often been done merely because of habits developed in the making of entertainment film, and results in inclusion of material that has no proper place in a film intended to impart understanding to persons with a serious interest in the subject. I labored this point at some length because at that time there was very little appreciation of the principles expounded. Since that time, I am very happy to say, there has been a much wider realization of the fact that the training film is a training film and not an entertainment film. Where once it was common to see a training film intended to teach the workings of a lathe, or riveting machine, for instance, open and close with music and have a musical background for the announcer's voice, that is now exceptional, and is generally the earmark of the newcomer in the field of the training film. It is not that the training film scorns the devices of the entertainment film, but rather that any such device must be utilized only functionally—that is, when it is useful for a training purpose, and not merely when it is entertaining, and therefore distracting.

The Navy—and along with the Navy, the many companies that are producing films for us—is learning a great deal about the development of this medium for training purposes. One of the important developments within the Navy itself is the assignment to the many training activities of officers who are specialists in the utilization of motion pictures. These experts in visual aids guide instructors so that they may get the best results from the use of the many visual aids increasingly being made available.

One of the most interesting things about the development of the training film and in envisioning the future of this development, is the concept of the changing, indeed, the ever rising, standards. There are standards for the training film existing today in the minds of certain individuals that are considerably higher than any actual attainments to date. There are officers of the armed services who have spent literally thousands of hours looking at training films collected from many different sources. They have seen English, German, Russian, Japanese, Canadian, and other training films as well as those of our own Armed Forces and many developed by educational organizations and by private industry. They have been faced with numerous problems involving the development of visual aids for specific purposes. They have seen these individual projects developed, and they have viewed the final products. They have evaluated these products in terms of actual use for the purposes intended. They have seen many efforts to produce training films made by persons who had distinguished themselves in the production of motion pictures for entertainment. And they have been able to see the obvious shortcomings, for the purposes intended, of many of these efforts. They have listened to innumerable ideas, theories, and proposals from many sources. As a result of all this there has been built up a very definite consciousness on the part of many of those now connected with the armed services, of what is required in a general way and frequently in a specific way, if a film is actually to succeed in serving a valuable purpose. In connection with any given training problem in the solution of which films are to play a part, we have learned the necessity of organizing the material for maximum assimilability. We have learned the need of exploring in its every aspect the function to be performed by those who are to be trained. We have been conscious of the fact that we must often provide for the pedagogical effect of repetition—not necessarily for repetition within the film itself, but the film must sometimes be planned so that it can profitably be repeated. No element in it must seem to deteriorate on repetition. The successful training film must be a very skillful and effective blend of intelligent pedagogy (which applies the teaching methods proper to the presentation of the subject), of technical knowledge (which insures that the subject-matter presented is accurate and effective), and of good production (so that the film will do complete justice to both the pedagogical and technical elements).

Generally speaking, in planning a film it is necessary to have a pretty fair idea of the subject to be taught. It is just as necessary to have a good understanding of the application of that subject to the service for which it is intended. Then one must have a knowledge of the kind of men who are to be taught, and the facilities that will be available for teaching them; that is, the general conditions under which the film is to be utilized. On the basis of an appreciation of these four factors, it should be possible to plan the production of a training film that will be accurate in content; designed to be understood by the men for whom it is intended; and convey to them in a manner justifying the use of the medium, the information that it is necessary that they should have.

The fault in many of the training films that have already been produced too often lies in the omission or abuse of one or more of these factors. A film may be technically correct but badly produced; or its pedagogy may be effective for the more intelligent person but poor for those who have not had much education. There may be excellent pedagogy but poor technology, or excellent technology with poor pedagogy. In a few cases good pedagogy plus good technology have been ruined by bad production. In the production of films there are often several elements of production. For instance, many of our training films are composed partly of animation and partly straight photography. In some cases the animation is excellent but the photography fails in its purpose. In others the photography is excellent but the animation does not do all that might be expected of it. Sometimes much footage is wasted on a sequence that could be handled as well or better by the use of film strips.

The use of the commentator—the monologue of explanation—is extremely common. It is possible that great advances will be made in the effective use of the voice of the commentator, and in the technique of such comment. There is little appreciation of the part this element plays in the total effect.

The use of acting, of dialogue, for training purposes has, of course, been highly developed. When well done and when done with an understanding of the purpose, it can be invaluable. There is, however, a tendency, especially on the part of those who have made film for entertainment, to abuse this element by overemphasis, thus introducing all sorts of distracting elements.

When we speak of training films we mean films covering a very large variety of subjects and also even of interests. We usually, among ourselves, specify the major purpose of the film, indicating whether it is a film of purely technical instruction, such as *Forming Sheet Metal*, or whether it is an indoctrinal film intended to provide general familiarity with a subject rather than specific knowledge to be utilized. It may be specific visual education, such as the many films that have been made on identification of ships and planes; or it may be a film that is shown for its general effect, such as some of the inspirational short subjects that have been produced for general popular distribution.

The production of each kind of training film involves, of course, problems that the other types may not present. Individuals who may be eminently fitted to produce a film of one kind may not do very well with another. There is a growing tendency for persons who are charged with the production of films for technical training to attempt to include a psychological or inspirational introduction, showing the importance of the job to be learned and its place in the total war effort. There is much logic in this; for instance, a man who must be instructed in the duties of a lookout should be impressed with the importance of his function. However, a person skilled in technical presentations may not do as well with the less tangible subjects, and this is, perhaps, another example of the need for integrated collaboration.

In general it may be said that the production of a training film requires a coördination of essential creative elements that is rather difficult to attain. It is rarely that all these elements can be found in one person. Lacking such an unusual individual, it is necessary that these elements be found in several persons, who can coöperate effectively and successfully. Lacking such coöperation, the film produced will be deficient, and will to a greater or lesser extent fail in its purpose.

One of the most interesting of creative developments occurs in the kind of coöperation that various individuals have been giving one another in the production of training films. As this type of cooperation is developed and as those who are outstandingly capable of contributing certain essential elements come more and more to realize the necessity for simultaneous contribution by other persons in the interests of achieving best ultimate results, we may look forward to the realization of many of the standards now merely visualized. The realization of these standards will constitute the blazing of a trail which should have an invaluable effect upon the production of training and educational films for civilian purposes. In addition, many films being produced for the Armed Forces have application to civilian purposes, and plans are afoot to make such of them available as need not be withheld for reasons of security. As these films come to be widely shown, it is likely that they will have the effect of stimulating civilian demand for the production of such films.

The many commercial producers now working with the Navy will have had invaluable experience that may enable some of them to help fill this demand satisfactorily. There is no question in my mind that we are actually dealing with the early stages of development of an educational medium that will truly revolutionize life. When every crossroads school can have the benefit of the direct application of educational materials and methods, and even actual instruction created by the best qualified talent instead of relying entirely upon the local teacher, there will undoubtedly be effected a change in the effectiveness of education, the results of which can not be foreseen.

It is possible and even probable that the educational film will be used to condition children in early life to conduct themselves among their fellows and their elders in such a way as to predispose them for successful and effective living in the kind of democracy whose future we are defending.

The technology of the motion picture, the engineering aspects, the physics, chemistry, and even the economics of the motion picture, are already well advanced. The motion picture has been able to dominate the field of entertainment, a universal and important field previously reserved for a comparatively few talented individuals as to performance, and for a comparatively few urban centers as to enjoyment. But the application of the motion picture to the inculcation and dissemination of ideas and to the imparting of specific knowledge and techniques is in its early infancy. The Armed Forces have, through force of circumstance, the privilege of bringing its development to a much higher point than any previously attained. Their contribution to the development of this medium may well be regarded in the future as one of the important results of the war.

THE UNDERGROUND MOTION PICTURE INDUSTRY IN CHINA*

T. Y. LO**

Summary.—*Motion picture production carries on in China under the most hazardous conditions of war. The industry has literally had to go underground. As protection against the Japanese bombings the laboratories and editing and storage compartments are built in tunnels as deep as thirty feet below the surface. At the alarm the equipment and portions of the sets and props are carried into the dugouts. Actors and directors go on with their rehearsing, while editors and cutters continue with their work to the hum of the approaching raiders. Thus production today in valiant China.*

The motion picture industry today in China is carried on in dugouts. The motion picture industry is a modern industry, and bombproof dugouts are even more modern. But before we look at the modern aspect of the Chinese motion picture industry, first let us go back two thousand years.

Those were the days before electric lights. In the market square after sundown, someone had put up a screen of white cloth stretched across two bamboo poles. Behind it, a bright oil lantern burned, throwing its light upon the screen. A crowd began to gather to watch the spectacle. Music started, and on the screen shadows appeared—shadows of puppets, images of scholars, warriors, and women. A play was enacted. The puppets were skillfully manipulated by hand, and because they were made of translucent colored material, they looked very lifelike and real.

That was the ancient Chinese "screen show." Today we may well regard such a show as good enough only for children, but in those days and for the succeeding centuries up to the beginning of the Twentieth, these shadow shows, together with the stage plays, held

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** Deputy Chief, Film Section, Political Department, Military Affairs Commission, Government of the Republic of China.

the field of popular entertainment in China. The ancient Chinese were very proud of this all-action-dialogue-singing-dancing-music-and-color screen show. Two thousand years later, we moderns are still struggling with the problems that our forefathers imagined were completely solved.

Now, we take a gigantic leap from 100 B.C. to the first decade of the Twentieth Century. The first cinema theater in Shanghai was opened by a Spanish showman in 1909. The moving picture novelty took China by storm. The Chinese called the shadow show "lantern shadows." Now, by substituting an electrical contraption for the oil lantern, we introduce the fascinating motion picture. So, in the image-suggesting language for which we Chinese are famous, we call the modern motion picture the "electric shadows"—*tien ying*—which is still the Chinese name for present-day motion pictures.

From 1931 to 1936, China was in a period of transition. The struggle for independence and for freedom from the shackles that the train of unequal treaties since the Opium War had put on the Chinese nation was still in progress. But above the horizon, another menace was rising. Japan, jealous of China's natural resources and her growing unity and power, had decided to carry out her plan of continental and world conquest. In 1931, she had occupied Manchuria. Stimulated by this unwarranted attack, Chinese nationalism rose to immense proportions. Reverberations were sounded in the motion picture world. Film stories produced in China during that period mostly reflected the spirit of the Chinese people, who fought against aggression on the one hand, and sought to rebuild the country into a new nation on the other.

Two films stood out during that period—*The Fisherman's Song*, directed by Mr. Tsai Chosheng, and *The Road to Life*, directed by Mr. Sun Yu. Both were imbued with the spirit of protest against oppression, and everywhere in the country they were greeted with rousing welcome. They were shown continuously for two months in Shanghai and broke all box-office records both for Chinese and imported films.

More and more films have been brought into China, including Soviet films. Two schools of critics arose with regard to American and Soviet films. One maintained that the Soviet film, with its serious theme, treated in a powerful style, is the height of cinematic art; while the other argued that since the movies are primarily for entertainment, the American films, with their gaiety, liveliness, and forwardness in style, are more universal in appeal.

Before the advent of the talkies there were about twenty motion picture companies in China. With the introduction of the sound picture a process of absorption and amalgamation began, until finally only five held the field, with a number of independent producers attaching to one or another of these. By 1933, the government had also set up several studios—the Central Studio, The Educational Film Studio, and the China Film Studio; the last to become later the China Motion Picture Corporation. A Visual Education Committee was also organized by the Ministry of Education to promote popular education through the medium of the cinema.

Prior to the outbreak of war in 1937, there were 375 cinema theaters in China, mostly concentrated in cities along the coast. This figure includes nearly a hundred theaters opened farther inland between 1936 and 1937, during which period there developed a tendency for the cinema to spread to the interior. At the same time, the Visual Education Committee of the Ministry of Education began to put the 16-mm silent films to extensive use. Two hundred 16-mm projection units were set up at various places throughout the country. The Political Department of the Military Affairs Commission organized mobile cinema units, showing films not only to the troops, but to the people in the villages and towns where the troops were garrisoned.

For the production of films, the companies imported foreign-made cameras, mostly from the United States, but small machines and equipment, such as lighting equipment, rewinders, splicers, and printers, were sometimes made in the studio workshops and other machine shops. In 1931, a recording machine was invented called the *tien tung*, and later another machine came into use, called the *chunghua tung*. In both, the variable-density system with the glow-lamp was used. The whole idea is to make the machine into an easily portable one. In 1935, an engineer in the Central Studio completed a machine for developing films. Besides these, many factories and machine shops in some coastal cities also made amplifiers and spare parts for sound projectors. The China Film Studio in Hankow built sound stages based on the latest models. It is reported that the Japanese have now turned these sound studios into stables.

Now we pass to the next stage in the history of the Chinese movie industry. At the end of 1937 the Chinese Army, having withstood for three months the violent onslaught of the Japanese invading forces, started to withdraw from Shanghai. With that withdrawal began one of the greatest migrations in all history. Slowly but steadily, the human stream moved west, first to Nanking, then to Wuhu and Hankow. Amidst this great migration were fifteen hundred people of the motion picture industry of Shanghai. These included producers, scenarists, directors, actors, actresses, technicians, and studio hands.

These people joined the government studios, one of which, the China Film Studio, moved to Hankow where it organized film production shock units devoted exclusively to war films. In four months these shock units completed eleven features and over forty short subjects. Another government studio, the Central Studio, was less fortunate. In its hasty withdrawal from Wuhu, which was very near Nanking, a large amount of its equipment was lost; so it was compelled to travel to Chungking where it could be safe from enemy bombings, and settled down for rehabilitation.

In the fall of 1938, Hankow itself was threatened and the last stage of the migration began. Three months before, preparations were already underway in the China Film Studio for the removal of all equipment to Chungking. Systematically, everything that could be carried away was transported up the river Yangtze, either by steamer or on barges. It was winter and water was low in the Yangtze. Wherever the currents ran too swiftly, the studio staff had to go ashore and help the boatmen drag the barges upstream by ropes.

It was in Chungking that the Chinese movie industry entered the dugouts. Although we are movie people, we had not gone to the length of building this subterranean show simply for the romantic ring of its name. It was done of necessity. All the headaches, heartaches, and backaches would have been for naught if within the hour the savage mass bombings of the brutal Japanese had reduced everything to ruins.

Now let us see this strangely located industry in action. Of course, not all the work is done in the dugouts. The sound stages, for example, are on the ground surface. But the laboratories, and editing and storage compartments are built in the tunnels which in some parts reach as far as thirty feet below ground. As soon as an air-raid alarm is sounded, things start to move. Studio lights, cameras, sound equipment, even portions of studio sets and important "props," are carried down into the dugouts. Once there, work is resumed.

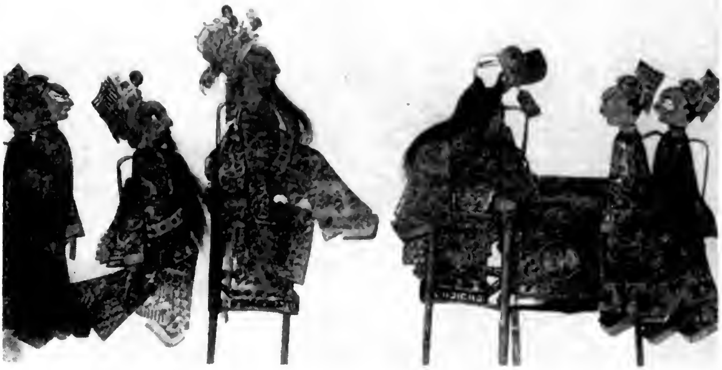

FIG. 1. A "long shot" scene taken from Chinese "Lantern Shadow." For the convenience of photographing, the "moving sticks" and "supporting stick" are not shown.

FIG. 2. Actors, actresses, and extras studying and rehearsing their parts in the tunnel during an air-raid.

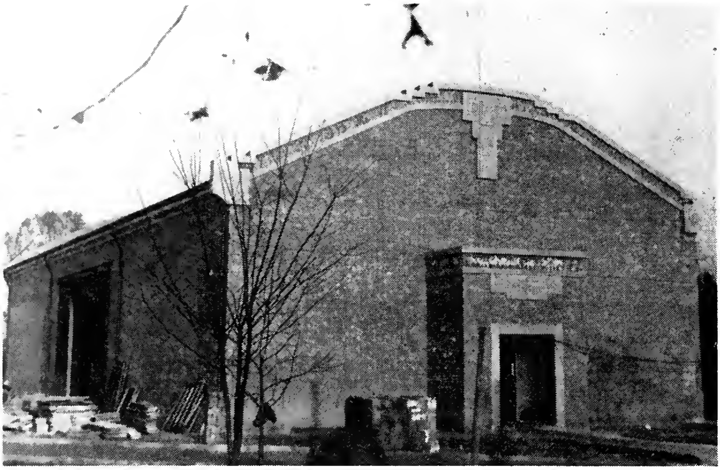

FIG. 3. One of China Film Studio's sound stages located in Hankow and designed by Mr. T. Y. Lo in 1936. The Japanese have turned it into a stable.

FIG. 4. Miss Lily Lee (Mrs. T. Y. Lo, standing in center) in *Storm over the Border*. Miss Lee spent a year in Inner Mongolia with a crew to get the real background for the picture.

Directors confer with scenarists on scripts, actors and actresses study and rehearse their parts, editors work at their benches, cutting and splicing furiously to the horrible hum of approaching enemy raiders.

One of our great worries is the possible destruction of stages or studio sets by Japanese bombs. The worst problem, however, is the destruction of the water mains. The China Film Studio is situated at the highest point in Chungking. When electric supply is cut off, we can still use our own generators as a makeshift. But when the water supply is cut off, as it was in 1939, we are compelled to carry water from the river at the foot of the hill up to the studio, and by this painful means fill a reservoir made specially for the purpose. About two hundred people were needed for this task alone.

I remember an interesting incident that happened in June, 1939. We were at that time producing a film called *The Light of East Asia*, with a large Japanese cast. These Japanese were originally war captives who, after spending two years in the Chinese internment camp, became aware of the fact that they had been fooled by the Japanese militarists. They sent a petition to the Chinese government for permission to form a "Japanese Anti-War Federation in China." It was some of these Federation members who played in this film, *The Light of East Asia*.

One day, these Japanese were working on one of our back lots, quite a distance away from the studio dugouts. An air raid came. In the hurry, an amplifier was forgotten. When that was discovered, enemy planes were already above Chungking. One of the Japanese, Takahashi by name, volunteered to fetch the amplifier. But before he got out of the dugout, bombs fell thick and fast. The blast sent Takahashi rolling down the steps at the entrance of the tunnel.

The amplifier was destroyed after all. The wrecked sets could be put up again in two days, but the amplifier was quite another matter. Furthermore, we had at that time only one portable recording machine. But a resourceful recording engineer confidently told the director that he could have everything fixed up for use in two days. Promptly on time, he produced his amplifier for the shooting. It was made out of the parts of a 7-tube d-c radio receiver.

There are at present three film studios in Chungking, namely, the China Film Studio, the Central Studio, and the Educational Film Studio, all under various government departments. The China Film Studio has a working staff of 700 people. Its work is chiefly connected with military training. All three studios together produce annually about 20 features and 80 short subjects and training films. For example, there are story films like *Good Husband,* about military service; *Victory Symphony,* about the well known victory at Changsha, both directed by China's famous director, Mr. T. S. Shih; *Storm over the Border* played by the writer's wife, Miss Lily Lee, which is her 21st picture; and films like *Anti-Tank Methods,* to show how the civilians close to the battle front can play their part to stop the advance of Japanese tanks. The production of films is greatly affected by the transportation problem, since all film has to be imported from America.

I have mentioned other migrant factories. Naturally, these factories devote themselves to the production of arms and other needs more directly connected with the war. The making of spare parts and small machines for the movie industry is thus handicapped. But we can still obtain the coöperation of these factories, which are themselves built in the dugouts. For example, they make sprockets to supply our mobile units and lights for use in the studios. In 1940, one of the arms factories made for the China Film Studio a five-plane cartoon photographing machine. In a dugout of the China Film Studio, there is a repair shop, which also produces tripods and camera dollies. An unusual achievement of this repair shop was the transformation of an old-model Bell & Howell silent camera into a sound camera. The shutter and some gears of the old machine were removed but the center axle was retained. The result was a purely noiseless sound camera. We are compelled to make all these improvisations because to obtain a priority on the supply and transport of movie equipment from the United States is very much of a happy dream.

The question may be asked as to what we do with the films we produce. In Free China, we have 112 theaters as against the prewar figure of 375. These theaters also have their own dugouts to store away their projectors during an air raid. Some of them install generators to supply the current against a sudden cut-off as a result of bombing. The generators use charcoal or vegetable oil for fuel. In addition to our own productions, these theaters also show American and Soviet films.

Apart from the theaters, the mobile cinema units of the Political Department, under the Military Affairs Commission, do some excellent work. There are ten of these units, first organized by Mr. Y. C. Cheng, of the China Film Studio. Each unit has a captain, two projectionists, two electricians, and four carriers. Sometimes they have to tour parts of Free China where there are even no roads. They visit villages near the front, showing films to soldiers and farmers. The generator alone weighs 150 pounds. Due to the shortage of gasoline, alcohol is used.

According to the report sent in by the captain of one of the units, during a period of seven months beginning January, 1940, his unit made a journey of three thousand miles from Chungking to Inner Mongolia, showing films to audiences totaling one and a half million people. They travelled by trucks or on camels. Sometimes they could obtain only two mules to carry the generator, so they themselves had to travel on foot. Once, they lost their way in the desert, and managed to get out of it only by tracking the trail of another caravan.

But the labor and hardships that these men had to go through were duly rewarded. In Inner Mongolia, they showed films to people who had never seen motion pictures before, and these people were so elated over the fascinating spectacle that they made up a song, set it to Mongolian music, and dedicated it to this unit. The song was named, *Down with the Little Japs*.

Although suffering from a shortage of equipment and raw film, these units have done some wonderful work. For instance, the Seventh Mobile Unit went right behind the Japanese lines and showed films to Chinese people in villages in an area that the Japanese believed was under their control. On the wall of the China Film Studio hangs a slogan that represents the spirit of these mobile units. It reads as follows: *Remember—One Foot of Film Properly Used Is as Deadly as a Bullet Fired against the Enemy.*

This is the simple story of the Chinese motion picture industry of the present day. Compared with the great American motion picture industry, we are but a toddling infant. We have yet to grow and to learn. But we share with you the belief that the motion picture is a very effective educational and cultural force. More than that, it is an indispensable means of promoting international understanding and good-will.

Today, our one great concern is to win this war. Let us never forget that in the motion picture the United Nations have a powerful weapon that will make a vital contribution toward a glorious victory for justice and democracy.

WRIGHT FIELD TRAINING FILM PRODUCTION LABORATORY*

H. C. BRECHA**

Summary.—*The Army must train more than 2,000,000 men for the world's air fronts as quickly as possible. This requires, in addition to instructors, a streamlined program of visual education by means of training films. The Wright Field Training Film Laboratory is a most modern establishment, and is manned by the most capable and experienced producers, writers, directors, and technicians.*

Some of the features described are the portable sound-truck, animation, special effects facilities, the film processing plant, and some of the equipment used at the Field.

The U. S. Army Air Forces must train more than two million men for the air fronts of the world, as soon as possible. These men will not all be pilots—there will be bombardiers, gunners, radiomen, navigators, and observers—and vitally important—the maintenance crews: mechanics, armorers, radio repairmen, on all of whom the Air Forces depend to "Keep 'Em Flying."

To prepare this tremendous and diverse body of men requires more than instructors, more than the standard teaching aids now employed. It requires a new and completely streamlined program of visual education which can be accomplished only through the powerful medium of motion pictures.

And that's where training films come in. By closely coördinating its program with the courses taught at the various Air Forces Schools, the Signal Corps Training Film Laboratory at Wright Field is providing training films that have cut weeks from current courses, at a time when every minute counts.

Of course, this is not an overnight development. Long before most of the United States was aware we might be drawn into war, the Army Air Forces and Signal Corps planned and created a Training Film Production Laboratory at Wright Field to streamline and standardize visual education for aviation personnel. The Signal

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* Presented at the 1942 Fall Meeting at New York, N. Y.; received October 27, 1942.

** Wright Field, Dayton, Ohio.

Corps assigned an outstanding motion picture expert, Colonel Frederick W. Hoorn, to do the job. Colonel Hoorn, who came to Wright Field in 1939 with one civilian assistant, now heads a laboratory consisting of several hundred persons, including officers and civilians.

These people are putting forth their extreme effort in expediting the production of these training films, thus enabling the Army Air Forces, in turn, to speed up their vital training courses.

Training films require a different technique from the motion pictures you are accustomed to seeing Saturday night at your favorite theater. Instruction—not entertainment—is sought, and the "star" of the training film may be a mechanic or the airport weatherman. Tempo of action varies from the careful unscrewing of nuts and bolts to the flash of *P-40s* and Japanese *Zeros* locked in aerial battle. But regardless of the tempo of the picture, every moment of it is planned to prepare our pilots and mechanics to do their jobs more thoroughly and with greater understanding. Throughout the making of the picture, the producers, writers, and directors have the collaboration and advice of the "Number One" specialists in the Air Forces.

Colonel Hoorn has assembled as his staff a capable group of officers and civilians who are old hands at making motion pictures. The Executive Department, headed by Lt. Colonel H. W. Mixson, assists Colonel Hoorn in long-range planning, procurement of personnel and administration.

There are three other major departments that supervise the making of training films—the scenario, production, and editing departments.

Director of scenarios is Captain Robert Kissack, whose job is to see that the Air Forces' ideas for films are translated into finished working scripts. Captain Kissack was formerly head of the department of visual education at the University of Minnesota.

Production Manager is Lt. Hiram Brown, who correlates all phases of production and keeps the plant running smoothly. Lt. Brown was formerly an executive producer at Republic Pictures.

The Editorial Department is headed by Major Bertram Kalisch who makes it his responsibility to smooth out the picture by effective editing. He is also in charge of scoring the narration and synchronizing it with the picture. Major Kalisch was for many years Assistant Editor of *Pathé News* and *News of the Day*, and also wrote and supervised the production of many theatrical, educational, and propaganda shorts.

Each of these men is assisted by competent aides who have had wide experience in the making of motion pictures. A partial list includes Assistant Editor Captain Jack Bradford, formerly with the *March of Time;* and Lt. Richard D. Goldstone, formerly executive producer of MGM shorts.

So much for the executive staff of the organization. Let us look over the activities of the skilled craftsmen who direct the pictures, make the sets, expose the films, put on the sound-track and perform other highly specialized duties. From Hollywood, New York, Detroit, Chicago, and even from foreign lands, the Laboratory has recruited the best talent available. There are seven producers who supervise the various production groups of directors and writers.

It is the writer's job to translate to teaching film the *knowledge* that the foremost Army Air Force authorities wish to inculcate in the thousands of up-and-coming pilots, bombardiers, and other aviation students. In order to transfer this knowledge to film most effectively, the writer himself must become familiar with the subject. He has frequent conferences with the Army Air Force advisers who oversee the script throughout its preparation.

The director who receives the script after it has been approved by the proper Army Air Force authorities and by Captain Kissack's scenario department prepares to shoot the picture. He often has extensive conferences with the writer who can give him invaluable aid.

The director is perhaps the closest to a training film, because once he takes charge of it, it is his responsibility during the rest of its production. He has at his command the services of all the craftsmen in the Laboratory. He is responsible more than anyone else for the quality.

Let us take a look at the various departments whose services a director often uses. The Camera Department is composed of twelve ace cameramen, most of whom are leaders in the field of cinematography. All types and makes of camera are used. B&H, Eyemo, and Mitchell cameras are used extensively. As for the lenses, the stock is most complete; thus both long and short focus lenses are in general use.

The Sound Department is being built up rapidly, and is provided at the present time with three truck channels, a fixed channel, and a re-recording channel. New equipment will permit handling five sound-tracks simultaneously; *e. g.*, narration, synchronous dialogue, music, and two types of sound-effects. Variable-area recording apparatus is used and most of the narration that accompanies the pictorial part of the film is non-synchronous. A studio has been set up and most of the films being made at the present time are scored here.

A portable sound-truck goes on location in cases where direct sound recording is desired, while a library of sound-effects for dubbing purposes is being augmented daily.

Animation is more than the stuff Donald Duck is made of. At the Training Film Production Laboratory, animation drawings are deadly serious work. Educators have found that they provide the best means of teaching, and they are used by the Laboratory whenever a point is to be driven home that can not be shown pictorially. Some pictures are nearly one hundred per cent animation. A staff of 80 animators keeps things moving night and day!

Special effects, like animation, is a trick way of getting across a point. In the special-effects department at the Training Film Production Laboratory, such dangerous scenes as a forced landing or a wrecked oil depot are realistically photographed in miniature with a special type of camera. Naturally, this is an old art to Hollywood, and so, many of the special-effects staff have been drawn from the film capital. Samples of the work of the special-effects staff may be found in almost every picture.

A developing and printing plant has recently been installed. By virtue of its completion the Training Film Production Laboratory is now entirely self-contained. The new film-processing laboratory occupies 2500 sq. ft. of floor space. First tests have proved successful and production will go into high gear within the next few days. The laboratory is the Army's most modern film-processing unit.

Designed and installed by Consolidated Film Laboratory's Engineering Department, the machines use variable-speed torque motors whose speed varies as the tension on the film increases or decreases, as the case may be. A million feet of film per month is a possible output, but actual production will be proportional, of course, to the varying demand. The new laboratory, which, incidentally, is completely sprocketless, is headed by Lt. Ted Hirsch, formerly of Consolidated.

It is a straight-line processing unit in which the exposed film is fed into the developing machine; comes out completely developed, fixed, washed, and dried; then goes to the negative breakdown assembly, into timing, cleaning and printing, projection inspection; and finally into the finishing room for possible additional prints.

The completed laboratory will include special rooms for developing (wet and dry sections); timing; negative cleaning; printing; sensitometry and control; stock vaults; loading; test projection; optical printing; and finishing. Facilities are also provided for chemical mixing, circulation, storage, laboratory control, and silver reclamation.

The *spirit* of the Laboratory—something that can not be defined easily—is high. Coöperation exists throughout the whole structure of the organization, and each person likes to feel that he is contributing in some small way to victory.

THE DOCUMENTARY, SCIENTIFIC, AND MILITARY FILMS OF THE SOVIET UNION*

GREGORY L. IRSKY**

Summary.—*The documentary, scientific, and military films produced in the studios of USSR have one basic, main purpose—to show the Soviet people themselves, and the rest of the world as well, how the Soviet citizen is living and fighting; how, as a result of the war, factories and plants have been established in new localities; how the tempo of production has increased; and how the people have contributed and sacrificed to hasten the defeat of the enemy. And, despite the exigencies and demands of war, cultural, educational, and scientific films continue to be produced in greater numbers than before. The war has not hindered or stopped the cultural growth of the country.*

As I reported to you at the Hollywood Convention last spring, during the war period Soviet Cinematography has been able to reorganize its resources to meet the demands of the times. All documentary, scientific, and military films that are produced by our studios have one basic idea, one main purpose—to show not only to the Soviet people themselves, but to the whole world, how the Soviet citizen is living and fighting; how the people, at short notice, have reëstablished their factories and plants in new localities; how they have increased their tempo of production; and how they have sacrificed themselves in every way to strike blow after blow at the bloodthirsty Fascists. These pictures are very valuable in acquainting the Red Army and the Soviet people with the modern technique that is helping us to crush our common enemy.

Our documentary films and newsreels, which are being released regularly, are especially outstanding in this respect—the directors and cameramen risk their very lives to make these films under the fire of battle, working side by side with the soldiers, to give the world the true picture of the present war. These films show the terror and atrocities brought by the Hitlerite despots. These films show how

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* Presented at the 1942 Fall Meeting at New York, N. Y.; received October 27, 1942.

** Cinema Committee of the U.S.S.R., Washington, D. C.

the Soviet people are heroically and valiantly defending not only the liberty of their own country, but that of the entire world as well. Despite grave dangers and great difficulties our cameramen film the most vivid episodes in the heroic struggles of our Red Army against the Hitlerites. Flying with the bombers, they film aerial bombings of enemy troops and parachute landings, while on the battlefield they film the actual operations of our tank units, infantry, cavalry, and artillery. Behind the enemies' lines they find excellent subjects in the activities of our people's fearless avengers—the guerrillas, both men and women.

A few of our documentary films as, for instance, *Our Russian Front*, *Moscow Strikes Back*, and others, have already been shown here in the United States. Their reception by the American people and the American press has been excellent and very gratifying.

The subject-matter of our documentary films is very diversified, portraying the intensity and the strenuousness of our lives. Aside from the more recent military aspect of these films, the majority of them deal with our industrial achievements and our scientific progress. They also reveal the intense research of our laboratories. They show the great experiments being conducted in our leading factories and on our collective farm fields, where our peasants, using modern methods, have successfully surmounted many obstacles and are supplying the towns with their products.

Our Soviet people know only too well how much success on the front lines is dependent upon the home front. More than a million feet of documentary film has been taken by our cameramen from the time the Hitlerite hordes suddenly attacked our country. Years will pass, and these historical films will be a permanent record, forming a perfect tribute to our heroes. They will show our future generations how heroically and valiantly their forefathers fought for liberty, suffered profoundly, and died nobly to insure the future happiness of their children. These films will ever stand as an example of the great heroism of the millions of people in the present war, who have never faltered or surrendered their right to liberty. These films will inspire our future youth also to hold high the banner of liberty and independence.

Let us consider now what we are doing along scientific and educational lines. Undoubtedly you all know what great attention we give in our young country to the matter of educational films, since the law gives every youth the right to an education. We have a great many high schools. We have special technical schools where the people can listen to lectures by the various specialists in order to improve the quality and increase the quantity of their production. We have many institutes, universities, and colleges with students representing all the nationalities of the Soviet Union. All the peoples of our country start on an equal basis and enjoy equally the inherent right to study and pursue their respective studies.

Before the war, there were approximately 700,000 students enrolled in the country's 800 institutes. Among the 600,000 graduated from these institutes are to be found engineers, doctors, teachers, leading scientists, artists, architects, design engineers, famous Red Army commanders, and leading experts in industries and transportation. In wartime the Soviet institutes continue their work, revising their schedules and programs of study to meet the basic requirements and demands of the times. By increasing the number of study hours in the week and shortening the holiday periods without lowering our standards of education, we have been successful in accelerating the graduation of students with such favorable results that in the year 1941–42 the institutes gave the country 170,000 trained specialists, which is almost double the number normally turned out. The institutes and colleges that have been moved to safer localities from the territories temporarily occupied by the enemy, continue to function normally. Upon arrival in the new towns, professors and students rapidly establish their laboratories and classrooms and begin working. Odessa and Kharkov's universities are functioning very well in their new homes and the Kiev industrial institute now in Tashkent has already graduated 200 engineers. The above résumé shows us that the war has not hindered or stopped the progress of the educational and scientific life of our country. Therefore, the role of scientific cinematography remains on a very high level as a vitally important factor in the training of our personnel.

During the years 1940–42 as many as 450 scientific and educational films containing 1559 reels and 1,500,000 feet were made. These films cover various subjects, such as geography, history, technology, agriculture, and military tactics. In other words, the topics or the subject-matter of the films are closely interrelated with those studied in the programs of our schools and colleges.

The Peoples Commissariat of Education has a cinema department that has approximately 20,000 16-mm projectors, which are furnished for lectures to the high schools upon request. Many of our technical and educational films are so effective that they enable us to teach our people without the actual presence of a teacher. Under the direction of Academician Choudakov, a cinema film entitled *The Automobile,* containing 90 reels, was produced. With the assistance of this film. several hundred thousand drivers of cars, trucks, tractors, tanks, and motorcycles received instructions in the correct methods of driving, and were well trained.

If some collective farm needs skilled drivers for tractors, this film is sent and a group of prospective drivers study the principles of the motor and other parts of the tractors and receive the consultations of an adviser. After reviewing the film they have actual practice in driving. Then they are qualified to drive.

When Moscow's famous turner Goudov invented a new method of increasing the tempo of production, we made a special film showing this method. This gave us the opportunity of utilizing Goudov's method in many factories throughout our country. Several pictures were made of the great work of our Academician Tsisin in growing a new kind of grain for Siberia. This film helped us to explain simply to our collective farmers this excellent experiment and, as a result, in many barren lands where farmers had never grown any wheat before there now appeared a harvest of wheat.

Pictures were made also for the medical profession and for students, medical institutes, and scientists. In the Institute for Medical Research and Experimentation there was conducted a great experiment in the revitalization of organisms. In order to familiarize our medical circles with this great experiment, we made a film under the title of *The Experience in Revitalizing* (by Director Iashin). This film shows how the separate parts of an organism, the heart, for instance, after having been taken out and put into a special receptacle continued to function for a certain period.

A very good reception was given to a film taken on the sea bottom, directed by Mr. Zgurydi. In this film the director and cameraman, very completely and entertainingly, show the colorful life on the bottom of the sea. For the filming of this picture, Soviet engineers designed a special camera and cabin in which the cameraman dived to the bottom of the water. Very complicated work in the field of filming scientific biological films was made under the direction of Professor Lebedev, who also designed special equipment for taking pictures of microbes.

In producing scientific and educational films, we have always paid particular attention to the military aspect. These training and instructional films have not only helped our fighters to familiarize themselves with tactics and the principles of operation of military equipment, but also with the methods of proper upkeep and servicing.

Naturally, the war has required more consideration of the filming of military pictures, and in order to meet the demand during recent years, our studios have had to make many military films which are successfully utilized in our military schools and camps on the battlefronts. In illustration, a few such pictures may be mentioned:

Hand to Hand Fighting: In this film are shown the methods of hand to hand fighting under various conditions.

The Training of Ski Troops: The Red Army fighters are enabled to study quickly the technique of using skis in combat, in reconnaissance and marching.

Defense in Tank Warfare: In this film the director and cameraman very successfully depict existing methods of defense against the onslaught of tanks under various conditions in open fields, forests, and the like.

Marksmanship: This film teaches the soldiers and civilians the minute details of good marksmanship so that they will at all times be ready to defend their native land from the enemy.

Camouflage in Winter: This film was made on the basis of much experience gained when our Red Army fought the Hitlerite invaders in the winter time and is a very good subject for training new fighters.

Mine Control: Emphasizes the caution that must be exercised in regard to the mines planted by our enemies and demonstrates the modern methods of mine sweeping.

Training of Parachute Troops: This film shows the jump of the parachutist under various conditions and illustrates methods of training parachute troops.

The Anti-Tank Rifle: Shows the principles and action of the anti-tank rifle designed by Soviet inventors. This particular rifle has had exceptional success in the struggle against Nazi tanks, and the film makes possible the training of masses of our fighters.

The great experience gained in producing documentary and scientific films will enable us to utilize our resources to the utmost advantage in the future for the purposes of reconstruction, further progress, and the assurance of a happy life, after we have finally crushed the destructive forces of mankind.

A ONE-RAY SYSTEM FOR DESIGNING SPHERICAL CONDENSERS*

L. T. SACHTLEBEN**

Summary.—*A spherical condenser is a simple lens of relatively large aperture. The outer portions of such a lens focus the rays much nearer to the lens than do the center portions. As a result the lens as a whole fails to produce a sharp image. This defect of the lens is known as spherical aberration.*

While in the case of spherical aberration no sharp image is produced, an image-like region of best focus does exist. This is known as the disk of least confusion. Its diameter may be minimized by shaping the lens so as to minimize spherical aberration. It is with this disk of least confusion and its required location that the designer of a spherical condenser must deal.

Without a knowledge of the properties of the disk of least confusion a designer might compute rays through a large number of trial lenses until, by an extensive and costly trial-and-error process, a condenser, having the correct shape for minimal spherical aberration and the disk of least confusion at the required location, is obtained.

The present paper examines some simple properties of the disk of least confusion. In consequence it shows how, by computing the course of a single ray through the proposed lens, a spherical condenser will result having the correct shape for minimizing spherical aberration, and the correct center thickness for its assumed diameter and edge thickness; and for which, finally, the location of the disk of least confusion is known. The method is applicable to condensers comprising more than one lens, and leads to the required design with a minimum of relatively simple trials.

Optical condensers are an important part of the motion picture engineer's equipment. They are essential in optical systems for the recording and reproduction of sound, and only by means of them can the motion picture itself be adequately and efficiently illuminated. In simplest terms, a condenser is the optical means by which the area of a light-source is virtually increased manyfold, in order that a specific point or area may be illuminated more strongly than is possible with the naked light-source alone.

Condensers are of various forms and types. The reflecting condenser of ellipsoidal form is widely used in picture projectors; aspherical-glass refracting condensers of the parabolic type are used in pic-

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* Presented at the 1942 Spring Meeting at Hollywood, Calif.; received April 14, 1942.

** RCA Manufacturing Co., Indianapolis, Ind.

ture projectors, and in sound reproducing optical systems. Simpler and cheaper, if less efficient, spherical-glass refracting condensers are widely used in all types of motion picture equipment employing optical condensers, and it is to the problem of their design that attention is directed in the present paper. The author does not claim to have made an exhaustive study of the problem; the purpose here is to indicate the direction in which the solution has been found to lie during the course of designing several condenser systems. The subject does not seem to have been treated systematically in any published work of which the author is aware, and the problem is worthy of considerable further study and elaboration.

In what follows the author has endeavored to adhere to the sign and symbol conventions (see Appendix I) established by Professor A. E. Conrady in his treatise on "Applied Optics and Optical Design."[1] The interested reader is urged to consult that work, if he is not already familiar with it, as a practically unfailing aid in the understanding and solution of many optical problems.

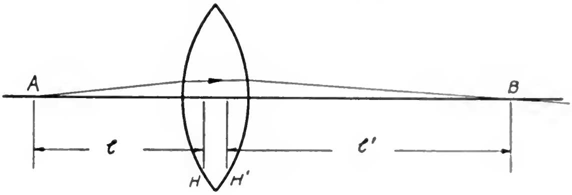

FIG. 1. A simple lens.

INTRODUCTION

The conjugate axial object and image points, A and B, of the simple spherical lens shown in Fig. 1, have their positions related to each other by the simple formula

$$\frac{1}{l'} - \frac{1}{l} = \frac{1}{f'}$$

where f' is the equivalent focal length of the lens, and l and l' are measured from the first and second principal planes of the lens, H and H', respectively. This relation holds true for any position of the object point A along the axis, but it is mathematically true only for the so-called paraxial rays, which lie infinitely close to the axis of the system. In a practical sense it is true for rays inclined as much as

2 degrees to the axis or to the incidence normals to the spherical surfaces of the lens.[2] (The incidence normal is the normal to the refracting surface that passes through the point of intersection of the ray with the surface.)

If in Fig. 2 a cone of rays of large angle originating at A and entering the lens at height Y_z from the axis be considered, it will be found upon computing its course through the system that it fails to focus at the point B, but comes to focus on the axis at a point somewhat nearer the lens, say B_z', at distance L_z' from the second principal plane of the lens. The focal error, $B_z'B = l' - L_z'$, is known as the spherical aberration of the lens for the zone of radius Y_z, and may be included in the above formula, which then becomes

$$\frac{1}{L_z' + B_z'B} - \frac{1}{l} = \frac{1}{f'}$$

for rays at any inclination to the axis.

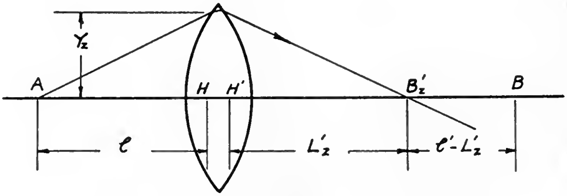

FIG. 2. Spherical aberration in a simple lens.

It is not possible to formulate an exact algebraic expression for the spherical aberration in terms of l, Y_z, and the radii and refractive index of the lens, for the law of refraction is itself trigonometric or transcendental in nature. Frequently the spherical aberration is expressed as a series in Y_z, the constants of which must be evaluated for the particular case under consideration. This series takes the form

$$B_z'B = a_2Y_z^2 + a_4Y_z^4 + a_6Y_z^6 + \ldots$$

there being no constant term and no odd powers of the variable Y_z in the expression.[3] The successive terms of the series are said to express the primary, secondary, tertiary, *etc.*, spherical aberrations of the system. (In general, Y_1 may be any reasonable measure of the aperture of the lens, and need not be restricted to the height of the point of incidence above the axis. In the practical part of this paper Y_z will be taken as the tangent of the inclination angle U_z, between the ray and the axis.[3])

In view of the above-given statement that the simple lens formula holds true, practically, only for rays having inclinations or incidences up to 2 degrees, it is obvious that it can not be relied upon when designing a condenser for which these angles may be as large as 20 degrees or more. Evidently the presence of spherical aberration must be considered.

THE CONDENSER DESIGN PROBLEM

It is the function of a condenser ordinarily to direct all the light from an illuminated object into a lens that is to project an image of the object. Except in certain special cases a condenser is not required to be aberration free, but it is usually required to be of quite large aperture and frequently must be designed so that the brightest, or most concentrated part of the beam emerging from it falls in the plane of a lens or other aperture. In general, condensers are simple lenses of large aperture required to cover a relatively small field. As such they may be studied by considering only the images of object points lying on the axis.

Since a high degree of freedom from spherical aberration is usually not one of the conditions of condenser design, it will suffice to assume that the actual aberrations of the condenser obey the law of primary spherical aberration

$$B_z'B = a_2 Y_z^2$$

For simple condensers up to a speed of *f*/2, this equation represents the spherical aberration to a sufficiently good approximation if a_2 is evaluated by computing $B_z'B$ for an edge or marginal ray, and dividing that value by the square of the effective semi-aperture of the lens.

Professor Conrady proves[4] that when the focal errors of a lens system obey the law of primary spherical aberration, the best focus occurs three-fourths of the way from the focus for the center of the lens, to the focus for the edge of the lens. (The proof is corollary to a proof[4] that the disk of least confusion occurs "at the point of intersection of the arriving rays from the half-aperture, with the produced marginal rays.") This constricted region in the emerging beam of light represents the nearest possible approach to a true image in the presence of primary spherical aberration, and is known as the disk of least confusion. It is with this disk of least confusion, and its location on the axis of the system, that the designer of spherical condensers is concerned; rather than with the image point B, which exists only for rays having inclinations and incidences of 2 degrees or less.

FUNDAMENTAL CONDITIONS OF THE SOLUTION

If the spherical aberration of any zone of the lens of Fig. 2 is expressed as

$$B_z'B = a_2 Y_z^2$$

and the spherical aberration of the margin of the lens as

$$B_m'B = a_2 Y_m^2$$

then by division

$$\frac{B_z'B}{B_m'B} = Y_z^2/Y_m^2$$

Remembering that for the point B_z', corresponding to the position of the disk of least confusion

$$\frac{B_z'B}{B_m'B} = {}^3/_4$$

it is seen that for this point the corresponding Y_z is given by

$$Y_z^2 = {}^3/_4 Y_m^2$$

or

$$Y_z = \sqrt{{}^3/_4 Y_m}$$

That is, the zone through which the rays must pass, if they are to come to focus at a point B_z' corresponding to the position of the disk of least confusion, has an aperture which is $\sqrt{{}^3/_4} = 0.8660 \times$ the full effective aperture of the lens. This zone of the lens, which is thus associated with this important point, shall be called the "square-root-of-three-fourths-zone"; written simply as the "$\sqrt{{}^3/_4}$ zone." The determinate diameter of this zone is the fundamental fact upon which the present solution of the condenser problem is based. It is thus clear that only the rays from the object-point A that enter the lens at an aperture equal to $\sqrt{{}^3/_4}$ times the full effective aperture of the first surface of the lens need be considered. And since all such rays form an axial cone or pencil of rays, which are all refracted exactly alike, it becomes necessary to consider only one ray as the key to the solution of the problem.

In Professor Conrady's proof referred to above, it is shown that the diameter of the disk of least confusion is proportional both to the spherical aberration $B_m'B$ of the rays from the margin of the lens, and to the tangent of the angle U_m' which they make with the axis at their focus. It is desirable in any condenser system that this diameter shall be kept as small as conveniently possible, and since both these quantities vary in the same sense, the diameter of the disk will be smallest when the spherical aberration of the marginal ray is smallest. It is well known that a simple lens has minimal spherical aberration when its shape is such that the change in direction, or deviation of the edge ray, is the same at both surfaces. It shall here be prescribed that the deviation of the $\sqrt{3/4}$ zone ray, rather than the edge ray, shall be equally divided between the two surfaces. This will give the lens a shape slightly different from that necessary to divide the total deviation of the edge ray equally between the two surfaces. But since for that shape the total deviation of the edge ray is a minimum, the prescribed small departure from it will change the total deviation of the edge ray by a negligible amount. If the condenser is to have four or more glass-air surfaces the total deviation of the $\sqrt{3/4}$ zone ray shall be divided equally among all of the surfaces. The component lenses will thus all have approximately the same power; they will each have very nearly the correct shape for minimal spherical aberration; and as will be seen, this equal apportionment of the deviation among the surfaces makes it possible to calculate all lens thicknesses, and the curvature of every surface after the first, by means of a very simple formula.

SOLUTION OF THE CONDENSER DESIGN PROBLEM

Having determined the fundamental conditions that the finished condenser must fulfill, it is possible to proceed with the actual problem of its design. The problem can not well be put into a general form, for each design becomes a problem of itself, depending upon the particular combination of requirements that must be fulfilled, and upon which of the variables are left to be determined by the convenience of the designer. In general the designer begins with some information regarding certain of the following: magnification of the system; speed or diameter of the system; distance from system to source or image; separation of source and image; allowable thickness of system; allowable cost of system; *etc.* The problem may thus present itself in innumerable ways. Frequently certain assumptions or estimates must be made, and trial designs based upon them until a design is found that meets the stated requirements. In such cases the assumptions are based upon actual designing experience.

The initial inclination of the ray that will traverse the $\sqrt{3/4}$ zone of the lens may be readily calculated from that of the edge ray, which may be known or readily determined from the general requirements of the proposed condenser system. Thus, if the initial inclination of the edge ray is U_m, then the initial inclinaton of the $\sqrt{3/4}$ zone ray is

$$U_z = \tan^{-1}\sqrt{3/4}\,\tan U_m \tag{1}$$

Occasionally U_z must be estimated, and the design approached through a succession of such estimates.

It is usual for a condenser to be designed to work at some specified magnification, say, M, in which case

$$\sin U_z = M \sin \text{final } U_z'$$

or

$$\text{final } U_z' = \sin^{-1}\frac{\sin U_z}{M} \tag{2}$$

If M is not given, a trial estimate of it may also be necessary. Thus the total deviation of the ray becomes simply

$$-U_z + \text{final } U_z' \tag{3}$$

If, further, $I - I' = \theta$ is the deviation of the ray at each surface, and Q is the number of individual lens elements comprising the proposed condenser, then

$$2Q \times \theta = -U_z + \text{final } U_z'$$

or

$$\theta = \frac{-U_z + \text{final } U_z'}{2Q} \tag{4}$$

After choosing the glass from which the condenser is to be made (usually some variety of Crown), the initial angle of incidence I, of the ray, may be calculated. Snell's Law of Refraction is expressed in terms of the sines of the angles of incidence and refraction, I and I', respectively, and the corresponding indexes, N and N', of the first and second mediums, thus:

$$N \sin I = N' \sin I'$$

But where there are given only the indexes and the deviation $I - I' = \theta$, as in the present case, then from Snell's Law, by Appendix II,

$$I = \cot\text{an}^{-1}\left[\frac{\cos\theta - \dfrac{N}{N'}}{\sin\theta}\right] \tag{5}$$

Having computed U_z, and I by equations *1* and *5* above, it is finally necessary to choose the distance L_1 from the object-point A to the first surface of the condenser, if it is not already given; after which the radius of curvature r_1 of the first surface may be computed by the formula, derived in Appendix III

$$r_1 = \frac{L_1}{2} \sin U_z \sec \frac{I - U_z}{2} \operatorname{cosec} \frac{I + U_z}{2} \qquad (6)$$

Following this, the remaining curvatures and thicknesses of the system may be rapidly computed by alternate application of the standard trigonometric computing formulas[7, 8, 9] (see Appendix IV) and a simple algebraic formula to be deduced in Appendix V. (The Standard trigonometric computing formulas are a group of simple trigonometric equations by which the coördinates of a ray, after refraction at a spherical surface, are computed from its coördinates before refraction.)

The work is continued by introducing L_1, $U_1 = U_z$, and r_1 into the standard trigonometric-ray tracing formulas and computing L_1' and U_1' for the $\sqrt{3/4}$ zone ray in the second medium, after refraction at the first surface. This computation automatically yields the angles I_1 and I_1', whose difference $I_1 - I_1'$ should be equal to θ above. For the second surface of the lens $L_2 = L_1' - d_1'$, where d_1' is the center thickness of the lens (as yet undetermined).

The assumption of equal deviation of the ray at each surface now leads, by Appendix V, to the important algebraic formula relating L_2, and the second radius of curvature r_2, thus:

$$\frac{r_2}{L_2} = \frac{r_2}{L_1' - d_1'} = \frac{r_1}{2r_1 - L_1'} \qquad (7)$$

From equation *7* it is seen that the ratio of r_2 to L_2 is a constant which may be evaluated in terms of the now known data r_1 and L_1' for the first surface. Equation *7* makes possible a slide-rule computation of r_2, upon the assumption of any trial value of d_1', from which the edge thickness of the lens at its assumed or required diameter may be computed (see Appendix VI). When a value of d_1' has been found that will yield a satisfactory edge thickness the corresponding value of r_2 is accurately computed. The values of L_2, U_2, and r_2 are then introduced into the standard ray-tracing formulas, and the new L_2' and U_2' computed trigonometrically for the $\sqrt{3/4}$ zone ray after its refraction at the second surface. The difference $I_2 - I_2'$ should again be computed and seen to be equal to θ.

Equation 7 may now be rewritten with suffixes increased by unity, as

$$\frac{r_3}{L_3} = \frac{r_3}{L_2' - d_2'} = \frac{r_2}{2r_2 - L_2'} \tag{7a}$$

and applied as before to compute the third radius of curvature. This is allowable, for the relation expressed by equation 7 is purely geometrical and unrelated to the laws of optics. Ordinarily, the second and third surfaces of the lens are separated by an air-space d_2' of nominal length, say 0.5 mm. As there can be no question of edge thickness at the air-space for lenses of this form, since such spaces have negative curvature, it is permissible to assume a nominal thickness for the air-space and immediately compute r_3.

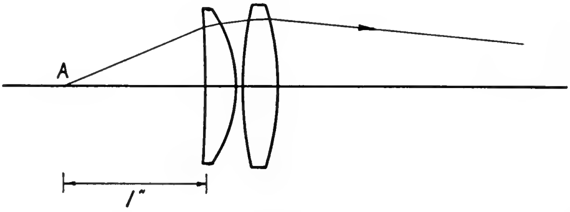

FIG. 3. Form and proportions of a lens designed by the one-ray method, showing the course of the $\sqrt{3/4}$ zone ray.

It is now evident that completion of the design of the condenser is only a matter of repeating the procedure, outlined above for the second and third surfaces of the lens, until all the radii and thicknesses of the originally assumed number of component lenses have been computed.

EXAMPLE

In Appendix VII, an actual design is carried through in detail, the condenser having a speed of about $f/1$, and a magnification of $M = -4.5\times$. Fig. 3 illustrates the form and proportions of the resulting lens, and shows the course of the $\sqrt{3/4}$ zone ray through it.

Fig. 4 illustrates the distribution of the rays in the vicinity of the focus. The focus of the $\sqrt{3/4}$ zone ray is seen to lie very near the disk of least confusion, which, due to the presence of the higher-order aberrations, is itself displaced toward the lens from the originally assumed theoretical position. The fact that the focus B of Fig. 4, computed by the simple lens formula, lies nearly $2^1/_4$ inches beyond the disk illustrates the futility of using the simple lens formula when designing lenses of this type.

The computations of Appendix VII would normally represent about three hours' work, and in actual practice two to four trials may be required to produce a condenser fulfilling all the requirements of a design.

APPENDIX

(I) SIGN AND SYMBOL CONVENTIONS[8]

A ray is completely designated with respect to a given spherical refracting surface if its point of intersection with the chosen axis of that surface and its angle of inclination to the axis are given. Professor Conrady chooses to apply the negative sign to all intersection-lengths lying to the left of a surface, and the positive sign to all those to the right. The radius of curvature of a surface is treated as the intersection-length of any normal to that surface, and is therefore negative if the center of curvature lies to the left of the surface, and positive if it lies to the right. He chooses to measure the inclination of a ray by the acute angle that the ray makes with the axis, calling the angle negative if it is generated by a counterclockwise rotation from the direction of the axis into that of the ray, and positive if generated by a clockwise rotation. Accordingly the angles of incidence and refraction are positive if generated by a clockwise rotation from the direction of the ray to the direction of the radius or incidence normal. The axis of a single spherical surface may be any straight line through the center of curvature, but in a system of two or more spherical refracting surfaces, the centers of curvature of all the surfaces are made to lie on the same straight line, which is then regarded as their common axis.

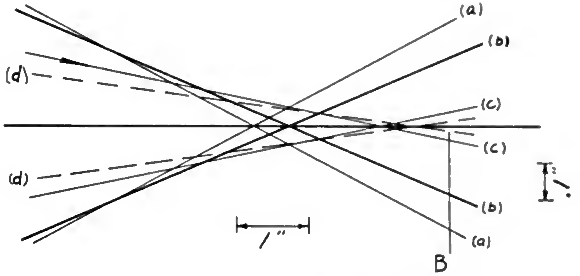

FIG. 4. Distribution of rays in the vicinity of the focus of the lens of Fig. 3. Computed rays: (*a*) marginal ray; (*b*) $\sqrt{3/4}$ zone ray; (*c*) half-aperture ray; (*d*) estimated ray (not computed). *B* represents the location of the image as computed by the simple lens formula. Vertical scale increased 5× for clarity.

Inclination angles for rays actually in the medium to the left of a refracting surface are designated by a plain vowel, as *U;* and in the medium to the right by a primed vowel, as U'. Intersection-lengths for rays actually in the medium to the left of a surface are designated by a plain consonant, as L; and in the medium to the right by a primed consonant, as L'. In like manner I and I' designate the angles of incidence for rays actually in the mediums to left and right of a surface, respectively. Capital letters designate the data of rays at finite angles to the axis, and small letters the data of rays lying indefinitely close to the axis.

N and N' designate the indexes of refraction of the mediums to the left and right of a surface, respectively; d and d', which are always positive in the usual left-to-right computation, designate the axial thicknesses of elements to the left and right of a surface, respectively.

Numerical subscripts refer the above symbols to particular surfaces that are numbered successively from left to right, beginning with 1.

(II) THE ANGLE OF INCIDENCE

The relation between the angles of incidence and refraction, I and I', and the corresponding indexes of refraction, N and N', is known as Snell's Law of Refraction and is stated thus:

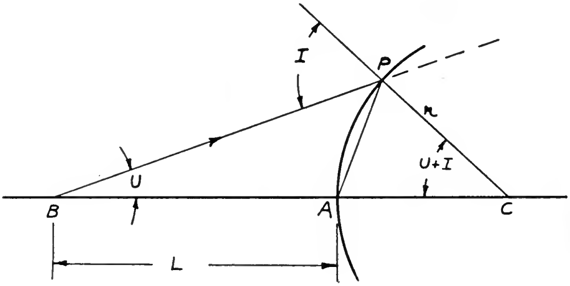

FIG. 5.

$$N \sin I = N' \sin I'$$

The change in the direction of the ray or its deviation upon refraction is equal to

$$I - I' = \theta$$

By transposition and substitution Snell's Law becomes

$$N \sin I = N' \sin (I - \theta)$$

Upon expansion of the right hand term

$$N \sin I = N' (\sin I \cos \theta - \cos I \sin \theta)$$

and upon dividing this equation by $\sin I$, and transposing

$$I = \operatorname{cotan}^{-1} \left[\frac{\cos \theta - \dfrac{N}{N'}}{\sin \theta} \right] \qquad (5)$$

(III) THE FIRST RADIUS

Professor Conrady proves[6] (see Fig. 5) that if a ray at inclination U intersects the axis of a spherical surface of radius r at a point B, which is separated a distance L from the vertex A of the surface, and meets the surface at an angle of incidence I, then the length of the chord connecting the point of incidence P with the vertex A may be written

$$PA = L \sin U \sec \left(\frac{I - U}{2}\right)$$

But since also

$$PA = 2r \sin \left(\frac{I + U}{2}\right)$$

then by substitution and transposition

$$r = \frac{L}{2} \sin U \sec \frac{I - U}{2} \operatorname{cosec} \frac{I + U}{2} \qquad (6)$$

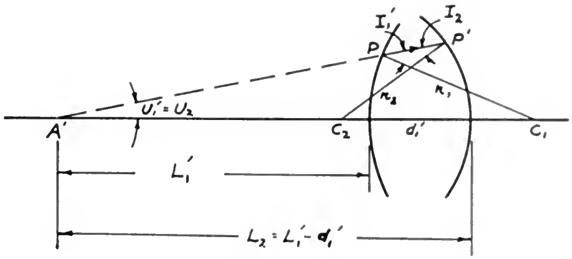

FIG. 6.

(IV) STANDARD TRIGONOMETRIC COMPUTING FORMULAS[7]

If the axial intersection length L, and the inclination U of a ray are given, and if the refractive indexes N and N' of the first and second mediums, respectively, are given, and if, furthermore, the radius of curvature r of the spherical refracting surface is known, then the new intersection length L' and new inclination U' of the ray after refraction may be computed by the following formulas:[8, 9]

The angle of incidence I in the first medium of index N is given by

$$\sin I = \sin U \left(\frac{L - r}{r}\right) \qquad (A)$$

The angle of incidence I' in the second medium of index N' is given by

$$\sin I' = \frac{N}{N'} \sin I \qquad (B)$$

The inclination U' of the ray after refraction is given by

$$U' = U + I - I' \qquad (C)$$

The intersection-length L' of the ray after refraction is given by

$$L' = r\frac{\sin I'}{\sin U'} + r \qquad (D)$$

Where d' is the axial distance to the next succeeding surface, the new L for that surface becomes $L' - d'$, and the new U is obviously equal to U'.

(V) ANY RADIUS AFTER THE FIRST

Given two spherical surfaces of radii r_1 and r_2, separated a distance d_1' (Fig. 6). Consider any line PP' which connects the two surfaces, and whose extension intersects the axis of the two surfaces in the point A' at a distance L_1' from the vertex of the surface of radius r_1. In general the line PP' will make an angle I_1' with the radius C_1P of the surface of radius r_1, and an angle I_2 with the radius C_2P' of the surface of radius r_2. The line PP' will be inclined at an angle $U_1' = U_2$ to the axis of the two surfaces.

From the triangle $A'C_1P$, for the first suface

$$\frac{L_1' - r_1}{\sin I_1'} = \frac{r_1}{\sin U_1'}$$

and from the triangle $A'C_2P'$, for the second surface

$$\frac{L_2 - r_2}{\sin I_2} = \frac{r_2}{\sin U_2}$$

By division of the second equation by the first

$$\frac{L_2 - r_2}{L_1' - r_1} \cdot \frac{\sin I_1'}{\sin I_2} = \frac{r_2}{r_1} \cdot \frac{\sin U_1'}{\sin U_2}$$

By imposing the condition that $I_1' = -I_2$ and, at the same time, noting that $U_1' = U_2$, and $L_2 = L_1' - d_1'$, there results the simple algebraic equation

$$-\frac{r_2}{r_1} = \frac{L_2 - r_2}{L_1' - r_1}$$

from which

$$\frac{r_2}{L_2} = \frac{r_2}{L_1' - d_1'} = \frac{r_1}{2r_1 - L_1'} \qquad (7)$$

a purely geometrical relationship.

(VI) RADIUS, SEMICHORD, AND SAGITTA OF AN ARC

The radius r, semichord d, and sagitta h of the circular arc ACB (Fig. 7) are related by the formula

$$r = \frac{h^2 + d^2}{2h}$$

This may be written as

$$\frac{d}{r} = \sqrt{\frac{h}{r}\left(2 - \frac{h}{r}\right)}$$

By allowing h/r to assume an appropriate series of values from 0 to 2, a corresponding series of values of d/r may be computed, and plotted against h/r as abscissas. From this curve d may be readily determined when h and r are given, or h may be obtained when d and r are given.

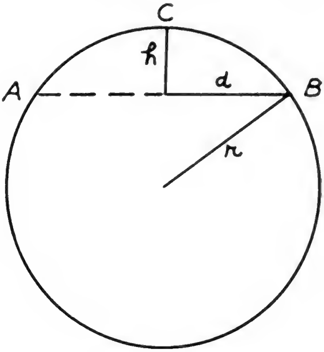

FIG. 7.

By dividing each member of the series of computed values of d/r by the corresponding values of h/r, a likewise corresponding series of values of d/h is obtained. When these values are plotted against h/r as abscissas the resulting curve easily yields d when h and r are given, or yields r when d and h are given.

The two curves thus obtained are invaluable in quickly solving problems involving the center and edge thicknesses, radii, and diameters of lenses. They quickly repay the trouble spent in computing and plotting them.

(VII) EXAMPLE

The lens to be designed will have a speed of about $f/1$, and will work at a magnification $M = -4.5\times$. The inclination U_M of the edge ray arriving from the source will be taken as −25 degrees, and the distance L_1 from the source to the first refracting surface will be taken as −1 inch. It is assumed that the lens will be made of glass having an index $N_1' = 1.5230$. The lens will comprise two elements, as the speed of any individual element should not exceed $f/2$.

By equation *1*

$$U_s (= U_1) = \tan^{-1} 0.866 \tan -25° = -22° \text{ (very nearly)}$$

By equation *2*

$$U_4' = \sin^{-1}\left(\frac{\sin -22°}{-4.5}\right) = 4°47'$$

Assuming, upon the basis of experience, that the distance L_4' from the last surface of the lens to the image will be 5 inches, the estimated diameter of the lens is calculated as

$$\text{Diameter} = \frac{2 \times 5}{0.866} \tan 4°47' = 0.96 \text{ inch}$$

(It will be convenient to take the diameter as 1 inch, and compute the center thicknesses upon an assumed edge thickness of 0.1 inch.)

By equation 3

$$-U_s + \text{final } U_s' = 26°47'$$

and by equation 4

$$\theta = \frac{26°47'}{2 \times 2} = 6°41'45''(Q = 2 \text{ elements})$$

By equation 5, I is computed as follows[10,11]

$$\begin{array}{rcrcl}
\log\cos\theta & = & 9.99703 & = & \log\ 0.993185 \\
\text{colog} -N' & = & 9.81730- & = & \log\ \underline{-0.656599} \\
\log\left(\cos\theta - \frac{N}{N'}\right) & = & 9.52710 & = & \log\ 0.336586 \\
\text{colog}\sin\theta & = & \underline{0.93331} & & \\
\log\text{cotan}\, I & = & 0.46041 & = & \log\text{cotan}\ 19\text{-}06\text{-}24
\end{array}$$

(The more convenient method of writing angles as 19-06-24, instead of the usual 19°6′24″, will be used beyond this point.)

A check of the last computation is most conveniently made by computing I' from Snell's Law. Thus $\sin I' = \sin I/N'$.

$$\begin{array}{rcrcl}
\log\sin I & = & 9.51498 & & \\
\text{colog}\, N' & = & \underline{9.81730} & & \\
\log\sin I' & = & 9.33228 & = & \log\sin 12\text{-}24\text{-}39 \\
I & = & 19\text{-}06\text{-}24 & & \\
I' & = & \underline{-12\text{-}24\text{-}39} & & \\
\theta & = & 6\text{-}41\text{-}45 & &
\end{array}$$

It will be well to precede the computation of r_1 by tabulation of the relevant data as required by equation 6.

$$\begin{array}{lcl@{\qquad\qquad}rcl}
L_1 & = & -1 & \frac{1}{2}(I - U_s) & = & 20\text{-}33\text{-}12 \\
U_s & = & -22\text{-}00\text{-}00 & \frac{1}{2}(I + U_s) & = & -1\text{-}26\text{-}48 \\
I & = & 19\text{-}06\text{-}24 & & &
\end{array}$$

By equation 6, r_1 is computed as follows

$$\begin{array}{rcrcl}
\log L_1 & = & 0.00000- & & \\
\text{colog}\ 2 & = & 9.69897 & & \\
\log\sin U_s & = & 9.57358- & & \\
\text{colog}\cos\frac{1}{2}(I - U_s) & = & 0.02856 & & \\
\text{colog}\sin\frac{1}{2}(I + U_s) & = & \underline{1.59780-} & & \\
\log r_1 & = & 0.89891- & = & \log -7.92337
\end{array}$$

From the now known values of L_1, U_1 and r_1 a computation[7] by the Standard trigonometric computing formulas yields

$L_1' = -1.47163$, and $U_1' = U_2 = -15\text{-}18\text{-}15$

By equation 7, r_2/L_2 is computed as follows (assuming $d_1' = 0$)

$$\begin{array}{rcrcl}
\log r_1 & = & 0.89891- & & \\
\text{colog}\ (2r_1 - L_1') & = & \underline{8.84239-} & & \\
\log r_2/L_2 & = & 9.74130 & = & \log 0.551188
\end{array}$$

A few trial values of d_1' show that an edge thickness of 0.1 inch will result from a center thickness $d_1' = 0.230$ inch.

By equation *7*, r_2 is computed as

$$r_2 = (L_1' - d_1')\frac{r_2}{L_2}$$

$$\begin{aligned} \log (L_1' - d_1') &= 0.23087- \quad (= \log L_2) \\ \log r_2/L_2 &= \underline{9.74130} \\ \log r_2 &= 9.97217- \quad = \log -0.93793 \end{aligned}$$

From the known values of L_2, U_2, and r_2, the standard computing formulas yield

$$L_2' = -2.98889, \text{ and } U_2' = U_3 = -8\text{-}36\text{-}32$$

The third radius may be immediately computed upon assumption of $d_2' = 0.020$ inch.

By equation *7*, r_3 is computed as follows

$$\begin{aligned} \log (L_2' - d_2') &= 0.47841- \quad (= \log L_3) \\ \log r_2 &= 9.97217- \\ \text{colog } (2r_2 - L_2') &= \underline{9.95349} \\ \log r_3 &= 0.40407 \quad = \log 2.53554 \end{aligned}$$

From the known values of L_3, U_3, and r_3 the standard computing formulas yield

$$L_3' = -13.7880, \text{ and } U_3' = U_4 = -1\text{-}54\text{-}57$$

If, as is advisable, a scale drawing is made as the design progresses, to show the course of the ray through the system, it will be apparent that the first element must be made about 1.062 inches in diameter and the second element must be made about 1.125 inches in diameter to accommodate the edge ray. With this in mind, the final radius r_4 may be computed.

By equation *7a*, r_4/L_4 is computed as follows (assuming $d_3' = 0$)

$$\begin{aligned} \log r_3 &= 0.40407 \\ \text{colog } (2r_3 - L_3') &= \underline{8.72448} \\ \log \frac{r_4}{L_4} &= 9.12855 \quad = \log 0.134447 \end{aligned}$$

It is seen that L_3' is very much larger than any probable value which d_3' may assume, and that as a result the value of r_4 will be only slightly different from the value obtained on the assumption that $d_3' = 0$. With this in mind it is quickly found that the edge thickness of the second lens (diameter = new value of 1.125 inches) will be very nearly 0.1 inch when the center thickness is 0.250 inch.

By equation *7a*, r_4 is computed as

$$r_4 = (L_3' - d_3')\frac{r_4}{L_4}$$

$$\begin{aligned} \log\,(L_3' - d_3') &= 1.14731- \quad (= \log L_4) \\ \log r_4/L_4 &= \underline{9.12855} \\ \log r_4 &= 0.27586- \quad = \log -1.88738 \end{aligned}$$

From the known values of L_4, U_4, and r_4 the standard computing formulas yield

$$L_4' = 5.52255, \text{ and } U_4' = 4\text{-}46\text{-}56$$

The height of the point of incidence at the last surface is

$$Y_4 = r_4 \sin\,(U_4 + I_4)^{12}$$

The free aperture of the last surface is thus $2Y_4/0.866$, and is computed to be 1.080 inches.

Thus the lens is specified as follows:

$N' = 1.5230$
$r_1 = -7.923$ inches $\quad d_1' = 0.230$ inch. Diameter = 1.062 inches
$r_2 = -0.938$ inch
$d_2' = 0.020$ inch (air-space)
$r_3 = +2.536$ inches $\quad d_3' = 0.250$ inch. Diameter = 1.125 inches
$r_4 = -1.887$ inch

Free aperture of first component = 1.030 inches.
Free aperture of second component = 1.080 inches.

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[11] Logarithms of negative natural numbers are followed by a minus (−) sign. The result of a logarithmic computation is positive if an even number of such signs is involved, and is negative if an odd number is involved.

[12] CONRADY, A. E.: "Applied Optics and Optical Design," Part One, p. 29.

LIGHT-SCATTERING AND THE GRAININESS OF PHOTOGRAPHIC EMULSIONS*

A. GOETZ AND F. W. BROWN**

Summary.—*The factors upon which the optical scattering power of a photographic emulsion depend and the relationship of the former to the graininess are investigated by a method that consists in determining the ratio of two average transparencies* (T_1/T_2) *of a moving emulsion sample of uniform density with a microphotometric device integrating simultaneously over a large* (T_1) *and a small* (T_2) *section of the sample. The variation of the scattering power (defined as* T_1/T_2) *with the density is determined (a) for negative emulsions: the finer grain has the larger* T_1/T_2; *(b) for a positive emulsion directly exposed and printed through various types of negative emulsions:* T_1/T_2 *is independent of the resulting graininess; (c) for positive emulsions printed with white and ultraviolet light:* T_1/T_2 *is not affected by the wavelength of the printing light; (d) for a positive emulsion with varying gamma (0.44 to 2.5): no influence upon* T_1/T_2 *by gamma is observed.*

(I) INTRODUCTION

Previously the senior author with his collaborators[1, 2, 3, 4] has published an approach to the absolute determination of the graininess of photographic emulsions based upon the statistical distribution of the relative transparency fluctuations in terms of the Gaussian probability function:

$$(2/G' \sqrt{\pi}) \int_0^x e^{-(x/G')^2} dx; \quad (\Delta T/T_m = x)$$

The graininess coefficient G has been found to be an accurate and universal representation of the graininess realization by the subjective optical as well as the sound observer, if certain factors such as the "discrimination factor" are considered.

An instrument has been designed and described[4] which by means of an automatic microphotometric analysis of a small area of the emulsion, exposed and developed to a known uniform density D permits the evaluation of the graininess coefficient G by a relatively simple manipulation. This graininess meter has been used for a

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number of years in the research laboratories of a large industrial producer of emulsions and a great deal of data have been thus accumulated, in particular with reference to the variation of G with D. The evaluation of this particular function brings forth a factor that has a major influence upon the subjective as well as the objective realization of the graininess, that is, the light-scattering power (Callier effect) of the emulsion. In order to clarify the relationship between this effect and other factors contributing to the evaluation of G, an experimental study of the causes of the light-scattering power under the particular conditions under which the graininess of an emulsion is measured was undertaken.

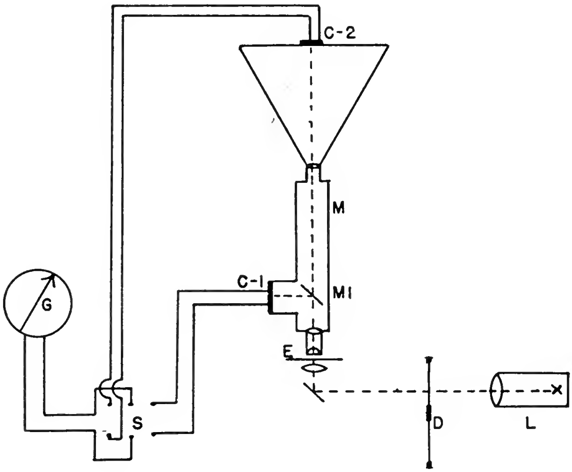

FIG. 1. Apparatus for measuring scattering in photographic emulsions: *L*, tungsten arc lamp; *D*, rotating shutter with adjustable sectors; *E*, emulsion sample on rotating stage; *MI*, transparent mirror; *C-1*, *C-2*, boundary layer photocells (Lange); *S*, double-pole double-throw switch; *G*, galvanometer.

(II) THE METHOD

The method employed is similar to the optical system in the graininess meter of Goetz, Gould, and Dember;[1, 4] it differs only in the elimination of mechanical parts not essential to the determination of the scattering power.

Fig. 1 gives a schematic view: The tungsten arc lamp L illuminates through an achromatic condenser of large aperture the emulsion *E* mounted upon the rotary stage of a microscope. The intensity of the illumination can be varied by a rotating disk *D* which carries a large number of equal-sized sectors which can be obscured individually. The speed of rotation of *D* was adjusted to be far above the mechanical frequency of any of the instruments used—hence the spectral distribution of the light-source as well as the aperture of the incident beam were always constant.

The rotary stage (not shown in the diagram) upon which the emulsion sample was mounted was driven by motor at 30 rpm, and was adjusted so that its center was several millimeters off of the optical axis of the condenser and objective. In this manner, the transparency was averaged over an annular section of the emulsion and local irregularities were avoided. The microscopic objective was a 20*X* apochromat with a numerical aperture of $f/0.60$. Above it the beam was split by a clear thin glass plate *MI* deflecting a fraction of the light transmitted through the objective into a horizontal direction upon a very sensitive photoelectric layer cell (Lange), *C-1*. The vertical beam projected through the tube *M* into an ocular (15*X* compensation) and from there through a camera. In the image plane a second photoelectric cell *C-2* was mounted. The difference between the positions of *C-1* and *C-2* effected thus, by scanning, an integration of the transmitted light over a large area of the emulsion in the former, and over a very small area in the latter cell. The ratio of the field diameters was approximately 70:1.

The photoelectric currents were measured with a mirror galvanometer *G* (Fig. 1) in alternate connection with each of the photoelectric cells through a double-throw switch *S*. The intensity of the light entering the objective was kept approximately independent of the density of the emulsion sample in order to obtain commensurable galvanometer readings, *i. e.*, by the adjustment of the sectors on *D*.

For the calibration of this instrument first a clear glass plate or film base (representative of a "non-scattering" object) was mounted upon the stage and the photo currents of the lower and the upper cell were determined and expressed as the ratio $I_1/I_2 = I_0$. Obviously I_0 is an instrument factor depending only upon the optical configuration and the geometry of the device. If a scattering object is placed on the stage, a change of the light distribution takes place and the ratio $I_1'/I_2' = I > I_0$ is observed. I/I_0 represents thus the scattering power of the object in arbitrary units.

The density D of the emulsion samples was measured with a gray wedge densitometer (Eastman).

(III) RESULTS

(*a*) *Various Emulsions.*—Fig. 2 represents a typical variation of the scattering power S with the density D for two different ***negative*** emulsions varying largely in grain size (A having rough, D having fine grain). The measurements were taken from sensitometric strips. The straight line in Fig. 2 indicates an approximately linear relationship between S and D for $D > 0.1$. The scattering for a given value of D is the larger, the smaller the grain of the emulsion.

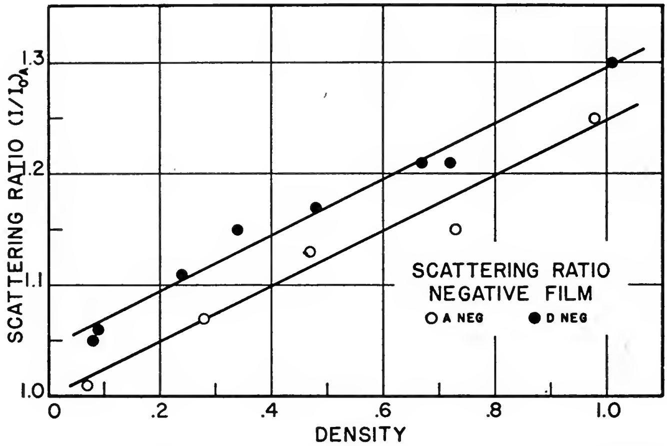

FIG. 2. *S-D* diagram: variation of scattering ratio I/I_0 with density, for two different negative emulsions (A rough grain, D fine grain).

(*b*) *Positive Prints.*—Fig. 3 represents measurements of the $S(D)$ function for a positive emulsion exposed directly and exposed (printed) through three different types of negative emulsions. It is well known that the graininess of a print is under most conditions larger than the graininess of the negative; hence the negative emulsions were chosen to vary considerably as far as their graininess is concerned. Some of these positive prints thus showed variations seen easily with the unaided eye. The observations nevertheless indicated that the scattering power of the prints is within the experimental error the same as for the directly exposed positive film. This proves that the scattering power is independent of the graininess, *i. e.*, size and the distribution of the statistical fluctuations of the grain.

(*c*) *Printing Method.*—It is well known that the wavelength of the printing light influences the graininess considerably, ultraviolet being considerably more favorable, probably due to its being more scattered in the negative emulsion. In order to study the effect of this type of printing upon the scattering power of the positive film, prints from the rough and fine-grain negative emulsions (shown in Fig. 2) were made, once with white and once with ultraviolet light.

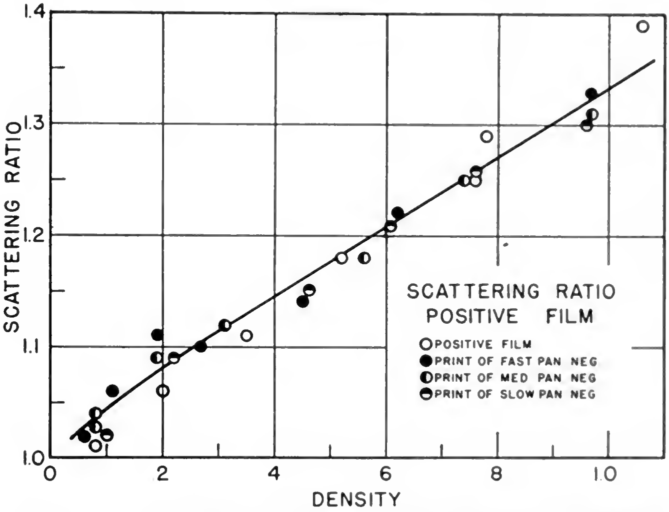

FIG. 3. *S-D* diagram: variation of scattering ratio I/I_0 for the same positive emulsion exposed directly and printed through emulsions of various grain sizes.

The results are plotted in Fig. 4, showing no systematic deviation of the scattering power for either the nature of the printing light or the graininess of the negative material.

(*d*) *Dependence upon Gamma.*—A set of sensitometric strips of positive film were exposed and developed within a gamma range varying from 0.44 to 2.50 and their scattering power measured at a density of approximately $D = 0.5$. The S-values were found to be identical within the experimental error; *i. e.*, within 2.5 per cent. It can thus be concluded that in spite of the large effect that gamma has upon the graininess, it does not influence the scattering power of the emulsion.

(IV) DISCUSSION OF RESULTS

From the results described above, it is evident that the statistical fluctuations of the grain configuration in an emulsion, that is, the factors that cause the chief limitation in the optical resolving power as well as produce the noise level on a sound-track and the discontinuity of a visually realized photographic image, do *not* influence the scattering power; but that the latter is dependent chiefly upon the size of the individual grain, *i. e.*, granularity. Thus neither the contrast (gamma) of a negative nor the color of the printing (not the illuminating) light-source was found to affect the scattering power of the positive print within the density range studied.

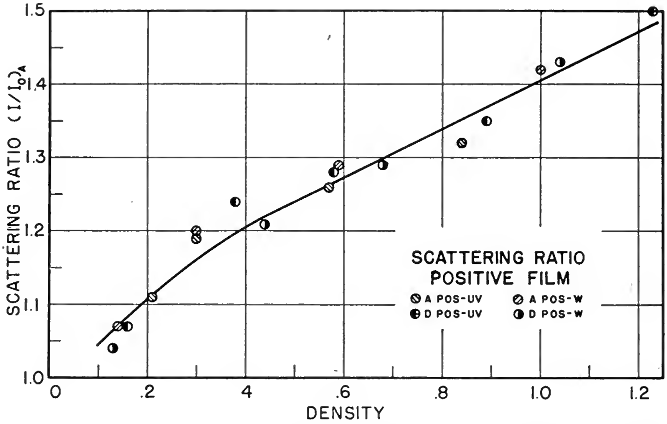

FIG. 4. *S-D* diagram: variation of scattering ratio I/I_0 for the same positive emulsion exposed with white and ultraviolet printing light through a rough-grain and a fine-grain negative emulsion.

The fact that the scattering power shows an inverse relationship to the grain size is in qualitative agreement with observations of various previous observers.[5, 6] The approximately linear relationship between scattering power and density, however, is not only at variance with the density dependence of the graininess but also with previously published results. Narath[7] observed in the density range between 0 and 1 a behavior so widely varying among different emulsions that one may suspect secondary influences (such as scattering irregularities in the emulsion and the base). As this author does not scan the sample, his observations are restricted necessarily to a small area of the emulsion, where accidental faults may influence the results.

Though Narath's optical arrangement was considerably different from the one used here, it is not plausible to explain the difference of the density function by the difference in the optical method.

The difference between the density functions of the scattering power and the graininess seem worthy of a brief discussion: Fig. 5 shows the graininess density function of two different emulsions,[4] measured with the graininess meter, *i. e.*, under optical conditions identical with those used for the measurement of the scattering power, G_1, G_2 are determined from *relative* transparency fluctuations, while G_{s1}, G_{s2} are determined from *absolute* transparency fluctuations, both from the same pair of emulsions. A comparison between, *e. g.*,

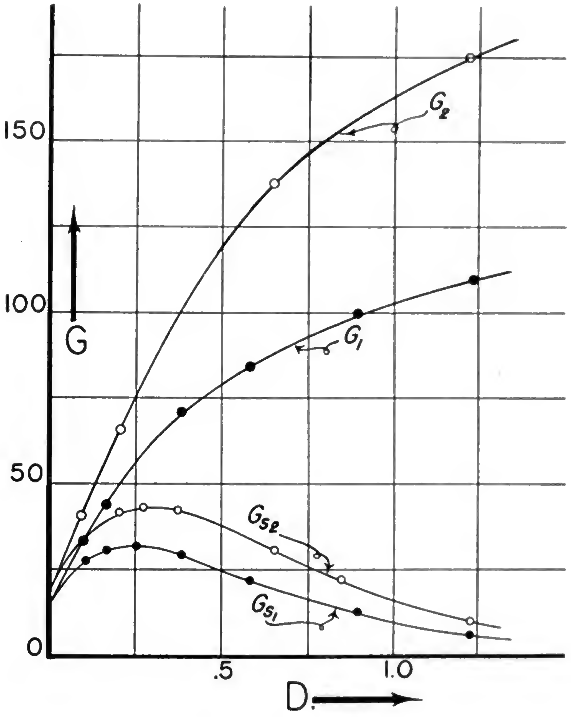

FIG. 5. *G-D* diagram: typical variation of graininess of two different emulsions with the density, where G_1, G_2 is based upon *relative* $(\Delta T/T_m)$ and G_{s1}, G_{s2} upon *absolute* transparency fluctuations.

Figs. 3 and 4, and Fig. 5 shows the obvious difference between the scattering power and the graininess. This difference results in a peculiar mutual relationship between graininess and scattering power when both are realized under optical conditions closely similar to those employed for image and sound reproduction. If the graininess G is defined in terms of $\Delta T/T_m$, *i. e.*, as relative transparency fluctuations, realized by determining the amplitude and frequency of fluctuations with constant field brightness (constant transmitted light), the scattering effect renders the absolute magnitude of ΔT, depending upon the size of the field to which the (constant) field brightness ($\sim T_m$) is adjusted. In a small field such as is scanned by the upper cell in Fig. 1, an emulsion with a large scattering power requires a large total field brightness while an emulsion of equal density but small scattering power needs less light; similarly, if a large field, such as the lower cell in Fig. 1, is referred to for the adjustment for the field brightness, an emulsion with a large scattering power will register a smaller ΔT at the upper cell than a sample causing only little scattering. In the first case the scattering power will cause the observation of a graininess larger than in the second instant, though the grain configuration will be identical. At the same field brightness a *large* field will consequently show less apparent graininess for an emulsion with a large than with a small scattering power, a *small* field produces, *cet. par.*, the opposite effect. Certain differences in the realization of the graininess of identical emulsions on large and small fields, such as in picture and sound projection, are likely to be due to this relationship.

Since the relative influence of both factors, graininess and scattering, varies with the density, the resulting effect is predictable only if both functions are known for the emulsion in question.

The authors wish to express their appreciation for considerable technical assistance received from Agfa Ansco, Binghampton, and Agfa Raw Film Corporation, Los Angeles.

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SOME ENGINEERING ASPECTS OF PORTABLE TELEVISION PICK-UPS*

HARRY R. LUBCKE**

Summary.—*The routine of portable television programing may be termed "applied" television engineering. The preceding is hardly more than a byplay of words, but is intended to convey the impression of an engineering technique evolved to put a program across regardless of extenuating circumstances. The emphasis is not on engineering, but on the program, with engineering as one of the tools used in accomplishing the program.*

The essentials of the technique are set forth. Proper preparation requires constant servicing of equipment when the latter and staff are available. A pre-program test several hours before program time is essential to consistent performance and allows reasonable time for correcting installation or transportation-caused faults. A suitable equipment "warm-up" period precedes the program. Service failures during the program are usually unpredictable but must be met by prompt diagnosis and repair. A thorough knowledge of the many circuits, normal and abnormal operational characteristics thereof, and the "knack" of finding trouble are requisites of this aspect.

Experience in the technique eliminates certain difficulties by methodical preparation. The television engineering attributes of a program location are tested and recorded prior to the arrival of equipment. Voltmeter, dummy load, photometer, field glasses, and photographic camera comprise the preliminary test equipment.

Significant experiences in televising 140 separate portable programs of the Don Lee Television Station, W6XAO, Hollywood, are recited.

"How many minutes until program time?" "Sorry, we were delayed; the space for our truck was filled with locked parked cars." "What did you do? It doubled the signal strength!" "Switch over to camera No. *1* direct, I've got a fire in master control!"

Such phrases are a part of portable television broadcasting. The emphasis is on the program. The action is applied engineering. The goal is an uninterrupted succession of perfect pictures.

A portable television pick-up staff has somewhat the problem of the young parent, of inducing the offspring to perform correctly at the proper time. The public never knows what may have occurred before program time, nor what happens after it, and it cares less.

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* Presented at the 1942 Spring Meeting at Hollywood, Calif.; received April 15, 1942.

** Don Lee Broadcasting System, Hollywood, Calif.

All activities are directed toward establishing the best insurance designed to accomplish peak technical performance during the program period.

Several factors contribute to the desired end: methodical preparation, adequate time for preparation, careful testing, an experienced crew having the "feel" of the equipment, technical-programing coördination, adequate policing to prevent damage to equipment during the program, and "luck." These factors will be treated in turn.

FIG. 1. The Mt. Lee television installation of the Don Lee Broadcasting System, Hollywood. This is the receiving location for all portable pick-ups where the incoming image on 324 megacycles is rebroadcast by station *W6XAO*. The tower is 2000 feet above sea level and the building houses all television operations.

The basis of methodical preparation lies in the formulation and use of suitable lists and forms. At the start of our portable pick-up endeavors a list of necessary items was formulated, down to pieces of rope, masking tape, screws, nails, and a hammer. Upon starting on a job, the equipment is checked off against the list. Experience dictates changes, and the lists are frequently revised. Large metal tool cases have been found convenient to carry parts, tools, and lenses; one case for each classification.

The principal form employed has been our "Mobile Television Pick-Up Work Sheet," which tabulates the information required for the pick-up. It is desirable to describe the television requirements to the manager and his electrician on the premises where the event occurs. The head of the portable television department surveys the site, getting the major portion of the information for the form by inspection and by asking questions.

Many questions are answered in consultation at the site. However, as regards important technical factors, the criterion of not taking anything for granted unearths difficulties at an early date when they are relatively harmless. Thus, the television engineer may include two heavy-current electric heaters and an a-c voltmeter among his equipment. Placing them on the line removes all doubts as to the regulation of the voltage and the ability of the fuses to carry the thirty-ampere load. Should this test not be performed at this time, it is then performed at the preliminary or propagation test, or finally, at the very start of operations as many hours before program time as possible.

Equipment always carried by the survey engineer comprises a photometer (or Weston brightness meter), field-glasses, and a photographic camera. The former is used to test the installed illumination, as at a prize fighting ring, or the effect of grandstand shadows. The field-glasses are used to determine whether a line-of-sight path exists from the program site to the home television station. Beam television transmitting and receiving equipment operating on a frequency of 324 megacycles, as used by the Don Lee Broadcasting System, requires substantially a line-of-sight transmission path. The camera is used to take photographs of the premises pertinent to the scene of action, the proposed points of installation, and as an additional check on the illumination of the scene. It is not difficult to calibrate a given film and camera to the sensitivity of the television system, and the photographs thus obtained are a definite guide and aid in evaluating existing conditions and in suggesting changes.

After the initial survey, which may be a week or even a month in advance of a new program or series of programs, "adequate time for preparation" and "careful testing" call for a propagation test if the relay distance is greater than five miles. This entails installing the portable transmitter and an antenna at the program site and sending a "dummy picture" back to the home station. The latter is comprised of a group of vertical black and white bars, and is produced by a small self-contained portable oscillator operating on a frequency of 94,500 cycles. Six white and six black bars are produced. By noting the evenness of the boundary from black to white the amount of "noise" on the relay propagation channel is indicated. Unevenness is caused by interference bursts occurring near the time of the high-frequency synchronizing pulse of sufficient amplitude to desynchronize the receiver scanning oscillator.

With relay equipment of given power and sensitivity the only method of increasing the signal-to-noise ratio on a pick-up is to vary the placement and the type of transmitting and receiving antennae. The rapidity and effectiveness with which a desirable combination can be effected may be regarded as half the requisite skill of portable pick-up work.

After a few years' work, an organization usually comes to rely upon a few types of antennae. In the Don Lee organization these have reduced to a "pitchfork" type for transmitting and either a pitchfork or *V*-antenna for receiving. The merit of the former lies in portability, ease of erection, and signal-strength performance, while the merit of the latter lies in extreme sensitivity or gain. A pitchfork antenna consists of sixteen half-wave elements arranged in four groups spaced vertically one-half wavelength and horizontally one-fourth wavelength. Eight elements are driven, and eight elements form parasitic reflectors spaced one-fourth wavelength away. A *V*-antenna consists of two wires ten wavelengths long forming a *V* with a central angle of 30 degrees and the open ends terminated in a small inductance, a 50-ohm resistor, and a vertical half-wave element "ground," while the closed end comprises a 300-ohm, two-wire transmission line which conveys energy to the receiver.

As important as the antenna itself is its placement in space. I am impelled to mention an experience recently related to me, of the National Broadcasting Company with the Empire State Building installation. This experience emphasizes the importance of antenna placement and also shows that the problems and technique of this work are not unique to one organization, but are common to all in the field.

A pre-program test was in progress at the New York station with not too encouraging results. The signal-to-noise ratio was not as high as desirable. Suddenly it doubled for apparently no reason whatever. Investigation soon revealed that a routine window washer had just raised the window frame on which was attached the ultra-high-frequency receiving antenna, raising it vertically about three feet! The effect of this increment in relation to the 1200-ft antenna height requires little further comment on the importance of antenna placement.

The experience of the Don Lee organization has shown that increased elevation of antennae, even above purely wooden roofs, invariably increases the signal-to-noise ratio. Roughly, considering the placement of the transmitting antenna particularly, and in the range of from ten to fifty feet above a building structure, doubling the height of the antenna *above the structure* will double the signal-to-noise ratio. This holds whether the propagation path is line-of-sight or not, whether there is a clear sweep in front of the building toward the receiving station, and whether the building is ten or a hundred feet high.

It is important to note that this occurs in spite of the reverse effect of increased feeder loss with increased length. The above statements include this countereffect, which latter may double for each doubling of height if the transmitter is located at the base of the antenna mast. This performance is all the more surprising when it is recalled that feeder losses at 324 megacycles are large. We invariably use a two-inch-spaced number-twelve two-wire feeder, Victron insulated.

Horizontal positions are equally important. The antenna is kept as far as possible from all objects, metallic or non-metallic, but the combined effect of several objects in the neighborhood can not be known until experimentally determined. Proper technique requires that all reasonable displacements be made during the propagation-test period.

V-antennae must be oriented to the transmitter in order to achieve maximum response, and besides properly locating the antenna in azimuth the vertical clearance above ground and the geometry of the *V* must be adjusted. The vertical angle of maximum receptivity decreases with vertical clearance. Particularly when the receiving location is a few thousand feet above the program location on the plain below, as at Mt. Lee, Hollywood, the *V* must be at least five wavelengths above ground. Alteration of the central angle of the *V* three degrees either side of the theoretical often results in reasonable signal increases, thereby compensating for some local idiosyncrasy.

The last phase, allowing adequate time for preparation, is concerned with the day of the telecast. Circumstances permitting, the portable crew is dispatched eight working hours before the scheduled conclusion of the telecast. A crew of two engineers and an assistant are then able to drive the equipment truck to the location, establish necessary connections, place the cameras in position, install sound equipment, and make a complete test of facilities two to four hours before program time on a pick-up of fixed format, such as a baseball game or a boxing or wrestling match.

On more involved pick-ups, such as a soap-box derby, held in the hills and necessitating a portable gasoline-driven power truck, antenna erected in a field, cameras established on hillsides, telephone lines extended, and conditions of self-sufficiency met as would become a military expedition, a crew of six men dispatched ten hours before conclusion of the program is required.

On Easter Sunrise pick-ups from the Hollywood Bowl it has been our practice to start installation Saturday afternoon, make tests with the failing light of evening, and then with the artificial light installed, work until nine o'clock Saturday night and then return at four A. M. Sunday morning. Electric heaters are kept on the equipment all through the night in order to prevent the infiltration of dampness, which lengthens the warm-up period considerably.

On the other hand, we have occasionally televised two portable pick-up programs in one day from locations several miles apart, with one set of equipment and one crew. With a trained crew of six men the equipment can be in operation one hour after arriving at a location.

Careful testing and complete familiarity of the crew with the equipment are the best forms of program insurance. Capable portable pick-up television engineers must carefully scrutinize the equipment performance under all sorts of conditions. The manner in which equipment begins and ceases to function upon being switched on or off provides a definite indication of any probable surge-provoked failure. If a condenser, resistor, or other component fails it does so usually during an "on" or "off" operation. The seriousness of a failure caused by shutting off the equipment at the end of a successful pre-program test will be appreciated. Engineers are instructed to observe carefully the "die-down" behavior of the equipment;

such as the manner in which the images leave the monitor cathode-ray tubes, the rapidity with which transmitter meters return to zero, a crackle, a minute spark, and, of course, any odor of burning insulation. The behavior of properly functioning equipment is invariably uniform. Anything unusual is a danger signal.

In addition, the functioning of the equipment during the pre-program test tells an experienced operator whether everything is normal, or whether the unusual operation of one or more controls indicates a forthcoming failure. An engineer with a keen perception of these many operating indications has the "feel" of the equipment.

Technical-programing coördination is important in preventing avoidable disasters. The technical and production heads witness a performance, or the sequence and locale of events are described on the location by a qualified executive associated with the event. Decisions from artistic and technologic viewpoints are reached, and departures therefrom involving general movement of the equipment just prior to program time are not allowed.

Adequate policing is important to prevent damage to the television equipment. At one Easter Sunrise service our portable transmitter was taken off the air for a few minutes at the close of the program by a young man utilizing the power cable as a rope for climbing a steep hillside in the Hollywood Bowl. Our operator at the top of the hill saw the cable move, engaged in a tug-of-war with the unknown climber and a large plug was pulled from its socket in the equipment. The next year the cable was firmly tied to a stout stake driven in the ground, and a safety loop of cable was interposed between the stake and the socket.

In general, one or more policemen, Boy Scouts, or uniformed officials should be detailed to guard the cables and equipment of an installation.

No consideration of portable television operations would be complete without mention of the unpredictable combinations of circumstances and consequences briefly described as "luck." It is futile to attempt to enumerate the countless happenings that occur in such operations. The requirements of portability preclude duplicate channels of equipment, the vagaries of weather and natural illumination are factors beyond human control, and the newness of television instrumentalities does not provide the reliability to be found in other arts and acquired through years of experience. However, a conscious alertness of staff tends to minimize the consequences of "bad luck" and enhances the opportunities for "good luck."

CURRENT LITERATURE OF INTEREST TO THE MOTION PICTURE ENGINEER

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

American Cinematographer

23 (Nov., 1942), No. 11

A Portable Developing-Machine for Field Service with the Army (pp. 473, 489)	W. Stull
The First Real Combat Camera (pp. 474–475, 489–490)	W. Stull
"Post-Recording" Dialog for Educational and Training Films (pp. 477, 500)	J. A. Larsen, Jr.
A Professional Sunshade for the Eastman Special (pp. 485, 492)	C. Murray

British Kinematograph Society, Journal

5 (Oct., 1942), No. 4

The Electron Multiplier and Its Application to Sound Reproduction (pp. 102–110)	F. J. G. Van Den Bosch
The Post-War Organization of Scientific Films (pp. 111–113)	H. D. Waley
High-Speed Photography and Its Application to Industrial Problems (pp. 114–127)	E. D. Eyles

Educational Screen

21 (Oct., 1942), No. 8

Motion Pictures—Not for Theaters (pp. 302–304, 306), Pt. 40	A. E. Krows

Electronics

15 (Nov., 1942), No. 11

Recording Machinery Noise Characteristics (pp. 46–51, 164–165)	H. D. Brailsford

Motion Picture Herald (Better Theaters Section)

149 (Oct. 17, 1942), No. 3

How Viewing Angles Determine the Basic Form of the Auditorium (pp. 8–9, 22)	B. Schlanger

Photographische Industrie

40 (Jan. 20, 1942), No. 3/4	
Zeitraffung und Zeitdehnung (Time-Lapse and Slow Motion) (pp. 22–23)	
40 (Feb. 4, 1942), No. 5/6	
Stereophonie mit Dynamikerweiterung (Stereophonic Sound with Wider Dynamic Range) (pp. 34–36)	P. HATSCHEK
40 (Feb. 17, 1942), No. 7/8	
Ein neuer franzosisches Verfahren für plastische Kinoprojektion (A New French Method for Stereoscopic Motion Picture Projection) (p. 47)	LUSCHER
40 (March 3, 1942), No. 9/10	
30 Jahre plastischer Farbentonfilm (30 Years of Stereoscopic Color Sound Film) (pp. 71–72)	W. SELLE
40 (March 31, 1942), No. 13/14	
Die Widerstandsfahigkeit des Film Behalters gegen Feuer (Resistance of the Film Container to Fire) (pp. 98–100)	
40 (Apr. 14, 1942), No. 15/16	
Neuzeitliche Lichtgebung in Filmtheatern (Modern Lighting in Motion Picture Theaters) (pp. 108–111)	H. WINKLER
40 (Apr. 28, 1942), No. 17/18	
Neuer Normblattentwurf. DIN ENTWURF 15632 Film 16-mm Aufnahmespulen (DIN Standard 15632. 16-Mm Film Take-Up Spool) (p. 123)	
40 (May 12, 1942), No. 19/20	
Das Auflosungsvermogen bei der photographiscen Aufnahme (The Resolving Power of the Photographic Emulsion). Pt. I (pp. 128–130)	H. ROEDER AND G. HANSEN
Optische Kopiermaschine statt Filmtrick (The Optical Printer Instead of Film Tricks) (pp. 135–136)	C. EMMERMAN
40 (May 26, 1942), No. 21/22	
Das Auflosungsvermogen bei der photographiscen Aufnahme (The Resolving Power of the Photographic Emulsion). Pt. II (pp. 139–140)	H. ROEDER AND G. HANSEN
Filmentwicklungsmaschine ohne Zahntrommeln (Film Developing Machine without Sprockets) (pp. 146–148)	W. NAUCK
40 (June 9, 1942), No. 23/24	
Kohlenachschub bei H. I. Spiegelbogenlampen (Carbon Feeding in High Intensity Reflector Arc Lamps) (pp. 158–160)	
40 (June 23, 1942), No. 25/26	
GerauscharmerTonfilm (Low Noise Level Sound Film) (pp. 170–172)	P. HATSCHEK

PROGRAM OF THE 1942 FALL MEETING*

OCTOBER 27th–29th, HOTEL PENNSYLVANIA, NEW YORK, N. Y.

TUESDAY, OCTOBER 27, 1942

Morning Session: General Session; A. C. Downes, *Chairman*

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

Report of the Financial Vice-President, A. S. Dickinson.

Report of the Engineering Vice-President, D. E. Hyndman.

Welcome by the Past-President, E. Allan Williford.

Election of Officers and Governors for 1943.

"Wright Field Training Film Laboratory;" H. C. Brecha, Dayton, Ohio.

"The Navy's Utilization of Film for Training Purposes;" Wm. Exton, Jr., Lt. U.S.N.R., Bureau of Navigation, Navy Department, Washington, D. C.

"The Documentary, Scientific, and Military Films of the Soviet Union;" Gregory L. Irsky, Cinema Committee of the U.S.R.R., Washington, D. C.

"The Underground Motion Picture Industry in China;" T. Y. Lo, Deputy Chief, Film Section, Military Affairs Commission, Government of the Republic of China.

Noon: Informal Get-Together Luncheon; E. Allan Williford, *Presiding.*

Introduction of Officers-Elect for 1943.

Addresses by:

Mr. Claude Lee, Director of Public Relations, Paramount Pictures, Inc., New York, N. Y.

Colonel M. E. Gillette, Commanding Officer, U. S. Army Signal Corps Photographic Center, Astoria, L. I., N. Y.

Colonel Montgomery Schuyler, Assistant Director of Disaster Relief, New York Chapter, American Red Cross.

Afternoon Session: Radio City Music Hall Tour; Sylvan Harris, *Chairman.*

An extensive tour of the technical facilities of the Radio City Music Hall, front-stage and back-stage; arranged by courtesy of Mr. G. S. Eyssell, president and managing director of Radio City Music Hall; Mr. Fred L. Lynch, publicity director; and Mr. Harry Braun, sound director.

Evening Session: Museum of Modern Art Film Library; E. F. Kerns (Technical Director, Film Library), *Chairman.*

Address on the development of the motion picture by Miss Iris Barry, accompanied by a showing of pictures selected for their importance in the development of the art.

"Motion Pictures and the War Effort;" by Captain John G. Bradley, National Archives, Washington, D. C.

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* As actually followed at the sessions.

WEDNESDAY, OCTOBER 28, 1942

Morning Session: General Session; D. E. Hyndman, ***Chairman.***

"Sound Control in the Theater Comes of Age;" H. Burris-Meyer, Stevens Institute of Technology, Hoboken, N. J.

"Recent Developments in Sound-Tracks;" Edward M. Honan and Clyde R. Keith, Electrical Research Products Division of Western Electric Co., Hollywood, Calif.

Society Business

Report of the Theater Engineering Committee; Alfred N. Goldsmith, *Chairman.*

"Effect of High Gate Temperatures on 35-Mm Film Projection;" E. K. Carver, R. H. Talbot, and H. A. Loomis, Eastman Kodak Co., Rochester, N. Y.

"Film Distortions and Their Effect on Projection Quality;" E. K. Carver, R. H. Talbot, and H. A. Loomis, Eastman Kodak Co., Rochester N. Y.

Afternoon Session: General Session; J. A. Maurer, ***Chairman.***

"Recent Laboratory Studies of Optical Reduction Printing;" R. O. Drew and L. T. Sachtleben, RCA Manufacturing Co., Inc., Indianapolis, Ind.

"Some Characteristics of Ammonium Thiosulfate Fixing Baths;" Donald B. Alnutt, Mallinckrodt Chemical Works, St. Louis, Mo.

"Copper and Sulfide in Developers;" R. M. Evans, W. T. Hanson, Jr., and P. K. Glasoe, Eastman Kodak Co., Rochester, N. Y.

"Factors Affecting the Accumulation of Iodide in Used Photographic Developers;" R. M. Evans, W. T. Hanson, Jr., and P. K. Glasoe, Eastman Kodak Co., Rochester, N. Y.

"Effect of Composition of Processing Solutions on Removal of Silver from Photographic Materials;" J. I. Crabtree, G. T. Eaton, and L. E. Muehler, Eastman Kodak Co., Rochester, N. Y.

"A Precision Recording Instrument for Measuring Film Width;" S. C. Coroniti and H. S. Baldwin, Agfa Ansco, Binghamton, N. Y.

Evening Session: Fifty-Second Semi-Annual Banquet and Dance.

Introduction of Officers-Elect for 1943.

SMPE Journal Award.

THURSDAY, OCTOBER 29, 1942

Morning Session: Symposium on the Production of 16-Mm Motion Pictures; Ralph E. Farnham, ***Chairman.***

Introduction by John A. Maurer, *Chairman* of the Committee on Non-Theatrical Equipment.

"Sixteen-Mm Production Planning;" Russell C. Holslag, J. A. Maurer, Inc., New York, N. Y.

"The Practical Side of Direct 16-Mm Laboratory Work;" Lloyd Thompson, The Calvin Co., Kansas City, Mo.

"Sixteen-Mm Laboratory Practice;" Wm. H. Offenhauser, Jr., Washington, D. C.

Afternoon Session: Symposium on the Production of 16-Mm Motion Pictures (Continued); Frank E. Carlson, *Chairman*

"Sixteen-Mm Sound Recording;" John A. Maurer, J. A. Maurer, Inc., New York, N. Y.

"Sixteen-Mm Editing and Photographic Embellishment;" Larry Sherwood, The Calvin Co., Kansas City, Mo.

"Sixteen-Mm Screen Illumination;" Frank E. Carlson, General Electric Co., Cleveland, Ohio.

"Carbon Arc Projection of 16-Mm Film;" W. C. Kalb, National Carbon Co., Cleveland, Ohio.

"Application and Distribution of 16-Mm Motion Pictures;" F. W. Bright, The Aetna Casualty and Surety Co., Hartford, Conn.

"Improvement in Motion Picture Printer Illumination Efficiency;" C. J. Kunz, H. Goldberg, and C. E. Ives, Eastman Kodak Co., Rochester, N. Y.

Evening Session: U. S. Army Signal Corps Photographic Center; General Session; E. Allan Williford, *Chairman.*

Welcome by Colonel M. E. Gillette, Commanding.

"Analysis of Fast Action by Motion Pictures;" E. M. Watson, Capt., Ordnance Dept., Watervliet Arsenal, Watervliet, N. Y.

"Sixteen-Mm Motion Pictures and the War Effort;" Michael S. David, General Motors Corp., Detroit, Mich.

"Motion Pictures in Aircraft Production;" Norman Matthews, Bell Aircraft Co., Buffalo, N. Y.

Exhibition of Army Training Films produced by the U. S. Army Signal Corps, and conducted tour of the Photographic Center, U. S. Signal Corps.

HIGHLIGHTS OF THE FALL MEETING

HOTEL PENNSYLVANIA
NEW YORK
OCTOBER 27–29, 1942

The 1942 Fall Meeting of the Society, recently concluded at New York, reflected very strongly the state of the times. The program included seven presentations dealing directly with the uses and applications of motion pictures in the prosecution of the war, and a number of other papers on industrial applications of motion pictures in the war industries.

The sessions were remarkably well attended, as well as the sessions of any previous Meeting, far beyond expectations in view of the pressure under which the members of the motion picture industry are laboring in these troublous times. The interest of the Armed Services of the nation in our semi-annual meetings is also very gratifying; the Army, the Navy, and the Air Forces are all represented on the program, and an outstanding feature of the three-day conclave was the session held at the Photographic Center of the U. S. Army Signal Corps at Astoria, Long Island.

An innovation of the Meeting was the holding of three of the sessions away from the Hotel headquarters: one at the Museum of Modern Art Film Library, another at the Radio City Music Hall, and the third, as mentioned, at the Army Signal Corps Photographic Center. These sessions provided interesting and profitable relief from the routine, and sometimes arduous, regular papers sessions.

After the usual reports of the Officers of the Society, the Tuesday (October 27th) morning session opened with a description by H. C. Brecha of the new Army Air Forces Laboratory at Wright Field and an account of the production of training films for the Air Forces. This was followed by a discussion by Lt. Wm. Exton, Jr., of the Navy's program in the utilization of training films. Of especial interest were the papers by Gregory L. Irsky and T. Y. Lo, describing the progress of the motion picture industries in the U.S.S.R. and in China under the difficulties of actual warfare. Motion pictures play an exceedingly important role on the Russian front, not only in helping to maintain the morale of the fighting forces and the civilian population in the fighting areas, but also in training the soldiers actually at the front. In China, Mr. Lo reported, the motion picture studios actually had to move from place to place to avoid the Japanese bombings, and, in fact, eventually had to construct laboratories and other facilities below ground.

At the informal luncheon held at noon in the Roof Garden of the Hotel Mr. E. A. Williford, presiding in the absence of the Mr. Emery Huse, president of the Society, announced the results of the elections for 1943. The successful candidates were as follows:

President: Herbert Griffin
Executive Vice-President: Loren L. Ryder
Editorial Vice-President: Arthur C. Downes
Convention Vice-President: William C. Kunzmann

Secretary: E. Allan Williford
Treasurer: M. R. Boyer
Governors: W. A. Mueller
H. W. Remersheid

Mr. Emery Huse continues as a member of the Board in the capacity of Past-President. Terms of office of those listed above are for two years, except for the Secretary and Treasurer, who held office for one year.

Additional members of the Board of Governors are Dr. Alfred N. Goldsmith, who was reëlected Chairman of the Atlantic Coast Section, and Charles W. Handley, elected Chairman of the Pacific Coast Section. At the business meeting of the Society, held on the morning of Wednesday, October 28th, amendments of the Constitution and By-Laws were adopted providing for five additional Board members. Those appointed to fill the vacancies created by the establishment of these new Board members were H. D. Bradbury, J. H. Spray, R. O. Strock, A. M. Gundelfinger, and H. W. Moyse. The amendments referred to were published in the September issue of the JOURNAL, p. 208.

Following the announcements by Mr. Williford, the principal speaker at the luncheon was Mr. Claude Lee, Director of Public Relations of Paramount Pictures, Inc., New York. Seated also at the speakers' table were Col. M. E. Gillette of the U. S. Army Signal Corps, and Col. Montgomery Schuyler, Assistant Director of Disaster Relief of the New York Chapter of the American Red Cross.

In the afternoon the members of the Society were the guests of the Radio City Music Hall. Through the courtesy of Mr. G. S. Eyssell, president and managing director of the Music Hall, Mr. Fred L. Lynch, publicity director, and Mr. Harry Braun, sound director, a special tour of the technical facilities of the Music Hall, both front-stage and back-stage, was provided. The tour included practically all the departments of the organization concerned with putting on the show: projection room, sound department, wardrobe department, power plant, refrigerating plant, stage equipment, music department, *etc.* The Society extends its thanks to Messrs. Eyssell, Lynch, and Braun for this interesting contribution to our sessions.

The evening session of Tuesday was held in the auditorium of the Museum of Modern Art, presided over by Mr. E. F. Kerns, of the Film Library staff. A series of early motion pictures, especially selected for their importance in the development of the cinematic art, were projected, and preceding each selection Miss Iris Barry, of the Museum, discussed the relation of the picture to the motion picture art as we know it today. Acknowledgment is due to Miss Barry and Mr. Kerns, and to Mr. John Abbott, curator of the Film Library, for their kindness in arranging this session.

The morning session of Wednesday, October 28th, opened with a paper by Harold Burris-Meyer on special applications of sound under the title, "Sound Control in the Theater Comes of Age." This was followed by an interesting paper by Messrs. E. M. Honan and C. R. Keith, of ERPI, discussing the various types of sound-tracks used by the motion picture industry. A feature of the session was the report of the Theater Engineering Committee of the Society, Dr. Alfred N. Goldsmith, Chairman, which included reports from the sub-committees on Projection Practice and on Civilian Defense in Theaters. The latter subcommittee has only recently been established, and its studies of the problems of air-raids and black-outs, *etc.*, are expected to be noteworthy contributions to the industry. The report of the Projection Practice Sub-Committee included an extremely valuable discussion of the problems involved in various mechanical systems that have recently been proposed for conserving motion picture film.

Other papers of the Wednesday morning session were two by Messrs. E. K. Carver, R. H. Talbot, and H. A. Loomis, of the Eastman Kodak Company, on the effect of high gate temperatures in 35-mm projection and on the effect of film distortion upon the quality of projection. These two papers provide very valuable studies of some serious problems that have been facing the industry.

The afternoon of Wednesday was devoted principally to processing and laboratory problems. R. O. Drew and L. T. Sachtleben, of RCA, presented some recent laboratory studies of optical reduction printing, followed by a paper by D. B. Alnutt, of the Mallinckrodt Chemical Works on "Some Characteristics of Ammonium Thiosulfate Fixing Baths." Other papers, by Messrs. Evans, Hanson, and Glasoe, and Messrs. Crabtree, Eaton, and Muehler, all of the Eastman Kodak Company, dealt with the questions of copper and sulfide in developers, the accumulation of iodide in developers, and the effect of the composition of processing solutions upon the removal of silver from photographic materials. The session concluded with a paper by S. C. Coroniti and H. S. Baldwin, of Agfa, describing a precision recording instrument for measuring film width.

The Fifty-Second Semi-Annual Banquet and Dance of the Society was held in the Georgian Room of the Hotel in the evening (Wednesday, October 28th), Mr. Williford presiding. The officers and governors-elect for 1943 were introduced, followed by the presentation of the 1941 Journal Award certificates to Mr. W. J. Albersheim and Donald MacKenzie for their paper entitled "Analysis of Sound-Film Drives," published in the July, 1941, issue of the JOURNAL.

Both morning and afternoon sessions of Thursday, October 29th, were devoted to a symposium on the production of 16-mm motion pictures, and included papers on practically all phases of this important branch of the industry. The morning session, presided over by Mr. Ralph E. Farnham, opened with an introduction by John A. Maurer, followed by papers on production planning, direct 16-mm laboratory work, and general 16-mm laboratory practice, by Messrs. R. C. Holslag, Lloyd Thompson, and Wm. H. Offenhauser.

In the afternoon, with Mr. Frank E. Carlson presiding, papers were presented dealing with 16-mm recording, 16-mm editing and photographic embellishment, carbon arc projection of 16-mm film, 16-mm screen illumination, and on applications and distribution problems of 16-mm pictures—by Messrs. J. A. Maurer, L. Sherwood, F. E. Carlson, W. C. Kalb, and F. W. Bright. This symposium of nine papers on 16-mm motion picture production is a valuable companion to the symposium on 35-mm production held at the Hollywood Convention last Spring.

The closing session of the three-day meeting was held at the U. S. Army Signal Corps Photographic Center at Astoria, Long Island, by courtesy of Col. M. E. Gillette, commanding. The evening opened with a paper by Capt. E. M. Watson, of Watervliet Arsenal, on the analysis of fast motion by means of motion pictures. Interesting slides and motion pictures taken at very high speed supplemented the paper. Following this, papers were presented by M. S. David, of the General Motors Corp., and Norman Matthews, of Bell Aircraft Corp., on additional applications of motion pictures in wartime training of industrial employees and men in the Service.

After a showing of some films that had been shot in the Astoria studio years ago by Paramount, long before the studio had been taken over and revamped by the Signal Corps, the evening concluded with a conducted tour through all the facilities of the studio.

The Society wishes to acknowledge its gratitude to the large number of persons and companies who collaborated in providing the various facilities for the Meeting. Acknowledgment is due also to the Capitol Theater, the Radio City Music Hall, the Roxy Theater, Warner's Strand Theater, and the Paramount Theater for the passes issued to SMPE delegates during the dates of the Meeting.

SOCIETY ANNOUNCEMENTS

OFFICERS AND GOVERNORS FOR 1943

As a result of the elections held at the recent Fifty-Second Semi-Annual Meeting at the Hotel Pennsylvania, New York, October 27th to 29th, the following will be the list of officers and governors of the Society beginning January 1st:

** *President:* HERBERT GRIFFIN
** *Past-President:* EMERY HUSE
** *Executive Vice-President:* LOREN L. RYDER
* *Engineering Vice-President:* DONALD E. HYNDMAN
** *Editorial Vice-President:* ARTHUR C. DOWNES
* *Financial Vice-President:* ARTHUR S. DICKINSON
** *Convention Vice-President:* WILLIAM C. KUNZMANN
* *Secretary:* E. ALLAN WILLIFORD
* *Treasurer:* M. R. BOYER
Governors: * H. D. BRADBURY
* FRANK E. CARLSON
* A. M. GUNDELFINGER
* EDWARD M. HONAN
* JOHN A. MAURER
** WILLIAM A. MUELLER
* HOLLIS W. MOYSE
** H. W. REMERSHIED
** JOSEPH H. SPRAY
** REEVE O. STROCK

Additional members of the Board of Governors are the Chairmen of the three Local Sections of the Society:

* Atlantic Coast Section: ALFRED N. GOLDSMITH
* Pacific Coast Section: CHARLES W. HANDLEY

Election results for the Mid-West Section will be available shortly.

ADMISSIONS COMMITTEE

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

CULL, R. A.
5743 Irving Park Rd.,
Chicago, Ill.

GOETZ, ALEXANDER
Rare Metals Institute,
Calif. Institute of Technology,
Pasadena, Calif.

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* Term expires December 31, 1943.
** Term expires December 31, 1944.

HOMSANY, EMIL F.
1405—8th Ave.,
Brooklyn, N. Y.

KNOWLES, GERALD L.
10411 Oletha Lane,
West Los Angeles, Calif.

ROSEN, NORMAN
28-17 38th Ave.,
Long Island City, N. Y.

In addition, the following applicants have been admitted to the Active grade:

ASHCRAFT, C S.
47-31 35th St.,
Long Island City, N. Y.

BENNETT, M. F.
Warner Bros. Pictures, Inc.,
321 West 44th St.,
New York, N. Y.

GASPAR, BELA
1050 Cahuenga Blvd.,
Hollywood, Calif.

PULMAN, ROBERT
12-A Brunswick Rd.,
Sutton, Surrey, England

TELLING, MARTINUS
Camp-N
Sherbrooke, Quebec,
Canada

The following applicant was admitted to the Student Membership grade:

HUFFORD, ROBERT GRAY
Clemson A. & M. College,
Clemson, S. C.

The following members were transferred from Associate to Active grade:

BACH, WALTER
E. M. Berndt Corp.,
5515 Sunset Blvd.,
Hollywood, Calif.

THOMPSON, LLOYD
The Calvin Company,
26th & Jefferson Sts.,
Kansas City, Mo.

JOURNAL

OF THE SOCIETY OF

MOTION PICTURE ENGINEERS

AUTHOR AND CLASSIFIED INDEXES

VOLUME XXXVIII
JULY–DECEMBER, 1942

AUTHOR INDEX, VOLUME XXXIX

JULY TO DECEMBER, 1942

CLASSIFIED INDEX, VOLUME XXXIX

JULY TO DECEMBER 1942

MEMBERS OF THE SOCIETY LOST IN THE SERVICE OF THEIR COUNTRY

FRANKLIN C. GILBERT
ISRAEL H. TILLES

BACK NUMBERS OF THE TRANSACTIONS AND JOURNALS

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

	No.	Price		No.	Price		No.	Price
1924	19	$1.25	1926	25	$1.25	1928	33	$2.50
	20	1.25		26	1.25		34	2.50
1925	21	1 25		27	1 25		35	2.50
	22	1 25		28	1 25		36	2.50
	23	1.25	1927	29	1.25	1929	37	3.00
	24	1.25		32	1.25		38	3.00

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

SOCIETY SUPPLIES

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

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

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

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

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

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