B. E. STECHBART

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UNDERSEA CINEMATOGRAPHY*

E. R. F. JOHNSON**

Summary.—*The dates of the first recorded use of underwater photography and the tendencies toward its increasing use by producers are noted, and the author's early experiences in this field are described. For work in natural settings the most useful equipment consists of submergible cameras placed on the bottom and operated by divers. The problems of and equipment for such work are dealt with and it is pointed out that studio tank work shares most of these problems.*

The optical properties of water are described. Since water is less transparent than air, photography by natural light is limited to shallow depths and more power is required for artificial illumination under water. Since colors are not absorbed equally, accurate monochrome rendering and photography in natural color are complicated. Haze limits the distance at which pictures can be taken under water, but is largely confined to a part of the spectrum and can be partially eliminated by the use of color filters. It is plane polarized and can, therefore, also be suppressed by the use of polarizing plates. The advantages of this method are briefly stated—it does not distort monochrome rendering and can be used in natural color photography.

The ideal attributes of equipment for use in underwater cinematography are outlined and available equipment is briefly described.

HISTORY AND CURRENT STATUS

The first recorded attempt to take photographs under water that has come to our attention was by Boutan in 1893 and we understand that he succeeded in securing a few fairly successful still pictures.

The possibilities of underwater motion pictures seem to have intrigued the fancy of commercial producers almost as early, if indeed not earlier, than it did the scientists and educators. Williamson produced the underwater picture, *Twenty Thousand Leagues under the Sea,* in 1915–16, and at about the same time scientists, among whom were Bartsch, Beebe, and Minor, started using water-tight motion picture camera housings in conjunction with the suitless type of diving helmet, in order to take motion pictures with which to illustrate their lectures upon underwater life.

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* Presented at the 1938 Fall Meeting at Detroit, Mich.; received October 3, 1938.

** Mechanical Improvements Corporation, Moorestown, N. J.

Recently the tendency of producers to show what happens under water as a part of their stories has grown vastly, to say nothing of pictures having the principal parts of their plots based on action allegedly taking place there. Indeed pictures of champion divers or swimmers are no longer considered complete without a view of their graceful evolutions after penetrating the surface. Some real ocean water scenes were used in the excellent story *Submarine DI* and underwater scenes can be used to add to the romantic touch of a picture, as was done in *Jungle Love.* The work of naval and commercial divers has as yet hardly been touched upon and their heroic exploits offer material for a host of future thrillers. People in ever-increasing numbers are becoming cognizant of the real underwater conditions. For instance, Miami University has a class in marine zoölogy where the students, using diving helmets, go below the surface. At the Marine Studios in Florida and at the Bermuda Aquarium tourists put on diving helmets, or observe the underwater world through ports. In France, Paul Painleve's underwater club is educating another section of the public. This increasing familiarity is making audiences more critical, and the technic and equipment for actual underwater photography as contrasted to shots through glass port-holes in tanks are of both present and growing importance to entertainment pictures, as well as to the scientist and educator.

PHOTOGRAPHIC CONDITIONS UNDER WATER

The author's vigorous attack on the problems involved in underwater photography was brought about by a stinging defeat in 1928. We read one of Beebe's glorious descriptions of the beauties of undersea gardens and the complete ease with which they could be visited and photographed. An Eyemo camera was enclosed in a simple case with a box of calcium chloride to keep the condensation off the lens and window. The result of several weeks' work was very mediocre, however, for we found out that if one can see forty feet that does not mean that he can take good pictures at more than ten, or always even up to ten. We found that natural light is strong enough for photography under water only between 10:30 A.M. and 3:30 P.M. in the summer and even less in winter; that the pellucid tropic seas are more often than not full of white sand, green algae, gray-green marl, or other detritus; and that if the undersea photographer hoped to get anything in a natural set he had to be lightning fast to grasp his opportunity.

Diving bells and baby submarines were considered, but after talking with a few persons who had had experience with such equipment, we saw that they could not be transported and put into position with sufficient ease and speed to suit the underwater photographer, and they are the plaything of every wave or squall of wind. We attached cameras to water telescopes; we shot them through glass-bottomed buckets; we submerged them and sighted through periscopes. But pictures from an unsteady base are unattractive and tend to make the audience seasick. It is our opinion, therefore, that underwater pictures can best be made from the bottom and not the surface; also, that a compact underwater camera operated by a diver should be used for all picture work in the open sea, lakes, and rivers. The same applies to a considerable degree also in swimming pools and tanks, for the cameraman shooting through a port-hole is greatly hampered in following a moving object, and most underwater subjects depend on action rather than expression to tell their story.

The physical qualities of water are responsible for many of the difficulties encountered in underwater photography. The purest of water is far less transparent than air; and, because it is an excellent solvent, it is rarely pure in nature; and dissolved matter profoundly affects the optical properties. Then, too, water, having greater density and viscosity than air, supports a much greater proportion of suspended matter both organic and inorganic, and this has an even greater effect on its optical properties. The quantity and kind of dissolved matter are relatively constant for any location and, at least in sea water, are nearly the same for almost all areas where underwater pictures can be taken. Suspended matter, on the other hand, is highly variable both for different locations and at the same location with varying season and weather. It is the quantity of suspended organisms and particles that finally determine whether or not satisfactory pictures can be taken at a particular place or time.

OPTICS OF UNDERWATER PHOTOGRAPHY

In undersea photography it is general practice to use ordinary cine lenses computed for use in air—protected by a plane window. This introduces a water-air boundary which affects the focus and corrections of the lens. Objects under water appear nearer and larger both to the eye and to a camera. We have computed the effect upon focus and it turns out that the ratio of the air focus to that under water is equal to the index of refraction of air with respect to water. The index varies with the salinity and temperature of the water but the value 0.750 may be used for all conditions with negligible error. It follows that to focus on an object at any distance under water the same lens extension is required as for an object at three-quarters of that distance in air.

The presence of the water-air boundary in front of the lens also introduces both spherical and chromatic aberration. Fortunately, if the plane of the window is perpendicular to the axis of the lens, they are both too small to require correction. In tank work any attempt to position a camera other than normal to the plane of the window will result in objectionable aberration.

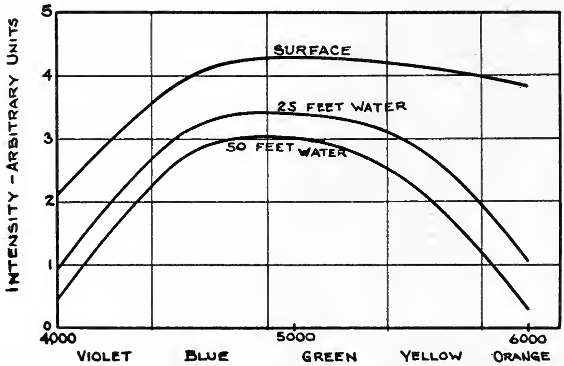

FIG. 1. Spectral quality of mean noon sunlight at the surface, and through 25 and 50 feet of water.

When photographing by sunlight, the first factor to be considered is the overall reduction in intensity of light. This varies greatly with conditions, but it is our experience that under average conditions twenty-five to thirty-five feet is the limiting depth using rapid lenses and Eastman Super *X* or Agfa Supreme film and a filter with a factor of from two to four. The newer ultra-rapid films extend this limit somewhat. Fortunately the largest percentage of interesting marine life and human activity is to be found within this range. At greater depths photographic subjects become more scarce and difficulties are materially increased.

A further complication is added by the fact that water does not absorb different colors equally. Fig. 1 shows the approximate intensity and spectral quality of sunlight at the surface and at several depths in water. The curves were computed from the laboratory measurements of the transparency of sea water by E. O. Hulbert[1] and approximate the conditions found in practice. It will be seen that sea water is most transparent in the blue-green region between 4400 and 5400 Å and that the red is quickly absorbed. This filtering action of water makes difficult a true monochrome rendering of subjects, and has an even greater effect on photography in natural colors. In color photography compensating filters can be used to correct for the spectral quality of the light at any given depth. It is to be noted, however, that theoretically a different filter would be required for every depth. Moreover, the same would be true for different distances from the camera to the object. Thus, if an object at six feet

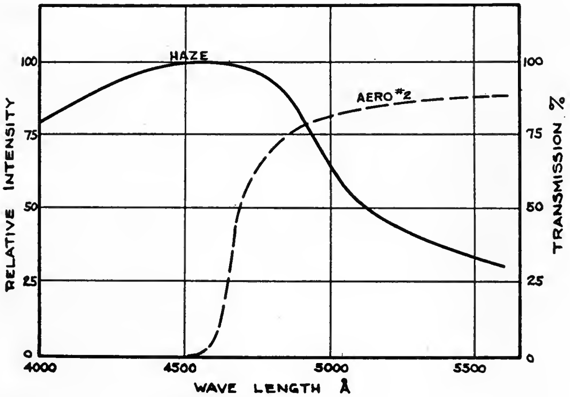

FIG. 2. Spectral distribution of water haze in sea water; transmission curve of Wratten Aero No. *2* filter.

from the camera and six feet deep is being photographed, a compensating filter correct for twelve feet of water would be required. However, even though filters are used objects closer than six feet would tend to be too red and at greater than six feet would be progressively greener—the background fading out in a uniform blue-green. This, in fact, is a real effect. Objects at a distance do not appear to be the same color to a diver as when they are close by. A diver's vision fades out in a misty blue-green haze. Color-film, however, accentuates this effect, making the background an unnaturally intense blue-green. We have taken both Kodachrome and Dufaycolor stills and Dufaycolor motion pictures, most of which exhibit this effect. By proper limitation of depth and distance, however, beautiful results can be obtained.

The greatest *bête noire* of the underwater photographer is water haze or "nuisance light." It is strictly analogous to aerial haze but being much more intense its effect shows up in the picture of an object only a few feet away rather than a matter of miles. This haze originates in the scattering of light by the water and by dissolved and suspended matter between the camera and the object. Its effect is to cause a uniform exposure over the whole picture, which tends to mask detail and contrast; as the distance becomes greater the haze becomes brighter, compared to the brightness of the object, finally masking it completely.

It was felt that water haze, like aerial haze, should consist principally of light in a limited spectral region and that a color filter would eliminate much of it. With this in mind we conducted a series of experiments with an underwater spectrograph. Fig. 2 gives the relative spectral distribution of the haze light in the sea water off the Florida Keys.[2] Tank tests with distilled water gave an almost identical curve. Camera tests showed a great improvement when a Wratten Aero No. *2* filter was used. The transmission curve of this filter is also given. Fig. 3 shows the improvement obtained by the use of filters: (*a*) is a scene at a distance of six feet with no filter; (*b*) a similar scene using an Aero No. *2;* and (*c*) with a Wratten No. *25* filter, which transmits only the red rays of wavelengths greater than 6000 Å. This last picture shows only very slight improvement in detail over the one taken with the Aero No. *2*, and this improvement is more than offset by the unnatural appearance of the subjects and by the extreme exposure increase required. The chief objection to the use of color filters to eliminate haze is the fact that water is most transparent to the blue-green region of the spectrum; but this is also the region of maximum intensity of the haze light, so in eliminating it the most efficient photographic light is also lost. Fortunately there is another means of cutting out this troublesome haze.

So far as haze light is concerned studio tank work offers the same problems as natural settings—as we believe at least one producer has found, to his sorrow, after putting several thousand gallons of expensive distilled water into a nicely scrubbed tank and then failing to get the clear crisp pictures he wanted so badly.

The fact that this nuisance light is present even in distilled water that has stood long enough to be free of air bubbles indicates that the origin of much of it must be molecular scattering by the water it-

(*a*)

(*b*)

(*c*)

FIG. 3. Use of color filters to reduce water haze; (*a*) no filter, (*b*) Wratten Aero No. *2* filter, (*c*) Wratten No. *25* filter.

self. Therefore, according to the Raman-Einstein-Smolchowski theory it should be almost completely plane polarized.[3] Our discovery of this fact led to our use of polarizing screens. By the use of these screens it is possible to eliminate a greater part of the "nuisance light" than by any other means. Their use requires an exposure increase of from two to four times. Unfortunately, the haze light is not completely polarized, so, while the distance at which satisfactory pictures can be obtained is extended, there is still a very definite limit.

Probably the most advantageous feature of this method of eliminating haze light is that polarizing screens are almost perfectly spectrally neutral. They do not distort the monochrome rendering nor do they eliminate the most useful portion of the spectrum as does a yellow or red filter. This spectral neutrality further makes possible haze elimination when using color-film. However, at present the speed of color-film does not permit the use of both a compensating filter and a polarizing plate under normal conditions. If the speed of these materials can be doubled a great improvement in the quality of undersea color pictures is anticipated by the use of polarizing screens.

Light-rays passing into water through the surface are bent until they travel nearly straight down, so by natural illumination subjects under water are inclined to be overly contrasty with highlights on top and densely shadowed undersides. We tried relieving this situation with reflector boards but found that boards large enough to help at all had so much water resistance that even in slack water they were difficult to handle and with any current it became impracticable either to set them or keep them in position. Shadows can be relieved to a certain extent by the use of artificial lights. Reflectors must be small and highly efficient or they become unmanageable in any current. In using lights, it is necessary to exercise extreme care in placement, otherwise haze light makes the lamp beam visible. Since most of the energy from incandescent lights is in the red end of the spectrum, in which region the water has its strongest absorption, the power requirements are much greater than for equivalent illumination at the surface.

EQUIPMENT

Having outlined the technical and practical difficulties confronting the underwater cinematographer we shall now briefly describe the ideal attributes of apparatus to meet these difficulties and the practical equipment developed by our company for this specialized field.

Motion picture producers early learned that dependence upon natural light could be extremely expensive, sometimes tying up the whole staff of actors and technicians for days waiting for favorable conditions. In underwater photography the clarity of the water and the size of the waves are also factors that can vary independently of sunlight, thus further limiting the useful part of time on location. Moreover, even under the best of conditions, the working day under sea is shorter than at the surface; first, because the sun reaches full brightness later and fades earlier; and, second, long exposure to water soon tires both cameramen and actors. These factors tend to run up the expense of underwater footage and demand a high standard of reliability, convenience, and speed of operation in the apparatus used.

Sending equipment to the surface for adjustments of stop or focus or change of filter is wasteful of time. It is, therefore, the first requirement of underwater equipment that the controls for all adjustments be quickly and conveniently operable under sea by the diver.

The fact that water is a far less yielding medium than air dictates other requirements. A camera that would be quite stable in a twenty-mile wind might easily be thrown over by even a two-mile current. When working at small depths the under-surface surge from waves tends to sway and billow both diver and equipment. Very often the diver has difficulty in standing or walking even without apparatus. Therefore, tripod mount and spring or electric motor drive are essential. Apparatus must be compact to keep down its water resistance; it must be light enough for ease in carrying, yet heavy enough to be stable. All connections must be rigid.

When under water, man becomes a clumsy, slow-moving creature. It is, therefore, important that any couplings that must be made should be large and simple. Calibration markings should be large and distinct, and all controls and calibrations should be visible and operable from one position.

Even after short submergence the skin of a diver's hands becomes softened and very easily cut by things that would not do so at the surface. For this reason everything must be smooth with no sharp edges.

The construction of diving helmets, and the fact that the cameraman has difficulty in remaining perfectly still, make it necessary that view-finders be corrected for an eye position well back of the port, and, further, the reduced illumination makes important a large brilliant image.

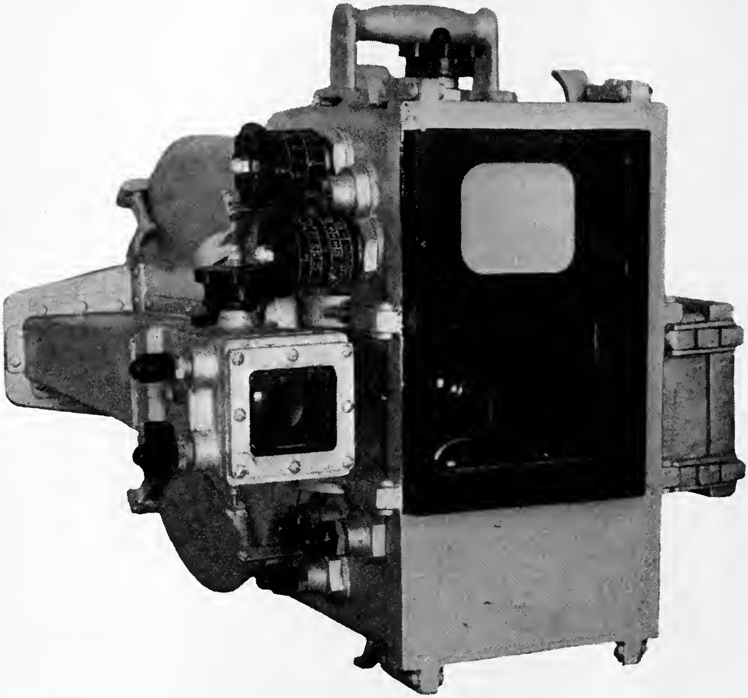

FIG. 4. Professional model underwater motion picture camera.

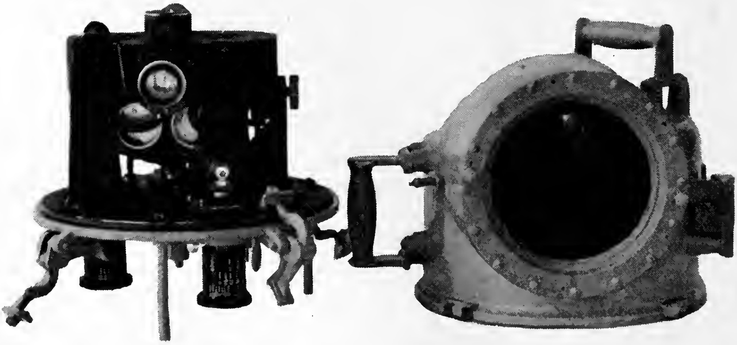

FIG. 5. Underwater housing for Bell & Howell Eyemo, open for loading.

Direct focusing is a difficult if not impossible task and therefore accurate focus calibration of lenses is a necessity.

In developing apparatus for underwater cinematography we have not undertaken the design of new camera mechanisms but rather have modified for underwater use the excellent existing surface equipment. The materials and construction of all apparatus are such that no condensation occurs on windows when submerged, thus eliminating the need of troublesome and time-consuming chemical driers. In general, it may be said that any surface camera can be encased for such use, but for our standard models we have selected those whose size and layout make them most adaptable for the purpose.

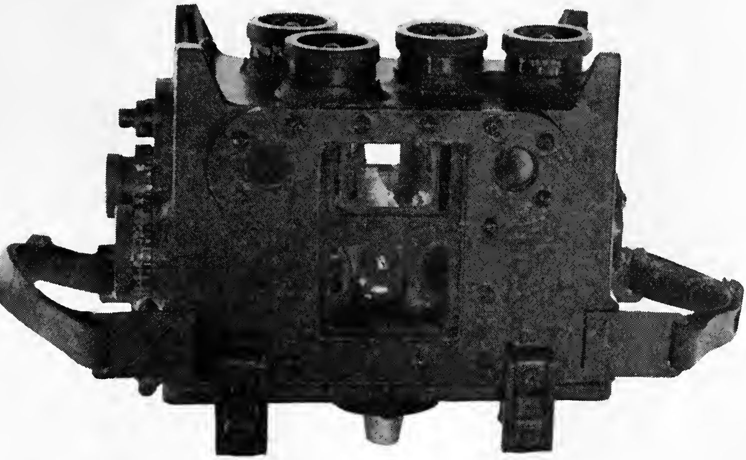

FIG. 6. Professional model underwater still camera.

The most complete unit is the professional model motion picture camera, Fig. 4, which was designed to give the underwater cinematographer an instrument possessed of the greatest possible flexibility and convenience of operation.

The camera mechanism is the Akeley, with a capacity of 200 feet of standard 35-mm. motion picture film. It is driven by an electric motor with external speed control. The trigger switch is in a separate water-tight case mounted on the cable; it may be used at a short distance from the camera or mounted on the guiding handle of the tripod, making it possible to guide and run the camera with the left hand, leaving the right hand free to adjust focus and aperture. A

Veeder type of footage counter is at the rear of the case, and every two feet a dim light flashes at one side of the view-finder, permitting the cameraman to keep count of footage without looking away from the scene. Three lenses, wide-angle, standard, and telephoto, are mounted in the instrument. These are in a vertical row rather than in the conventional turret, in the interest of simpler lens and filter control. Provision is made for two color filters, which may be thrown in or out at will, and a polarizing plate which may be racked in front of the lens or removed. It may also be rotated under water and a sun's position indicator on the rear of the camera indicates the proper rotation when using natural light.

The view-finder gives a large brilliant image and incorporates adjustment for correction of parallax. Supplementary lenses are used to obtain the fields of the different camera lenses without a reduction in the image size.

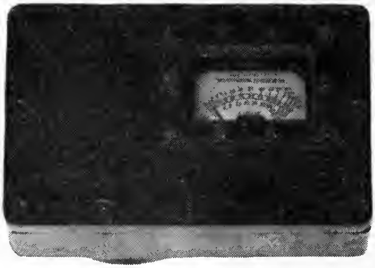

Fig. 7. Underwater housing for Weston exposure-meter.

In air the camera weighs approximately seventy-five pounds but submerged only twenty-five, which makes it an easy load for a single diver. The water-tight covers of the camera and lens compartments are gasketed and held fast by quick-acting latches which require no tools to operate and make loading an extremely rapid operation. All controls are clearly calibrated and visible from the operating position. The diver-cameraman can accomplish all adjustments under water with the exception, of course, of reloading.

We have also a housing for the Bell & Howell Eyemo, Fig. 5. In this case the camera is removable from the water-tight case. The only permanent alteration is the addition of fittings to the lenses which in no way interfere with the ordinary use of the camera in air. The case will accommodate any of the standard Eyemo lenses up to the 3 $^3/_4$-inch focal length. Lenses can not, however, be changed under water. Provision is made for the underwater adjustment of lens focus and aperture, for winding of the spring motor, and operation of the trigger. All controls are visible and adjustable from the rear of the camera. There is a single large case opening which is gasketed and held by quick-acting latches, and it is not necessary to remove the camera from the housing which reduces to a minimum the time required to load or change lenses and filters.

There is also available a professional model still camera, Fig. 6, which, because it uses standard 35-mm. motion picture film, can be

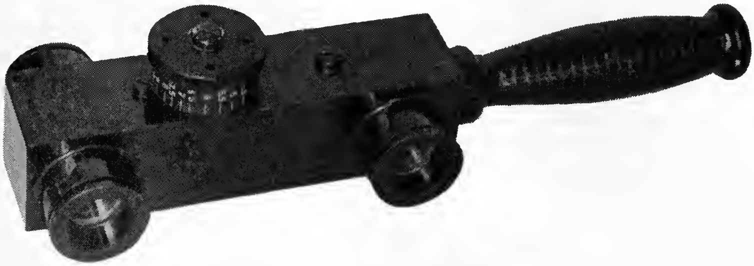

FIG. 8. Underwater range-finder.

used for taking check stills of motion picture scenes as well as for ordinary still pictures. This instrument makes use of the Leica camera mechanism, and all controls can be operated by the diver more conveniently than in the average air camera. It is necessary to take it to the surface only for film reloading. It weighs in air approximately twenty-four pounds and submerged, about ten. There is an underwater choice of no filter, either one of two color filters, a polarizing plate, or combination of filter and polarizing plate. There is also provided an indicator for determining the proper degree of rotation for the polarizing plate. A large brilliant-image field-finder is incorporated in the camera as well as a built-in range-finder coupled to the camera lens in the interest of rapid focusing.

FIG. 9. Underwater lamp.

For determining the correct exposure under water, which is essential as the light available varies greatly both in amount and color with differences in depth, the amount and kind of impurities present, and the condition of the water surface, there is a substantial water-tight housing for a Weston model *650* exposure-meter, Fig. 7.

Accurate measurement of distance is also necessary. Under most conditions illumination is relatively weak and aperture settings must be large, resulting in short focal depth. Under water the eye is a very poor judge of distance and yardstick measurements are often difficult. To make quick accurate measurements possible an underwater range-finder has been developed, Fig. 8. It is of the double-image type, different from the conventional instrument only in the increased size of the optical parts and in the calibration which gives true distances under water.

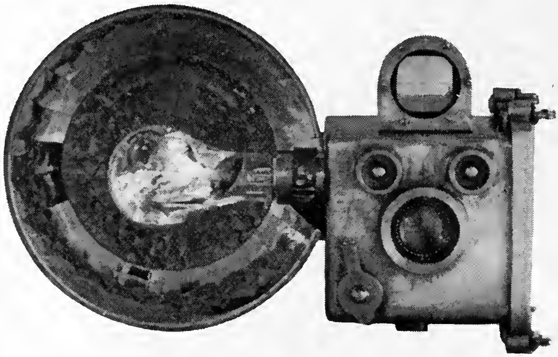

FIG. 10. Amateur underwater still camera.

For supplementing natural light there are special underwater lamps (Fig. 9) using corrosion-resistant reflectors, which for ease of handling in underwater currents are of comparatively small size. Special diving lamps as well as standard photoflood lamps in waterproof sockets can be used in these reflectors.

Because of an increasing interest on the part of amateurs in this field we have designed a compact still camera (Fig. 10). It takes pictures $2^1/_4 \times 2^1/_4$ inches and is equipped with a rapid lens. All necessary controls can be operated under water and filters and polarizing plate may be used. It incorporates a fitting for flash bulbs which is synchronized with the shutter. The only concession to the low price demanded of an amateur camera is a slight sacrifice in the convenience and rapidity of operation. In a short time we expect to have a similar case for one or more of the popular 16-mm. motion picture cameras.

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[3] RAMAN: "Molecular Diffraction of Light," *Proc. Royal Soc.*, **101** (1922), p. 64.

DISCUSSION

MR. KELLOGG: For getting a light background, do you ever inject into the water something that will produce a milky cloud behind the subject so that it will not obscure the picture?

MR. JOHNSON: We have never attempted to do that. There is so much milkiness in the water naturally that we have never thought about adding any. The background tends to come up and hit you in the face. You are seldom more than twenty feet away when this nuisance light or haze light obscures everything. Generally we try to get as much animal or plant life or coral growth or sand bank or other physical object in the background rather than to leave a lot of this fog.

MR. CRABTREE: Have you used artificial light?

MR. JOHNSON: Yes. The trouble with artificial light is that we have to have such a tremendous quantity of it to amount to anything. The red rays become dissipated in heat, and of course most artificial light has plenty of red rays in it.

MR. CRABTREE: Possibly the high-intensity mercury-vapor lamp would be useful. It would at least be water-cooled.

MR. JOHNSON: It would be a better lamp than some of the others. In tank work I am inclined to use a lot of artificial light, but from below rather than up above.

The light from a sodium lamp would introduce far less haze than that from a mercury lamp, but for underwater photographic use a lamp of high efficiency over a wide range of the spectrum should be selected. We therefore do not recommend either mercury-vapor or sodium lamps as especially useful to the underwater cinematographer.

MR. CRABTREE: I noticed a tripod in one of the pictures. The construction seemed to be quite different from that of the normal tripod.

MR. JOHNSON: The tripod was a specially built brass tripod, made like a slide trombone, so you could move it in and out from the standing position. It is made very solid, because under water one is pushed around a lot so he can not use a surface tripod.

THE ROAD AHEAD FOR TELEVISION*

I. J. KAAR**

Summary.—*Now that television standards have been agreed upon in the United States, commercial receiving sets will undoubtedly be available very soon, and regularly scheduled television programs may be expected at the same time. How good will the television be and what are the problems yet to be solved before television reaches the technical maturity that radio has today? These are questions of considerable interest to engineers in related fields, and are the subject matter of the present paper. The quality of present-day television pictures is compared with that of motion pictures both in the theater and in the home. A discussion is given of the problems that have been solved to make television what it is today, and consideration is given to the problems that must be solved to make television what we hope it will be tomorrow. The problems of signal propagation and interference are discussed, and the matter of network program distribution is considered. Finally, a short introduction is given to the commercial problems in television.*

For several years the public has been increasingly curious to know when television would be introduced commercially, and a great variety of explanations have been advanced by uninformed persons as to why it has not happened already. Of course, at first the reason was lack of technical quality; but in the past few years the quality of pictures achieved has certainly been good enough to interest an increasingly large proportion of the population. However, two major questions had still to be answered before the widespread commercial introduction of television. The first of these was the fixing of satisfactory television standards and the second was the discovery of a satisfactory method of paying for the programs. The first matter has practically been settled; the second has not.

Television differs from sound broadcasting very markedly in the importance of standards. In sound broadcasting, if the method of modulation (amplitude, frequency, or phase) is once determined, any receiver which can be tuned to the carrier frequency of a given transmitter can receive its program. The technical quality of transmitted

* Presented at the 1938 Fall Meeting at Detroit, Mich.; received October 21, 1938.

** General Electric Company, Bridgeport, Conn.

programs can be improved year by year, but while this happens, a receiver once purchased is always usable, even though it may become outmoded as compared with current models. The situation in television is quite different. Due to the use of scanning and the necessity of synchronization between the receiver and transmitter, if transmission standards are changed, receivers designed for the old standards become useless. Because of this fact, no responsible manufacturer would sell receivers to the public until standards were fixed by

FIG. 1. Typical scene in British television studio.

the industry and sponsored by the Federal Communications Commission. Furthermore, American manufacturers did not desire to fix standards, except at such a high quality that widespread and sustained interest on the part of the public would be assured and so that adequate provision for continued perfection was possible. It required considerable technical perfection to justify these high standards, but this has now been attained and the essential standards have been agreed upon. Consequently, it may be said with some assurance that the last technical obstacle in the path of commercial television has been removed, at least so far as the excellence of the picture under proper conditions is concerned.

The question of who shall pay for television programs has not yet been answered. As is well known, the cost of sound broadcasting is borne by "sponsors," who pay enough for their own programs to enable the stations and networks to fill-in the unsponsored time with sustaining programs of good quality and to make a profit in addition. However, this situation now requires the existence of tens of millions of receivers in the country with listeners who may be induced to buy the advertised products. Such an audience does not exist in television

FIG. 2. Typical scene in American television studio.

and can not be expected for several years. Of course, no such audience existed in the early days of sound broadcasting either, and the receiver manufacturers themselves, along with a few individual companies who built stations for their own advertising purposes, operated the stations. In those days, however, the thought of something coming through the air, receivable at no cost, was an entirely new one. People were quite satisfied with the new toy as such and program excellence was a secondary consideration. This, of course, meant that the cost of broadcasting (as compared to the present) was low. Now the public has been educated to expect a high degree of excellence in program material and it is doubtful if mediocre program material in television would be acceptable. This has been quite strikingly proved in England. In other words, when television is born, it must be born full-fledged as far as program material is concerned. This, of course, means great expense which, undoubtedly, will have to be borne by the pioneers.

In Great Britain commercial television is already a reality and it is of interest to consider some of its various aspects. American tele-

FIG. 3. An outside pick-up in England.

vision will be quite similar, except for improvements based upon the progress of the art since the British standards were set.

Fig. 1 is a photograph of a television studio showing the general layout. In particular there is seen the performer and the position of the camera tube and the microphone.

Fig. 2 is a similar set-up in an American studio.

Fig. 3 is a scene showing a camera tube being used for outside pick-up in England.

Fig. 4 is an unretouched photograph of an image on the screen of a picture tube in England.

Fig. 5 is a similar picture taken in America.

FIG. 4. Photograph of picture tube image in England.

FIG. 5. Photograph of picture tube image in America.

Fig. 6 is a view of the antenna tower of the London (Alexandra Palace) Television Transmitter. The mast carries two separate aerials, vision (above) and the accompanying sound (below).

Fig. 7 is a view of the interior of a mobile television control room in England. At the center of the photograph are the picture monitors. This equipment is mounted in a "van" and has been used very successfully at sporting events. The signals in this case are transmitted to the main transmitter at very short wavelengths and rebroadcast at high power.

Fig. 8 is a view inside an American "van" serving the same purpose.

STANDARDS

Let us next briefly consider the television standards which have been adopted in this country and the reasons for their adoption. The reader is no doubt acquainted with the general scheme of television used, but a quick review of the essentials may be in order. At both the camera tube and the picture tube, the picture is scanned by an electronic spot (beam of electrons) in a series of adjacent horizontal lines. The number of these lines into which the picture is divided in the scanning process determines the fineness of vertical detail which is reproducible. After scanning the whole picture, the electronic spot then repeats the process at a sufficiently rapid rate so that no apparent flicker exists. This process is essentially the same, so far as the effect upon the eye is concerned, as that performed by the shutter on a motion picture projector. The frequency of repetition of scanning of the whole picture is known as the frame frequency.

In order to conserve ether space, it is desirable to keep the frame frequency as low as possible. Consequently, an artifice is employed in order to increase the apparent frequency of repetition. This device is known as "interlace." In an "interlaced" picture every other line of a picture is scanned, and after the whole picture has been scanned in this way, the lines in between are scanned. This gives the physiological effect of scanning the picture twice, as far as flicker is concerned, even though all details of the picture have been completely scanned only once. The apparent flicker frequency under these conditions which is twice the frame frequency, is known as the field frequency. Now obviously, if anything other than a complete blur is to be obtained, it is necessary that the number of lines per frame, the order of scanning of the lines, and the number of frames per second be identical at the receiver and transmitter. These, accordingly, have been standardized in America as follows:

Number of lines per frame $= N = 441$
Number of frames per second $= F = 30$
Number of fields per second $= 60$ (interlaced)

To these we may also add the standard picture aspect ratio, which is 4:3—in agreement with the value used in motion pictures.

FIG. 6. The Alexandra Palace television station in London.

There is a reason for choosing the number 441 rather than some other number of about the same value. It may be shown that a necessary requirement for a stable relationship between the horizontal and vertical scanning oscillators, is that the number of lines per frame be a whole number having only small odd factors. If no factors larger than 7 be used, Table I shows the list of possible values of N. Four hundred and five lines per frame is the figure chosen as standard in Great Britain, while in some very fine laboratory pictures shown in Holland, 567 lines were used.

TABLE I

Possible Numbers of Lines for Odd-Line Interlace

Number	Factors	Number	Factors	Number	Factors
1	1	105	3 × 5 × 7	625	5 × 5 × 5 × 5
3	3	125	5 × 5 × 5	675	3 × 3 × 3 × 5 × 5
5	5	135	3 × 3 × 3 × 5	729	3 × 3 × 3 × 3 × 3 × 3
7	7	147	3 × 7 × 7	735	3 × 5 × 7 × 7
9	3 × 3	175	5 × 5 × 7	875	5 × 5 × 5 × 7
15	3 × 5	225	3 × 3 × 5 × 5	945	3 × 3 × 3 × 5 × 7
21	3 × 7	243	3 × 3 × 3 × 3 × 3	1029	3 × 7 × 7 × 7
25	5 × 5	245	5 × 7 × 7	1125	3 × 3 × 5 × 5 × 5
27	3 × 3 × 3	315	3 × 3 × 5 × 7	1215	3 × 3 × 3 × 3 × 3 × 5
35	5 × 7	343	7 × 7 × 7	1225	5 × 5 × 7 × 7
45	3 × 3 × 5	375	3 × 5 × 5 × 5	1323	3 × 3 × 3 × 7 × 7
49	7 × 7	405	3 × 3 × 3 × 3 × 5	1575	3 × 3 × 5 × 5 × 7
63	3 × 3 × 7	441	3 × 3 × 7 × 7	1701	3 × 3 × 3 × 3 × 3 × 7
75	3 × 5 × 5	525	3 × 5 × 5 × 7	1715	5 × 7 × 7 × 7
81	3 × 3 × 3 × 3	567	3 × 3 × 3 × 3 × 7		

There is also a good reason for using 30 as the frame frequency. It is found that unless the frame frequency is a multiple or a sub-multiple of the power supply frequency, a shadow will move across the picture. This moving shadow has about the same physiological effect as flicker and is very disturbing. However, if the frame frequency is a multiple or sub-multiple of the power line frequency the pattern of the ripple is stationary on the image and it is much less objectionable. Therefore, since 60 cycles is standard in American power distribution systems, 30 frames per second has been chosen as standard for the frame frequency; since this is the smallest sub-multiple of 60 whose double is above the maximum flicker frequency observable by the eye.

Among other matters requiring standardization are the synchronizing operations at both the transmitter and receiver. It is clear that scanning at the transmitter and receiver must be exactly synchronous to within an extremely small error. In order to accomplish this, synchronizing signals are always transmitted with the picture signals. The purpose of these synchronizing signals is to start the scanning of both the lines and frames at exactly the right time. A detailed investigation of synchronizing signals would be out of place here, but it may be stated as absolutely essential that the type of synchronizing signal transmitted should be completely standardized.

The decision as to which was the most desirable synchronizing signal was one of the most difficult of all questions which confronted the Television Standardizing Committee. The signal shown in Fig. 9 was ultimately fixed as standard. This synchronizing signal is described as of the "serrated vertical" type. It is believed that with the use of this signal, the most stable and accurate synchronization can be obtained. Furthermore, considerable latitude is offered to the designer as to the means chosen for utilizing the signal.

The next subject which we wish to consider is the frequency channel width required in television. It may be shown[1] that in order to transmit the available intelligence in a television picture with N scanning lines per frame, and a frame frequency of F, a minimum frequency range from zero to

$$f = \frac{FN^2R}{2\sqrt{2}} \qquad (1)$$

is required. In this equation R is the aspect ratio. Substituting into equation *1* the values which have been standardized, we get

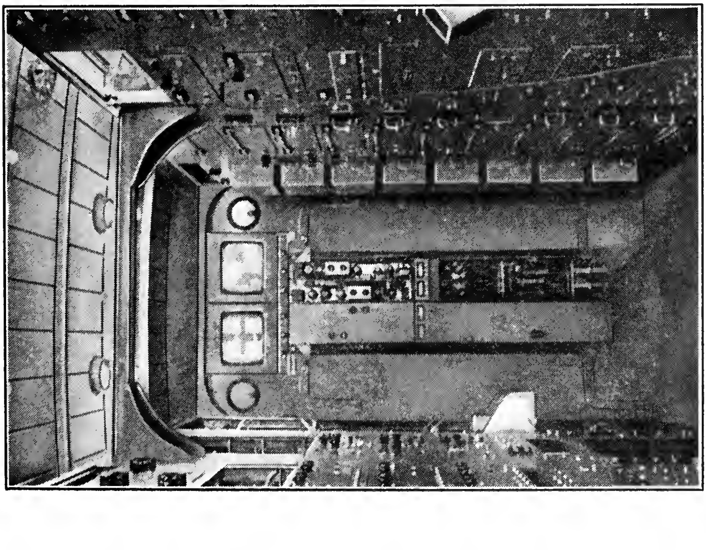

FIG. 7. Interior of British pick-up van.

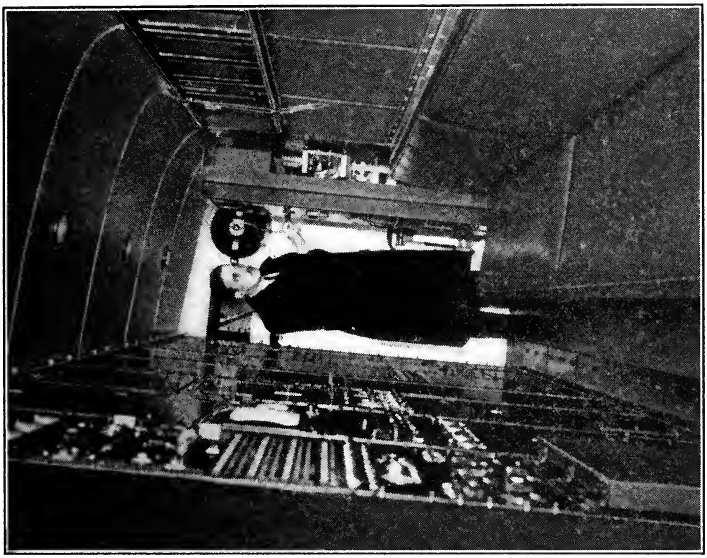

FIG. 8. Interior of American pick-up van.

$$f = \frac{30 \times (441)^2 \times 4/3}{2\sqrt{2}} = 2{,}750{,}000 \text{ cycles} \qquad (2)$$

Thus for effective utilization of the intelligence available from a standard television picture, there must be complete and undistorted transmission of all frequencies from zero to at least 2,750,000 cycles. If this signal is used to modulate a radio frequency carrier, an extremely wide frequency channel is obviously required.

In order to economize on the use of the frequency band thus required, single side-band transmission is proposed. The system may more properly be termed "sesqui-side-band." In this system, the elimination of one side-band is achieved by the use of band-pass filters which have a range of partial transmission in the region on either side of the transmission band. The carrier may be placed in one of these edge bands at a point where there is approximately 50 per cent transmission. It may be shown that such a system has essentially double side-band transmission for very low frequencies, and single side-band transmission for medium and high frequencies. To return now to the question of utilization of the frequency channel, it is noted that by means of "sesqui-side-band" transmission the frequency band required by the picture signal is reduced by almost 50 per cent.

In transmitting television programs, it has been found desirable to transmit the picture and sound in the same channel. This allows a single oscillator to be used for both sight and sound in a superheterodyne television receiver, thus greatly simplifying tuning. In this system, the sound and sight signals are separated by selective circuits in the intermediate frequency amplifiers. Fig. 10 is a diagram of a typical television receiver, showing how it transmits and separates the picture and audio signals.

In order to design television receivers, it is necessary that the relative positions of the audio and picture signals be accurately known. In order that this should be possible, the following standards have been set:

Television Channel Width.—The standard television channel shall not be less than 6 megacycles in width.

Television and Sound Carrier Spacing.—It shall be standard to separate the sound and picture carriers by approximately 4.5 MC. This standard shall go into effect just as soon as "single side-band" operation at the transmitter is practicable. (The previous standard of approximately 3.25 MC shall be superseded.)

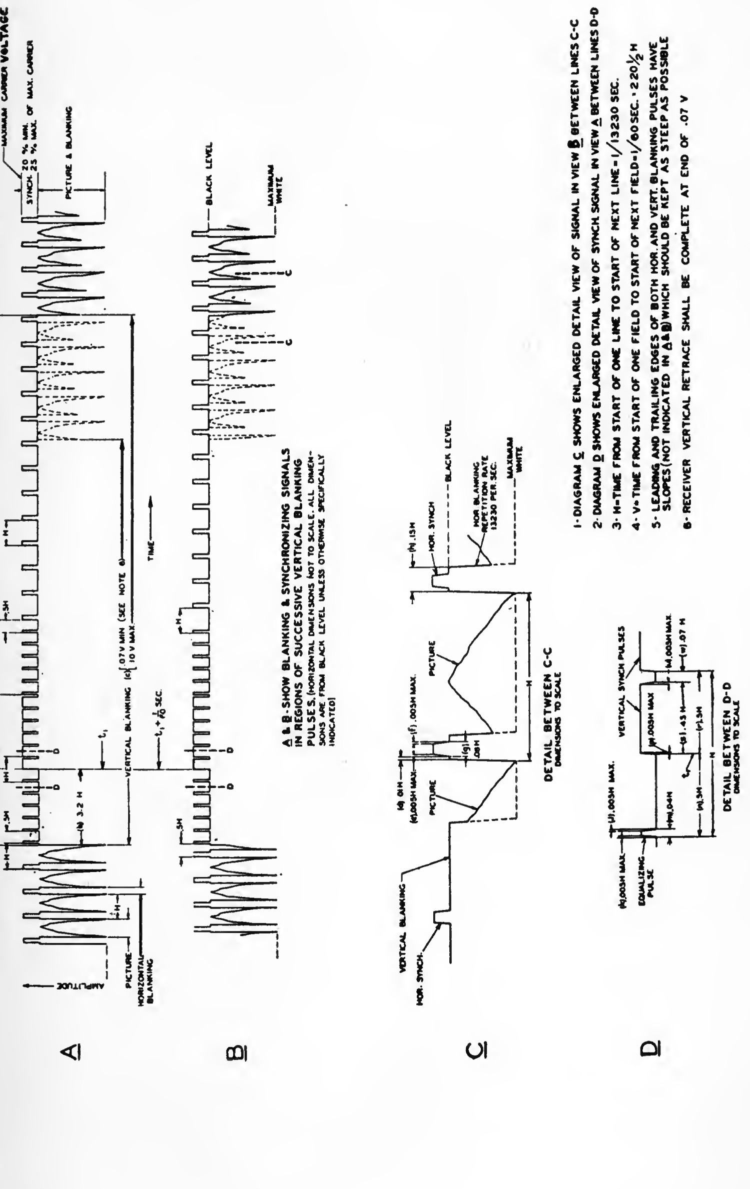

FIG. 9. The RMA T-III standard television signal: 441 lines, 30 frames per second, 60 fields per second, interlaced.

Sound Carrier and Television Carrier Relation.—It shall be standard in a television channel to place the sound carrier at a higher frequency than the television carrier.

Position of Sound Carrier.—It shall be standard to locate the sound carrier for a television channel 0.25 MC lower than the upper frequency limit of the channel.

In addition to the standards already mentioned, there are certain other standards which have been adopted, and these will be commented upon briefly. Thus:

It shall be standard in television transmission that black shall be represented by a definite carrier level independent of light and shade in the picture.

This means that the background level is transmitted in a television signal, thereby eliminating the need for readjustment of the receiver

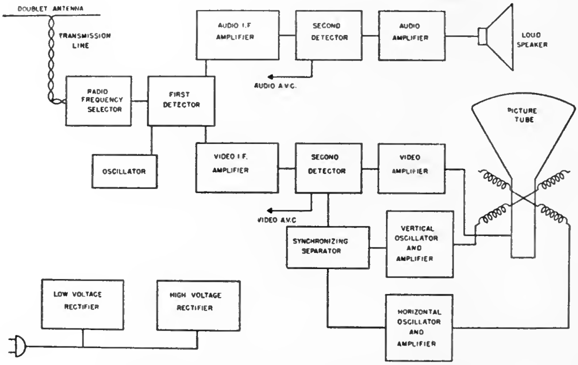

FIG. 10. A typical television receiver.

when the scene being televised changes from a preponderance of white to a preponderance of black.

It shall be standard for a decrease in initial light intensity to cause an increase in the radiated power.

A technical description of this standard is to say that the polarity of the transmission is negative. It is seen that a choice exists so it is necessary that this point be standardized, otherwise the picture tube at the receiver would frequently show the equivalent of a photographic negative. Even more important than this is the fact that unless the receiver were built for the polarity of transmission sent out by the transmitter, the synchronizing signals would not be effective.

Percentage of Television Signal Devoted to Synchronization.—If the peak amplitude of the radio frequency television signal is taken as 100 per cent, it shall be standard to use not less than 20 nor more than 25 per cent of the total amplitude for synchronizing pulses.

Transmitter Modulation Capability.—If the peak amplitude of the radio-frequency television signal is taken as 100 per cent, it shall be standard for the signal amplitude to drop to 25 per cent or less of peak amplitude for maximum white.

Transmitter Output Rating.—It shall be standard, in order to correspond as nearly as possible to equivalent rating of sound transmitters, that the power of

TABLE II

Some American Picture Tube Characteristics

Diameter (*Inches*)	Overall Tube Length (*Inches*)	Normal Operating Anode Voltage (*Volts*)	Spot Size (*Lines*)	Type of* Deflection	Type of** Focusing	Remarks
3	11 1/2	1,500	250	*S-S*	*S*	Green Screen White Screen
5 1/4	15 7/8	1,500–2,000	375–425	*S-S*	*S*	Green Screen White Screen
5	15 3/4	3,000	450	*M-M*	*S*	Yellow-Green Screen White Screen
9	21	6,000	450	*M-M*	*S*	Yellow-Green Screen White Screen
12	24 1/2	6,000	450	*M-M*	*S*	White Screen
4″ Projection	14 1/2	20,000	450	*M-M*	*S-M*	Green or Yellow-Green Screen

* *M-M* = magnetic deflection both ways.
S-S = electrostatic deflection both ways.
** *S* = electrostatic focusing.
S-M = combined electrostatic and magnetic focusing.

television picture transmitters be nominally rated at the output terminals in peak power divided by four.

Relative Radiated Power for Picture and for Sound.—It shall be standard to have the radiated power for the picture approximately the same as for sound.

The last four standards related particularly to output powers and power ratings, and while they are important in regulating the design of transmitters and receivers, they are not intimately connected with picture quality, which is of principal concern here.

THE TELEVISION PICTURE

When television is discussed by the public, the questions most frequently asked are "How good is television?" "How good will it be?" and "How much will it cost?" The answers to these questions involve such matters as: How large will the picture be? How bright will it be? How much detail will it show? How clear will it be? A discussion of these considerations will be of interest.

The standard high-quality television system which will possibly be commercialized shortly will have a 12-inch tube with a $7^1/_2$ by 10-inch picture. Three, 5-, 7-, and 9-inch tubes will probably also be standard commercial sizes. Compared with the size of a motion picture or even a home movie, these dimensions seem small. However, considering the fact that the audience viewing a television picture will ordinarily not be more than perhaps four feet from the screen, and in the case of the small tubes, even one foot from the screen, these sizes do have considerable entertainment value. Anyone who has seen good pictures on 9-inch or 12-inch tubes will testify that when the program is interesting, the observer forgets that he is viewing television and becomes completely absorbed in the action on the screen. Nevertheless, it is reasonable to expect larger pictures in the best systems of the future. Table II shows the characteristics of some present-day television tubes.

The matter of increasing the size of the cathode-ray picture presents some serious obstacles. As tubes become larger they also become longer and their overall size becomes such that it is difficult to find suitable cabinets for them, which at the same time lend themselves to attractive styling. For this reason, when a 12-inch tube is used, it is invariably mounted vertically in a cabinet, and the picture is seen as a mirror image by the observer. Since a mirror causes a loss of light, and possible double images and distortion, it is an undesirable adjunct at best. As a further difficulty, as cathode ray tubes are increased in size, they require more driving power, which is expensive, and higher anode voltages, which besides the additional cost, also represents a shock hazard. Thus the prospect of making cathode-ray tubes for home use with screen diameters exceeding 12 or possibly 15 inches does not seem promising at this time.

As an alternate method of increasing the size of the picture obtainable by electronic means, the projection picture tube may be considered. In this case a very brilliant picture on the screen of a 4-inch cathode-ray tube is enlarged by an external optical system and is projected on a screen to a size of, say, 3 × 4 feet. This system requires an exceedingly bright tube with a very fine spot. The ultimate size of projection tube pictures is limited, on the one hand, by the brightness obtainable from a fluorescent screen without causing its rapid deterioration and, on the other hand, by the detail which can be obtained which is closely associated with the fineness of the spot achievable. Projection tube apparatus is probably too large, complicated, and costly for home use, but for public performances of television programs, it undoubtedly has a future.

Mechanical television systems have also been used for obtaining large pictures, with some degree of success. Of these, probably the most noteworthy is the system employed by Scophony. This system accomplishes modulation of the light-wave by utilizing fringe light, produced by virtue of passing a primary beam through a glass vessel in which is held gasoline or benzine, the liquid being subjected to vibration from a quartz crystal. The resulting modulated wave is then reflected successively by two rotating mirrors at right angles for accomplishing line and frame scanning. In the system as proposed, the line mirror rotates at a speed somewhat faster than 30,000 rpm.

Closely associated with the problem of picture size is the problem of picture detail. As has been pointed out, the vertical detail resolvable in a picture depends upon the number of scanning lines, and the horizontal detail depends upon the ability of the electrical system to pass extremely high frequencies. In addition to this, of course, neither can go beyond the effective diameter of the electron spot. Observers have found that if the diameter of a picture element subtends less than one minute of arc at the eye, a picture contains essentially all the detail resolvable by the observer. If the observer is considered to be 4 feet from the screen, a simple calculation will show that there are required 70 lines per inch and at 2 feet, 140 lines per inch. In present-day high-quality pictures on a 12-inch tube, with a $7^1/_2$ inch × 10-inch picture, and 400 useful lines,* there are 53 lines to the inch. It is not unreasonable, therefore to expect the number of lines in television pictures to be a matter for attention in the years to come.

Goldsmith states that a high-quality motion picture screen has 5,000,000 picture elements. This would be equivalent to a 2000-line

* Ten per cent of the 441 lines must be considered lost in the retrace interval.

picture, which would give 1 degree resolution on a picture 3 feet × 4 feet in size, viewed from a point 5 feet away. While it is not too much to expect such television pictures sometime in the future, certainly a great many problems must be solved first. For example, such a picture would require 150,000,000 picture elements per second, which, at a conservative estimate, would need a band width of 80 megacycles per program for its transmission. This would undoubtedly require the use of quasi-optical carrier frequencies and the whole problem would entail development in many fields. To make this statement more striking, the band required would be 80 times as wide as the whole spectrum now allocated to all broadcasting in the United States.

Another important consideration in television development is the problem of picture brightness. Cathode-ray tubes used in television receivers at present, are as bright as could be desired in a darkened room. Viewed in the daylight, however, or even in a well-lighted living room, their brightness is deficient. While it is always possible to darken motion picture theaters, television receivers will probably be expected to be more versatile, and to operate in bright light as well.

The problem of increasing picture brightness is being attacked in many ways. Operating voltages, for instance, can be and are being increased. This, however, is undesirable from the standpoint of safety and cost. More efficient luminescent materials are, of course, the most obvious solution, and such materials are constantly under development.

Another interesting development in this connection is the direct-viewing tube. This differs from the ordinary tube in that the bombarded side of the screen is viewed, instead of the opposite side, as is customary. Such tubes naturally require a construction of unorthodox shape. However, they may be the tubes of the future, both for reasons of brightness and also for reasons of contrast and detail, as will be pointed out later. Maloff[2] reports a direct-viewing tube having a maximum useful brightness of 100 candles per square-foot. This is more than ten times as bright as the highlights in a high-quality motion picture.

Finally, there must be considered the matters of contrast and detail. The present contrast available in television tubes is quite good, but much still remains to be done. For one thing a cathode-ray tube exhibits the phenomenon of halation. This is the optical effect of the diffusion of light in the screen material, and with it we may also group the internal reflection of light from the walls of the tube. Halation is well known in photography. It decreases the brightness of highlights and diffusely lights up points which are supposed to be dark, particularly in locations near the highlights. The general effect is thus to decrease the available contrast and to limit the possible fine detail. The direct-viewing tube is a very effective means of decreasing halation. When such a tube is used, the increased contrast is very striking.

In addition to halation, a cathode-ray tube also exhibits the phenomenon of "blooming," which is an electrical effect and results in defocusing the spot in the highlights. Improved focusing arrangements can be used to decrease "blooming," but even in the best of modern tubes it is still a problem. Since the contrast desired in a television picture requires an electronic beam of varying density, the focusing of the tube must be so arranged that the focal point does not change with current density, *i.e.*, brilliance. This is not an easy problem. However, it is evident that before the 2000-line pictures mentioned above are ever obtained, great advances must be made in the cure of "blooming."

PROPAGATION

The problem of signal propagation in television assumes an importance which, in many respects, is far more serious than that of the corresponding problem in sound transmission. In the first place, the exceedingly wide frequency channels required in television make it necessary that the signals be transmitted in the ultra-short-wave bands. At these frequencies, as is well known, there exists reliably only line-of-sight transmission, since there is no longer reflection from the Heaviside layer. While this fact limits the area of coverage of any transmitter, it is actually very desirable from the standpoint of interference. Thus there is far less likelihood of multiple images caused by multiple path reception, due to reflections from the Heaviside layer, or of interference from a distant station operating at the same frequency, or from atmospheric "static." The only serious sources of noise at these frequencies are those generators within approximately line-of-sight, of which noteworthy examples are automobile ignition systems and medical diathermy machines.

While reflections from the Heaviside layer are negligible, nevertheless, because of the very short waves employed, objects such as steel buildings, water towers, overhead wires, etc., provide efficient reflectors and give rise to "ghost" images. The severity of this problem will be realized much more fully than at present when the general public begins the erection of receiving antennae and the operation of receivers on a large scale.

The line-of-sight limitation greatly increases the difficulty of serving a large geographical area with a given program. A brief consideration of this problem will be of interest. It can logically be divided into two parts:

(*1*) The conditions necessary for adequate coverage of the line-of-sight area, and

(*2*) The problems involved in network distribution.

As a first step in finding the conditions necessary for adequate coverage of the line-of-sight area, we recall the formula

$$S = \sqrt{2r}\,[\sqrt{h_1} + \sqrt{h_2}] = 3560\,[\sqrt{h_1} + \sqrt{h_2}] \qquad (3)$$

where

S = distance over which line-of-sight transmission takes place (in meters)
h_1 = height above intervening ground level of transmitting antenna (in meters)
h_2 = height above intervening ground level of receiving antenna (in meters)
r = the radius of earth (in meters)

This formula can readily be derived by geometrical consideration of the curvature of the earth. Next consider the formula[3] for the field-strength, near the horizon, from a transmitting antenna:

$$E = \frac{88\sqrt{W}\,ah}{\lambda r2} \text{ volts per meter} \qquad (4)$$

where

E = the field strength

h = height of the transmitting antenna (in meters)
a = height of above effective ground of the receiving antenna (in meters)
r = distance of transmissions (in meters)
λ = wavelength (in meters)
W = effective* radiated power from the transmitter (in watts)

Now it is reasonable to expect a transmitting antenna to be located about 300 meters above ground and a residential receiving antenna to be a half-wave dipole located 4 meters above the roof (effective ground) while the roof itself is ten meters above ground. Under these circumstances there results from equation *3:*

$$S = 3560\,(\sqrt{300} + \sqrt{14}) = 75{,}000 \text{ meters}$$
$$= 75 \text{ km. or } 46.6 \text{ miles} \qquad (5)$$

* If a transmitting antenna other than a half-wave dipole, such as a directional array, is used, the effective value of W may be increased in certain directions.

This is the radius of the area over which reliable coverage can be obtained from the transmitter, provided that the power of the transmitter is sufficiently great. Consider, now what this transmitter power must be, in order to give reliable reception at the distance S from the transmitter.

It is an empirical fact that reliable reception of a television program requires an input signal of about one millivolt. Now the effective height[4] of the usual half-wave dipole receiving antenna is λ/π. Therefore, the required transmitter antenna power is given by the equation:

$$\frac{88\sqrt{W}\,ah}{\lambda S^2} \cdot \frac{\lambda}{\pi} = 10^{-3}$$

or

$$W = 1.28 \times 10^{-9} \frac{S^4}{a^2\,h^2} = \frac{1.28 \times 10^{-9}\,(75{,}000)^4}{4^2 \times (300)^2}$$

$$= 27{,}100 \text{ watts* or } 27.1 \text{ kw.} \qquad (6)$$

Actually, at the present time it is not feasible to radiate this much power, since no satisfactory tubes are available to generate it at these ultra high frequencies.

Using two of the latest high-power developmental tubes in push-pull, it is possible to generate 10 kw. (40 kw. peak) at fifty megacycles. The limiting factor in this case is the fact that the size of high power tubes makes it impossible to tune them above a certain critical frequency and their high interelectrode capacities make it difficult to load them properly and still preserve the desired band-pass characteristics. Thus with tubes of the present types, it is not yet possible to reach the desired power level; and the condition will become more serious as more of the still higher frequency channels are used for television. However, it is reasonable to expect that the ingenuity of tube designers will overcome this difficulty in the next few years. In the meantime, the condition can still be corrected by increasing the height of the transmitting antenna, and especially of the receiving antenna.

As a result of the above, an interesting fact is evident. If the height of the receiving antenna is neglected in calculating the line-of-sight distance, there results:

$$S = 3560\sqrt{h}$$

---

* Slightly in error because formula *4* is extrapolated beyond the horizon.

Substituting this value of S into equation 6 there results:

$$W = \frac{206{,}000}{a^2} = 12.9 \text{ kw.} \tag{7}$$

It is evident that this value of W is independent of h. In other words, it requires 12.9 kilowatts of transmitted power to generate a signal of one millivolt in a half-wave dipole 4 meters above the ground at the horizon. This value is independent both of the carrier frequency and of the height of the transmitting antenna. The latter result is

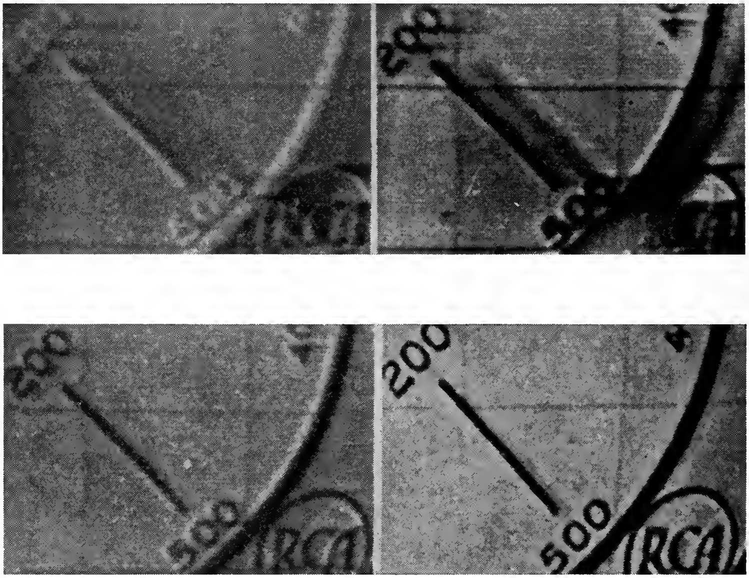

FIG. 11. The effect of multiple-path transmission or reflection upon the received image.

very surprising. It indicates that as the antenna height is increased, the same power still suffices to reach the horizon—the increased distance being just compensated by the increased antenna height.

Another problem of considerable importance in the adequate coverage of the line-of-sight area is the elimination of multiple reception or echoes. This problem is of practically no importance in sound broadcasting. To get a clear idea of the problem, suppose that in addition to the direct ray travelling from the transmitting to the receiving antenna there is also a ray which reaches the receiving antenna by way of reflection from a large building. This reflected ray will have travelled a greater distance than the direct ray before reaching the receiver. The picture which it carries will therefore be retarded in time, and it will consequently cause a similar but slightly displaced picture to appear next to the desired picture. This is a very annoying effect, and great effort must be made to avoid it. This effect is illustrated in Fig. 11.[5]

The path difference necessary to cause a disturbing echo can be easily computed. The time of retardation of the reflected ray is clearly equal to the difference in path of travel divided by the velocity of light. Then, remembering that the electron beam scans ($^4/_3 \times 30 \times 441 \times 441$) picture elements per second, the displacement of the echo from the main picture (in picture elements) is

$$D = \frac{4/3 \times 30 \times 441 \times 441}{3 \times 10^8}$$

$$= 0.026 \text{ times the path difference in meters}$$

In other words, a path difference of 127 feet will cause an echo displacement of one picture element. This is enough to detract from the quality of the picture.

The elimination or reduction of echoes is a complicated problem. In metropolitan areas, due to the presence of many reflectors in the form of tall buildings, the problem is serious indeed. The usual solution is to use a directional antenna which will discriminate against the undesired signal. Horizontal polarization of the radiated signal has been found to improve the signal-to-noise ratio at television carrier frequencies, and its use will therefore probably become a standard practice.

Some of the problems connected with the chain distribution of television programs may now be considered. There are two general methods which have been used to transmit television programs from a key transmitter to a distant transmitter. These are the use of (*1*) the radio relay or (*2*) the coaxial (or other) high-fidelity cable relay.

Whichever method is used, the relay stations must be sufficiently close together so that non-fading noise-free signals are received at each repeater location. It has been found that relay stations must be located from 30 to 70 miles apart, the exact distance depending on noise conditions and (in the case of the radio relay) on the topography of the landscape. It has been customary to operate radio relays at wavelengths of two meters or less. Each relay station, of whichever type, must reproduce the incoming signal with the highest fidelity, having neither amplitude, frequency, nor phase distortion. In other words, the picture must not be degraded in passing through the relays.

It is not surprising that the great problem in the relaying of television signals is cost. The cost per mile of a coaxial cable required to handle the exceedingly wide frequency bands of television programs is, at the present time, many times as great as the cost of corresponding networks used in sound broadcasting, both as regards initial cost and maintenance. If radio relaying is used, the cost of the relay transmitters required is obviously very great. However, the coming years are likely to bring great reductions in the costs of both methods of relaying, particularly the coaxial cable.

This paper has been an effort to point out the fact that many problems still must be solved before fully satisfying television pictures will be available in the home. However, it is not to be construed that the commercial introduction of television will await a solution to these problems. Undoubtedly television will be commercialized in the near future and the problems will be solved as time passes—much the same, for instance, as was the case in the motion picture industry. One fact is very clear, that the further development of television must come largely through findings in the field, that is, by actual trial.

The author wishes to acknowledge the assistance of Dr. Stanford Goldman in the preparation of this paper and the courtesy of the National Broadcasting Company and the British Broadcasting Company for the use of photographs of their equipment.

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DISCUSSION

MR. MCNABB: Referring to the reproductions (Figs. 4 and 5) of a British picture and an American picture, the line structure was quite evident in the British picture, but the contrast seemed a little better. Is the contrast better in the British picture due to the method of transmission, or is the transmission of direct current along with the signal better than the American method of adding the d-c. at the receiving end?

MR. KAAR: There is no essential difference in the method of transmission in England and here. The only difference is the means of synchronization. As far as contrast and detail are concerned, there should be no difference between the two systems except for the possible fact that we have 441 lines, whereas they have 405.

It is possible to photograph any kind of picture from the front of a picture tube and we can so adjust focus and contrast as to make the line structure visible on an American picture.

As a matter of fact, neither of these pictures is a good example because they have both been degraded by photographic processes in the original photograph, the enlargement, the negative, and the lenses, so in order to compare the two fairly the originals should actually be seen. Our pictures are somewhat better than the British pictures.

MR. FINN: In the choice of repeaters, Mr. Kaar suggested that the choice as between coaxial cables and straight etherization of a program is very close. Is it your suggestion that the coaxial cable be used, over hill and dale for thirty or sixty miles, throughout the whole broadcast circuit, to blanket the country?

MR. KAAR: That is a difficult question to answer because I am not familiar with the recent progress on coaxial cable. You will find a description of the New York-Philadelphia cable in the literature. As I remember, it has repeaters every ten miles and as yet will not transmit the full band required. Perhaps some day transcontinental cables may be laid capable of handling television programs, but I can not say that they will. The other system is satisfactory and has been tried. As to the economic balance between the future use of cables and ether channels, that still remains to be answered.

MR. GOLDSMITH: The New York-to-Philadelphia cable was said to have cost $540,000. Whether that included large engineering developmental expenses or not, it is now known. In any case, that would have indicated a per-mile cost of $5000 or $6000. The major broadcasting networks in the United States today use somewhere on the order of 40,000 or 45,000 miles of lines, and if one multiplies that by $5000 for the cost of laying a similar coaxial cable network, the result of the multiplication is an extremely large and uneconomic amount.

However, it is believed likely that development will lead ultimately to less costly coaxial cables with repeater stations closer together and satisfactory for the purpose, or to economic radio relay systems that will work very effectively.

MR. KAAR: The fact that such a serious problem exists in chain programs comes pretty closely home to the motion picture engineer, because for the immediate present there is an answer to the chain broadcasting of television programs, namely, the transmission of motion picture films, which will undoubtedly be done extensively.

MR. GOLDSMITH: There are many practical and artistic reasons why film will necessarily be widely used.

MR. WILLIFORD: Does the adoption of the 60-cycle frequency as standard mean that communities having 25- or 50-cycle power supply are definitely out of the picture as far as television is concerned?

MR. KAAR: There is no connection between the synchronizing mechanism of television and the power frequency. The synchronizing is accomplished by transmitted signals. The only reason for and the advantage of choosing a frame frequency that is a multiple or submultiple of the power-line frequency is this: If a system should develop a ripple, as we know it in audio work, that ripple would occur at power-line frequency. If the frame frequency occurred at some other frequency than that, this ripple, which would be either a light area or a dark area, would travel across the screen. If the system is perfect and there is no ripple, it makes no difference at all. This is simply chosen as a safety measure.

MR. GOLDSMITH: If the power-supply system of the receiver and its shielding are so engineered that no such effects appear, the receiver can be used equally well regardless of the power supply.

MR. CABLE: It seems to me that the frequency chosen as 30 places a definite limitation on the picture brightness, because the frequency is a function of brightness.

MR. GOLDSMITH: The present standard is 60 pictures per second. We see 60 "half pictures," with interlaced scanning. First is shown a picture with lines 1, 3, 7, and so on, as a full picture; and the one with lines 2, 4, 6, 8, and so on, as the next picture, a sixtieth of a second later. So the frame frequency is 30 but the field frequency is 60 per second. You substitute for picture flicker a new effect called inter-line flicker, which is practically invisible.

MR. FRIEDL: In selecting the number of frames projected, you have evidently regarded power-supply frequency as an important factor. Inasmuch as the motion picture film will be used as a means of widely distributing the program, the frame-frequency of the motion picture is a consideration. I would judge, from the decision, that the more difficult matter of control is the power supply, but we as motion picture engineers naturally ask why the 24-frame frequency with interlacing to give 48 images was not considered the more important factor.

You speak of standards in television. We are very standards-conscious in the SMPE and are aware of the importance of international as well as national standardization. I see a lack of uniformity among the standards adopted by Germany, Great Britain, France, and America. That might be excused at the moment because of the fact that the range of transmission is so limited and we can not expect immediately to transmit across the ocean; but inasmuch as the number of lines selected is 441, which has been selected mainly to allow room for improvement, can not we also anticipate improvement and have confidence in the effect of the development to look forward to transmission across the ocean, and, therefore, international standardization?

MR. GOLDSMITH: We may hope for this, because some such standard as 441 lines for the picture might be adopted by all the nations. But it must be admitted that at the present time radio differs from motion pictures in that international standardization is rather conspicuously absent. However, it may come with television.

MR. FRIEDL: We are conscious of the high voltages in the larger tubes—25,000 and 40,000 volts. What is the voltage on the 12-inch tube and how does the system meet with the protective requirements of the NFPA and the Fire Underwriters?

MR. KAAR: The voltage on the 12-inch tube will probably be 6000 volts. That sounds like a very serious matter, but really it is not. If you sit in a dentist's chair and he turns the X-ray on you, that is about 40,000 volts. It is protected.

It simply means we have a job of protecting the television receiver, possibly by an interlocked back.

MR. FRIEDL: All I can say is that conditions in the home where children might come in contact with the apparatus are different from what they are in a dentist's office.

MR. GOLDSMITH: The back of the receiver is an expanded metal mesh. If you open the back, you will open all power circuits and discharge the high-voltage condensers automatically. If you try to take the cathode-ray tube out you will similarly open up the circuits. You can not get into contact with a high voltage. It is generally so arranged that even people with screw-drivers and determination simply can not get into trouble, and we hope these practices will continue.

MR. FRIEDL: Does horizontal polarization mean that the antenna will be horizontal? Also, is that discussion of a three-meter receiving antenna going back to a multiplicity of "wash line" antennas on every roof?

MR. GOLDSMITH: The antenna wire or rod is only about six feet long. The two component rods are each about three feeet long.

MR. KAAR: They are half a wavelength long, and the wavelengths are of the order of five meters.

MR. MCNABB: In an article about six months ago in *Electronics*, regarding the quality of television pictures, it was the opinion of certain American engineers who investigated the British pictures that the British were ahead of us in their technical developments as well as their commercial exploitation of the art. That seems to disagree with the opinions of other American engineers. Exactly what are we to believe?

MR. GOLDSMITH: The consensus of engineering opinion among those who have seen television pictures in London and New York is that there is little if anything to choose between them. It is most unlikely that practice in either case is far ahead of the other.

REPORT OF THE STUDIO LIGHTING COMMITTEE*

Summary.—*In a previous report of the Studio Lighting Committee the need of a catalogue of studio lighting equipment was emphasized. A number of papers have been published which describe various lamps and light-sources in detail, but there has not been assembled in one paper a symposium of all types of equipment and light-sources used on motion picture sets.*

This report covers all types of equipment in general use. The various lighting units are numbered and briefly described. Photographs of popular lamps are shown. Tables give minimum and maximum beam divergences, carbon and bulb sizes. Reference numbers are assigned to the various lamps for convenience in listing their characteristics. Data on light control devices and lamp filters are included.

CARBON ARC LAMPS

(*1*) *MR Type 27 Scoop.*—Chromium plated reflector and Factrolite glass diffuser. Solenoid controlled. A twin-arc flood source, used for overhead illumination of walls, backings, and other areas that can not be lighted satisfactorily by spotlamps. Suspended singly or in groups. A smooth, general-purpose light-source.

(*2*) *MR Type 29 Broadside.*—Chromium plated reflector and Factrolite glass diffuser. Solenoid controlled. A twin-arc flood source that may be raised, lowered and tilted, and used as a floor-lighting unit for building up front light to the desired exposure level.

(*3*) *MR Type 40 Duarc Broadside.*—Chromium plated reflector and pebbled, sand-blasted Pyrex glass diffuser. An improved motor-controlled twin-arc flood-lamp that takes the place of both scoop and broadside of the older types.

(*4*) *MR Type 65 Arc Spotlamp.*—Eight-inch diameter Fresnel-type lens. High-intensity rotating mechanism. Used for front and back lighting, close-up and medium shots. The intensity is almost uniform in the main portion of the beam, tapering off at the edges to permit overlapping adjacent beams without producing objectionable high-intensity zones. Within its energy capacity this lamp may be used for all photographic spot lighting.

(*5*) *MR Type 90 Arc Spotlamp.*—Fourteen-inch diameter Fresnel-type lens. High-intensity rotating mechanism. Used for back

* Presented at the 1938 Fall Meeting at Detroit, Mich.

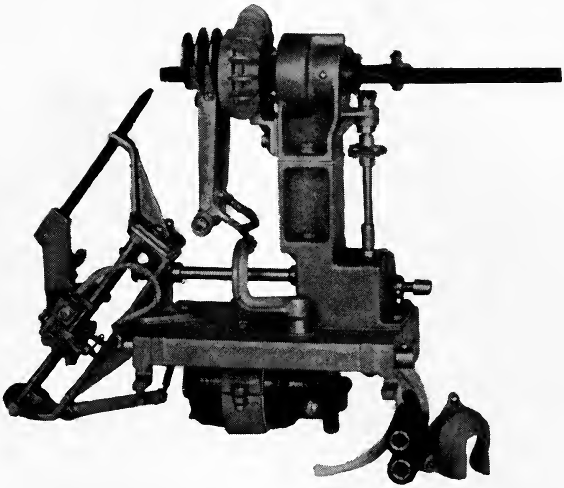


FIG. 1. Typical high-intensity rotating element.

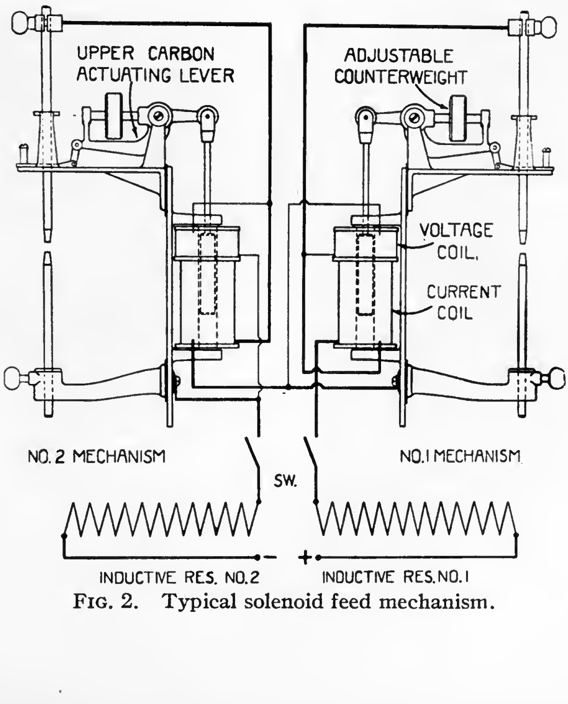
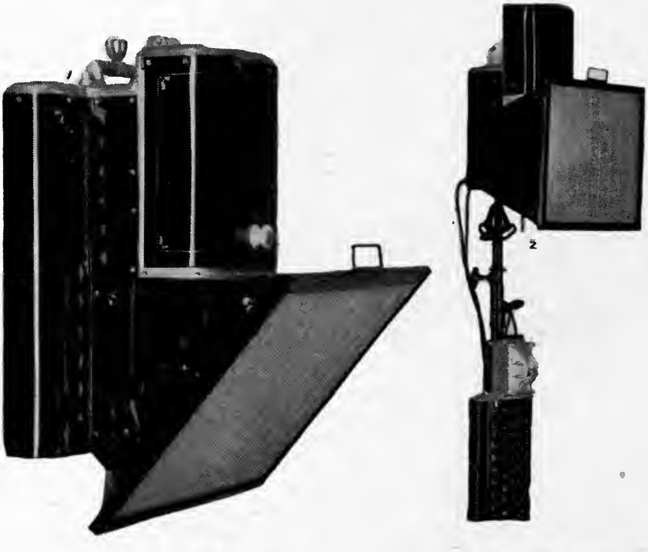


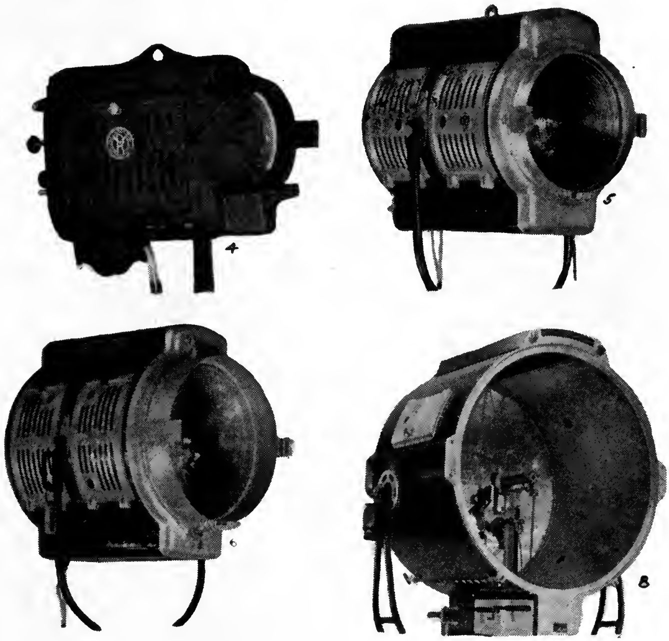
FIG. 2. Typical solenoid feed mechanism.



Lamp No.
1. *MR type 27* scoop.
2. *MR type 29* broadside.
3. *MR type 40* duarc broadside.

lighting, sunlight effects through doorways or windows, *etc.*, for key lighting on sets of moderate size, and for general front lighting into the rear areas of deep sets.

(6) *MR Type 170 Arc Spotlamp.*—Twenty-inch diameter Fresnel-type lens. High-intensity rotating mechanism. Used for back, cross, and key lighting, and for wide- and narrow-angle front and effect



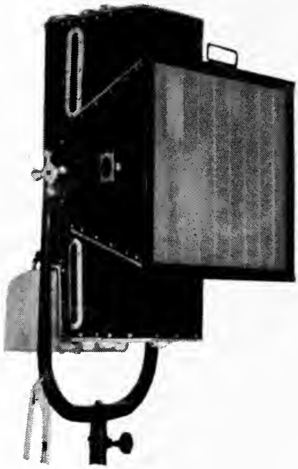
Lamp No.
4. *MR type 65* arc spotlamp.
5. *MR type 90* arc spotlamp.
6. *MR type 170* arc spotlamp.
8. 36-inch sun arc.

lighting. This unit has wider use for both black-and-white and color photography than any of the other arc units.

(7) *24-Inch Sun Arc.*—Twenty-four inch diameter glass mirror. High-intensity rotating mechanism. Normally used with the arc crater facing the mirror and a clear glass door on the front of the lamp house. Where very sharp shadows are necessary the clear glass door may be moved to the position normally occupied by the mirror. A metal door is then placed on the open end. A large number

of these lamps have been converted to use the same optical system as the *MR* type *170* lamp. Used for back lighting, sunlight effects through windows and doorways, *etc.*, for key lighting on sets of moderate size, and for general front lighting into the rear areas of deep sets.

(*8*) *36-Inch Sun Arc.*—Thirty-six inch diameter glass mirror. High-intensity rotating mechanism. Similar to the 24-inch Sun Arc except as to size. The 24-inch Sun Arc is rapidly being converted to the use of the Fresnel type of lens, but due to its great penetrating power, the 36-inch Sun Arc is valuable on extremely long throws and retains its popularity in its present form. When a large quantity of diffused light is required from this unit, a diverging door composed of strips of cylindrical lenses replaces the plain glass door. The lamp is used where a very high intensity of projected light is required, as in back lighting behind a high level of foreground illumination; or where well defined shadows are required; or where a clearly defined streak of light is required through the general illumination; or for producing a general illumination of great penetration and high intensity.



Lamp No. 10.

(*9*) *80-Ampere Rotary Arc Spotlamp.*—An 8-inch diameter plano-convex condenser or 12-inch Fresnel-type lens. High-intensity rotating mechanism. One of the early high-intensity arc spotlamps. This lamp is not suitable for color in its present form because of the spectral energy distribution of the carbon trim. A number of these lamps have recently been converted to the use of 11 mm. × 20-inch H. I. motion picture studio positive carbons to make them suitable for color photography. Used for back lighting on black-and-white sets and to increase the intensity of illumination at any point where projected light is required within the range of its intensity.

(*10*) *B & M Type 9 Twin-Arc Broadside.*—Chromium plated reflector and glass diffuser. Solenoid striker with direct motor feed. A twin-arc flood source that may be raised, lowered and tilted, and used as a floor-lighting unit for use in building up front light.

TABLE I

Arc Lamps for Set Lighting

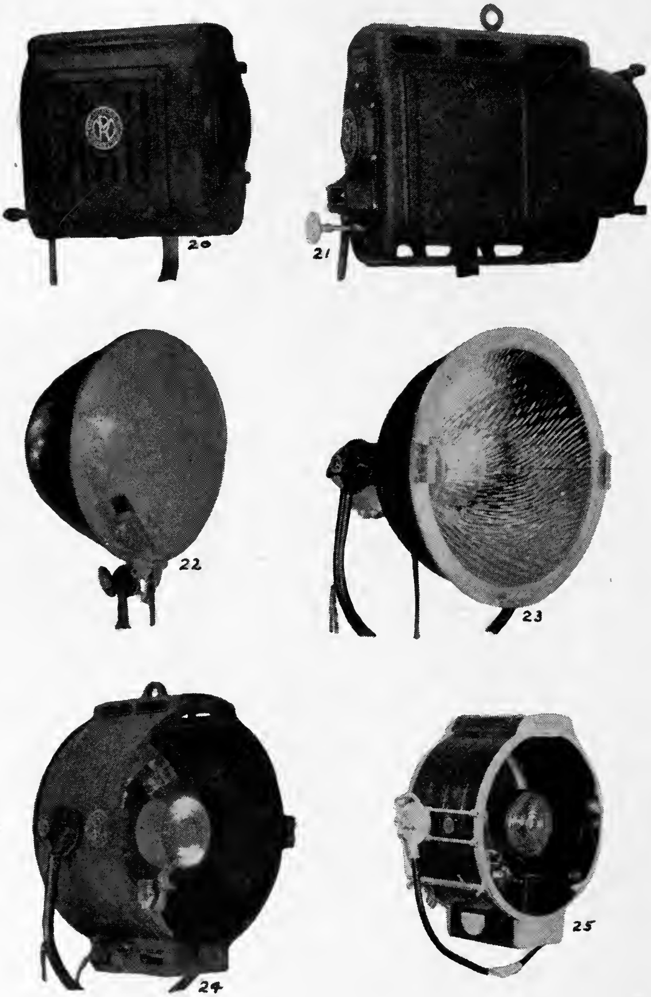
Lamp No.	Unit	*Degrees Beam Divergencies Min.	Max.	Positive Carbon No.	Negative Carbon No.
1	*MR 27 Scoop*[1]	90	90	1	10
2	*MR 29 Broadside*[1]	90	90	1	10
3	*MR 40 Broadside*	90	90	1	10
4	*MR 65 Spotlamp*[4]	8	44	2	11
5	*MR 90 Spotlamp*[3]	8	44	5	14
6	*MR 170 Spotlamp*[2]	8	48	6	15
7	*24-Inch Sun Arc*[2]	**10	24	6	13
8	*36-Inch Sun Arc*[2,4]	10	32	6	13
9	*80-Amp. Rotary Spot*[2]	**8	30	4	12
9*A*	*80-Amp. Rotary Spot (Converted)*	8	44	3	12
10	*B & M Type 9 Twin-Arc Broadside*	90	90	1	10

* Approximate figures referring to usable photographic light.
** With Fresnel-type lens divergences are approximately 8 to 44 degrees.

TABLE II

Carbons for Set Lighting

Carbon No.	Positive Carbons	Amperes	Arc Volts
1	8-Mm. × 12 NP MP Studio[2,6,7,8,9]	38–43	35–40
2	9-Mm. × 20″ Hilow Projector[5,9]	65–70	52–54
3	11-Mm. × 20″ HI MP Studio[9]	90–95	62–65
4	$^1/_2$″ × 12″ 80-Amp. Rotary Spot[2,7,8,9]	75–80	50–55
5	13.6-Mm. × 22″ HI Projector[4,5,9]	110–115	54–56
6	16-Mm. × 20″ HI MP Studio[2,4,5,7,8,9]	140–150	64–67
	Negative Carbons		
10	8-Mm. × 12″ NP MP Studio		
11	7-Mm. × 9″ Cored Suprex Negative		
12	$^3/_8$″ × 9″ Cored 80-Amp. Rotary Spot Negative		
13	11-Mm. × 10″ Plain-Cored MP Studio Negative		
14	$^3/_8$″ × 9″ Cored Orotip Negative		
15	$^7/_{16}$″ × 9″ Cored Orotip Negative		



Lamp No.

20. *MR type 36* studio spotlamp.
21. *MR type 26* studio spotlamp.
22. *MR type 16* cinelite.
23. *MR type 45* rifle lamp.
24. *MR type 220* 18-inch sun spot.
25. *B & M type T5* studio spotlamp.

INCANDESCENT LAMPS

(*20*) *MR Type 36 Studio Spotlamp.*—A 6-inch diameter, 9-inch focus plano-convex condenser. For use where a full controlled beam of light is required: in close-up photography for back and close lighting, particularly where the photography demands high contrast of light and shadows; in general motion picture set lighting it is useful for special effects and for illuminating areas that can be reached only by projected light.

(*21*) *MR Type 26 Studio Spotlamp.*—A spherical mirror is adjustably mounted behind the bulb to collect the rays of light and direct them upon an 8-inch plano-convex condenser. Used for back lighting, special effects, and particularly on sets where the general lighting must be in low key.

(*22*) *MR Type 16 Cinelite.*—A spun aluminum reflector, finished inside by wire brushing and chemical treatment, which gives it a diffusing characteristic. Used where light portable equipment is required.

(*23*) *MR Type 45 Rifle Lamp.*—Stamped metal reflector, chromium-plated with rifled corrugations for diffusion Used for general floor lighting.

Lamp No. 26. *MR type 226* 24-inch studio sun spot.

(*24*) *MR Type 220 18-Inch Sun Spot.*—An 18-inch diameter parabolic glass mirror or faceted metal reflector, with spill ring as standard adjunct. Used for general illumination, for back lighting and cross lighting in small and moderate size sets, and for projecting light into back areas of sets.

(*25*) *B & M Type T5 Studio Spotlamp.*—A short-focus Fresnel-type lens in front of the bulb and a small fixed spherical mirror behind the bulb project light forward into the field. This, in combination with the light projected around the lens from the 24-inch reflector, gives an even, intense light. For the large mirror, either a 24-inch diameter aplanatic reflector or a 10-inch focus glass mirror is used. The aplanatic reflector produces a very even field of light. Greater penetrating power for long throws may be obtained with the parabolic

Lamp No.
28. *MR type 206* baby solarspot.
29. *B & M type 6* baby keg-lite.
30. *B & M type K* keg-lite.

Lamp No.
31. *MR type 208* solarspot.
32. *MR type 210* junior solarspot.
33. *MR type 214* senior solarspot.

glass reflector. Used for back lighting, cross lighting, front lighting, and effect lighting.

(*26*) *MR Type 226 24-Inch Studio Sun Spot.*—A 24-inch diameter glass mirror, with a spill ring that allows only projected light to leave the lamp. Used for back lighting large sets, in which case the heads are removed from the pedestals and are mounted on parallels or platforms built at the top of the set or hung from the stage roof or ceiling.

TABLE III

Incandescent Lamps for Set Lighting

Lamp No.	Unit	*Degrees Beam Divergencies Min.	Max.	Bulb No. **(B & W)	Bulb No. (Color)
20	*MR 36 Studio Spotlamp*	8	44	8	
21	*MR 26 Studio Spotlamp*	8	44	8	
22	*MR 16 Cinelite*[12]	60	60	16	
23	*MR 45 Rifle Lamp*	60	60	4–5	15
24	*MR 220 18" Sun Spot*	8	18	3–7	14
25	*B & M T-5 Studio Spotlamp*[11]	8	40	2–3	13–14
26	*MR 226 24" Sun Spot*	12	24	2	13
27	*B & M 24" Sun Spot*	12	24	2	13
28	*MR 206 Baby Solarspot*[11]	8	40	9	
29	*B & M Baby Keg-Lite Type 6*	6	45	9	
30	*B & M Keg-Lite Type K*	4	44	3–7	14
31	*MR 208 Solarspot*[11]	10	44	8	
32	*MR 210 Junior Solarspot*[11]	10	44	3–7	14
33	*MR 214 Senior Solarspot*	10	44	2	13
34	*Sky Light*[12]	180	180	2	13
35	*Broadside (Doubles)*	90	90	5	15
36	*36" Sun Spot*	12	24	1	12
37	*Overhead Strip Lamp*			5	15

* Approximate figures referring to usable photographic light.
** For black-and-white photography.

The lamps are used where a large quantity of light is to be supplied by a small number of units; for front lighting on deep sets; for cross lighting where high contrast is desired or on wide sets where the camera angle requires that the cross light be projected from a distance; for effect lighting such as in simulating sunshine through windows or doorways, or interior light into exterior darkness in night shots; and for similar special requirements demanding beams of high intensity.

(*27*) *B & M 24-Inch Sun Spot.*—Similar to No. *26* in design and use.

(*28*) *MR Type 206 Baby Solarspot.*—A 6-inch diameter Fresnel-type lens. The small size of this lamp permits its use in places where the larger lamps can not be accommodated, particularly where it is necessary to conceal a source of high-intensity light.

(*29*) *B & M Baby Keg-Lite Type 6.*—A short-focus 6-inch diameter Fresnel-type lens combined with a prefocused mirror; used for special effects and where small units are required.

(*30*) *B & M Keg-Lite Type K.*—A 10-inch diameter by 6-inch focus Fresnel-type lens. A set spherical mirror projects the rear light from the bulb toward the lens. A general purpose unit within its intensity limits; used for front lighting, back lighting, and modeling.

Lamp No. 34. Sky light.

(*31*) *MR Type 208 Solarspot.*—An 8-inch diameter Fresnel-type lens. A rhodium-plated spherical mirror is used at the rear of the bulb to direct the light toward the lens. Used for back lighting, modeling, and general front lighting within its intensity range.

(*32*) *MR Type 210 Junior Solarspot.*—A 10-inch diameter Fresnel-type lens. A rhodium-plated spherical mirror is used at the rear of the bulb to direct the light toward the lens. Used for back lighting, front lighting, cross lighting, and modeling within its intensity range.

(*33*) *MR Type 214 Senior Solarspot.*—A 14-inch diameter Fresnel-type lens. A rhodium-plated spherical mirror is used at the rear of the bulb to direct the light toward the lens. Used where high-wattage units are desirable, for back lighting, front lighting, and side lighting.

(*34*) *Sky Light.*—A shallow diffuse reflector about 24 inches in diameter. Used below and above sky backings and screens, where a flat even light distribution is required.

(*35*) *Broadside* (*Doubles*).—Two flood-type reflectors housed in one unit, used for floor, side, and overhead lighting: One of the first incandescent units made.

(*36*) *36-Inch Sun Spot.*—A 36-inch diameter glass mirror. Used where the highest intensity of projected light is required from an incandescent tungsten source.

(37) *Overhead Strip Lamp.*—A trough-like unit containing sockets for five 1000-watt *PS 52* bulbs. Used to supply fill-in light where it is difficult to use a more bulky housing.

TABLE IV

Incandescent Bulbs

Bulb No.	Nominal Rated Watts	Type of Bulb**	Volts	Nominal Amps.	Base
	"MP" Type Lamps (for Black-and-White Photography)				
1	10,000	*G-96*[13]	110–115–120	87.0	Mog. Bip.
2	5,000	*G-64*[13]	110–115–120	43.5	Mog. Bip.
3	*2,000	*G-48*[13]	110–115–120	17.4	Mog. Bip.
4	1,500	*PS-52*[13]	110–115–120	13.1	Mog. Scr.
5	1,000	*PS-52*[13]	110–115–120	8.7	Mog. Scr.
6	****1,000	*T-20*[13]	110–115–120	8.7	Mog. Scr.
7	*1,000	*G-48*	110–115–120	8.7	Mog. Bip.
8	1,000	*G-40*	110–115–120	8.7	Med. Bip.
9	****500	*T-20*[13]	110–115–120	4.4	Medium***
10	****500	*G-30*	110–115–120	4.4	Mog. Scr.
11	****200	*T-10*	110–115–120	1.7	Medium
	"CP" Type Lamps (for Color Photography—with Proper Filter)				
	(All "*CP*" Type Lamps Operate ar 3380°K. Color Temperature)				
12	10,000	*G-96*[11]	110–115–120	87.0	Mog. Bip.
13	5,000	*G-64*[11]	110–115–120	43.5	Mog. Bip.
14	2,000	*G-48*[11]	110–115–120	17.4	Mog. Bip.
15	2,000	*PS-52*[11]	105–120	17.4	Mog. Scr.
	Additional Types Frequently Used in Studio Work				
16	1,000	*PS-35*[13] (No. *4* Photoflood)	105–120	8.7	Mog. Scr.
17	500	*A-25*[13] (No. *2* Photoflood)	105–120	4.4	Med. Scr.
18	250	*A-21*[13] (No. *1* Photoflood)	105–120	2.2	Med. Scr.

* Available also in Mogul screw base for older equipments.

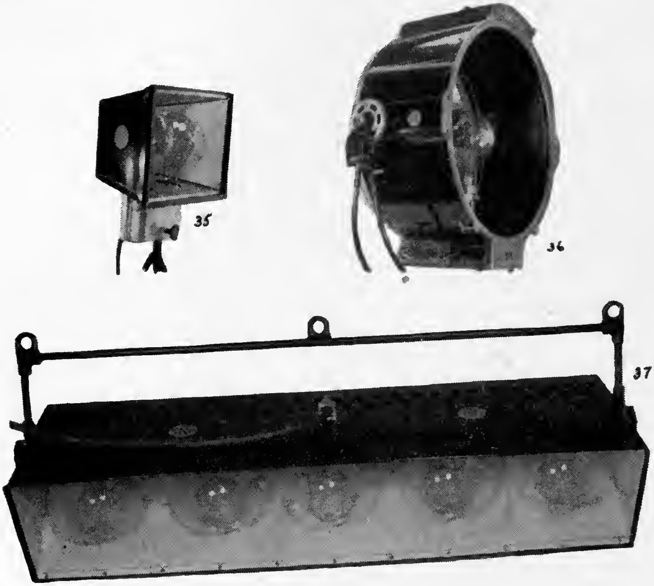
** *G* = spherical, *PS* = pear shaped, *T* = tubular, *A* = modified pear shaped. Numbers refer to diameter in $^1/_8$ inch.

*** Some units require the med. bip. base, others the med. scr. base or med. pref. base.

**** Used in utility lamps, lighting fixtures, table and floor lamps.

TERMS USED IN STUDIO LIGHTING PRACTICE

The terms applied to the various units of motion picture studio lighting equipment are legion and vary from studio to studio, and even from month to month. Sometimes a lamp is described by its type number alone; or by the rated current



Lamp No.
35. Broadside (doubles).
36. 36-inch sun spot.
37. Overhead strip lamp.

in the case of arc spotlights; or by the kilowatt rating of incandescent units. In some instances the mirror diameter supplies the name. Below are some commonly used terms, the "Lamp Numbers" referring to the preceding sections:

Term	Lamp No.	Term	Lamp No.
Broad	2–3–35	Twenty-Four Inkie	26–27
Side Arc	2–3	5KW	26–27
Sixty-Five	4	Baby	28–29
Ninety	5	Keg	30
One-Seventy	6	Junior	32
Twenty-Four	7	Senior	33
Thirty-Six	8	Pan or Skypan	34
Eighty	9	Doubles	35
1000-Watt Spot	20–21–31	10KW	36
Rifle	23	Strip	37
Eighteen	24		
T-5	25		

The following are a few terms used for material and equipment associated with the use of studio lamps:

Silks.—Frames equipped with china silk diffusers, hung on the fronts of lamps to diffuse the light and reduce the intensity.

Jellies.—Frames equipped with chemically treated gelatin. Used for the same purposes as silks.

Scrim.—Black gauze used in various places to reduce intensity and diffuse light.

Diverging Doors.—Strips of cylindrical glass lenses. Used on Sun Arcs for light diffusion.

Snouts.—Various shapes of black sheet metal hangars. Used on the front of lamps to block out undesired light.

Spill Rings.—A series of sheet metal tubes, used in front of incandescent bulbs in mirror type lamps to block off angular rays emanating from the front surface of the bulb filament (see photographs of lamps *24–26*).

Spot Projector.—A unit equipped with a condenser system that fits on the front of a Type *170* carbon arc lamp in place of the Fresnel-type lens; used to produce a sharply defined round spot of light.

Gobos, Flags, Cheese Cutters, Niggers, Etc.—It is often desirable to place opaque screens at various points on a set to keep all or a part of the light from reaching certain areas or objects. These screens are painted dull black and are rectangular, square, or circular, as the occasion may require.

LAMP FILTERS FOR COLOR PHOTOGRAPHY

Carbon Arc Lamps.—Carbon arc lamps *1–2–3* are used for Technicolor photography without color filters. All types of high-intensity rotating arc lamps require a Type *Y-1* straw gelatin filter.[4]

Incandescent Bulb Lamps.—Where incandescent bulbs are used on Technicolor photography a special blue glass filter is required along with a series of *CP* Type bulbs, which burn at a uniform color temperature of 3380°K.[11]

REFERENCES

(*All references are to J. Soc. Mot. Pict. Eng.*)

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C. W. HANDLEY, *Chairman*

R. E. FARNHAM	V. E. MILLER	G. F. RACKETT
W. C. KUNZMANN	M. W. PALMER	E. C. RICHARDSON
J. H. KURLANDER		F. WALLER

DISCUSSION

MR. GOLDSMITH: Is not this report the first assembly of such material in complete form?

MR. GEIB: Yes. This is the first time anyone has attempted to give a complete catalogue of studio lighting equipment.

MR. WOLF: Is the mercury-vapor arc lamp in commercial use?

MR. GEIB: No.

MR. WOLF: I understand they are used in Holland, in combination with sodium-vapor lamps to get a more balanced spectrum.

MR. GOLDSMITH: It would be interesting to know whether that type of combination could be used for color photography because while it might give a subjective effect of white with the addition of sodium vapor-lamps, it certainly would not give the physically continuous spectrum of an arc or an incandescent lamp.

It would therefore be interesting to know whether the Technicolor engineers could use a combination of that sort.

MR. WOLF: I understand that the combination is used a great deal in Holland for television work and for studio work.

MR. GOLDSMITH: As the pressure is increased in the mercury lamps the background spectrum becomes more and more intense and a certain quasi-continuity of the spectrum is obtained.

MR. CARLSON: That is correct. As the operating pressure in the mercury arc type of lamp is increased the continuity of the spectrum is definitely improved, together with an increased output of red energy.

In the case of medium-pressure air-cooled lamps the spectrum is still largely of the discontinuous or band type. The high-pressure water-cooled capillary lamp now on the market shows a continuous spectrum superimposed on the band spectrum. For still higher pressures the band characteristics largely disappear. Thus the mercury arcs that are now available are well adapted to monochromatic photography, but not for color work—nor is their light easily filtered because of the "humps" in the energy *vs.* wavelength curve. Possibly the sensitivity characteristics of the color film could be adapted to the light. Information on the lamp was published in the September, 1938, issue of the JOURNAL by Farnham and Noel.

MR. WOLF: What are the efficiencies of the light-sources now as compared with what they were, say, several years ago?

MR. DOWNES: The efficiency of light-sources in the studios is, so far as I have been able to learn, not of great importance. What is wanted is a steady light-source, and one that can be directed to the particular part of the set with certainty and assurance that it is going to continue to deliver uniform amount and quality of light during the time the photographing is done.

The efficiencies in lumens per watt on the sets in the studios must vary through tremendously wide limits because of the fact that a very large number of the light-sources used are focused to deliver spots of various sizes on the set and as a result the luminous efficiencies are extremely variable. These various spot units can be focused to deliver spots from about three feet in diameter to very large ones, and it would therefore be very difficult indeed to obtain any figures for lumens per watt except with a bare light-source which, considering how they are used, would mean little or nothing.

PHOTOGRAPHIC EFFECTS IN THE FEATURE PRODUCTION "TOPPER"*

R. SEAWRIGHT AND W. V. DRAPER**

Summary.—*An account is given of the various types of photography used in the feature production "Topper." Among the shots discussed are a split screen against a projected background, demonstrating the feasibility of such treatment. Other effects are: multiple exposures, animated split screen, animated travelling mattes, straight animation, intricate matching of action, and a new process of subtractive matting.*

A statement is included on the precautions taken to eliminate weave between the production shots taken with Mitchell cameras and the duping, which was done on Bell & Howell machines. The paper is illustrated with various selections from the picture, made by the processes described.

The reel witnessed at the Washington Convention of the Society on April 26, 1938, contained shots from the Hal Roach production *Topper* that are representative of the various types of trick photography used in the picture. They consist mainly of multiple exposures, animated split screen, animated travelling mattes, straight animation, intricate matching of action, and subtractive matting.

Most of the shots, particularly where the characters appear or disappear, are dupes made in contact on an optical printer with hard mattes in the optical head. The general procedure on the set was to take as much of the empty set as was needed, either before the scene was started or after it was finished, depending, of course, upon which end of the scene the split screen was to be used.

The camera was allowed to dolly or pan either before or after the part of the action requiring the split screen. At no time was the camera anchored. Of course, extreme care was taken not to move the camera while the portions of the scenes were being shot in which a character was to appear or disappear.

In most instances the action was taken on the set exactly as if

* Presented at the 1938 Spring Meeting at Washington, D. C.; received Nov. 11, 1938.

** Hal Roach Studios, Culver City, Calif.

there were no split screen involved. The invisible actor either occupied the position in which he would ultimately appear, or if the visible actor's action carried him too close to or past the spot, the invisible one would run in and occupy his position as soon as the visible actor was sufficiently clear of his position. The invisible actor would then be cut out on a dupe and blank set substituted in his position until time for him to appear.

The last three scenes in the reel shown at Washington—of the two materializing in the car seat, Miss Bennett materializing on the bed, and the background shot driving down Broadway—for various reasons were discarded, but were inserted in this reel to illustrate further what can be done by the simple treatment previously described.

It will be seen from the preceding that there was nothing particularly new in *Topper*. It was made, we might say, by doing what had to be done by the best available system known to the operators in charge. It is almost safe to say that, with what is now known about what can be done in the handling of film, there is a way of solving any problem if the result justifies the effort. The text describing the various scenes accompanies the appropriate illustrations on the following pages.

FIG. 1.

The first scene on the reel (Fig. 1), in which Constance Bennett and Cary Grant materialize on a log, is a combination split screen and lap dissolve. After Roland Young's action carried him to the left half of the set, the screen was split optically and a straight shot of the background substituted in the right half until such time as it took for Miss Bennett and Mr. Grant to enter and take their places. The matte was then dissolved out and the original scene dissolved in.

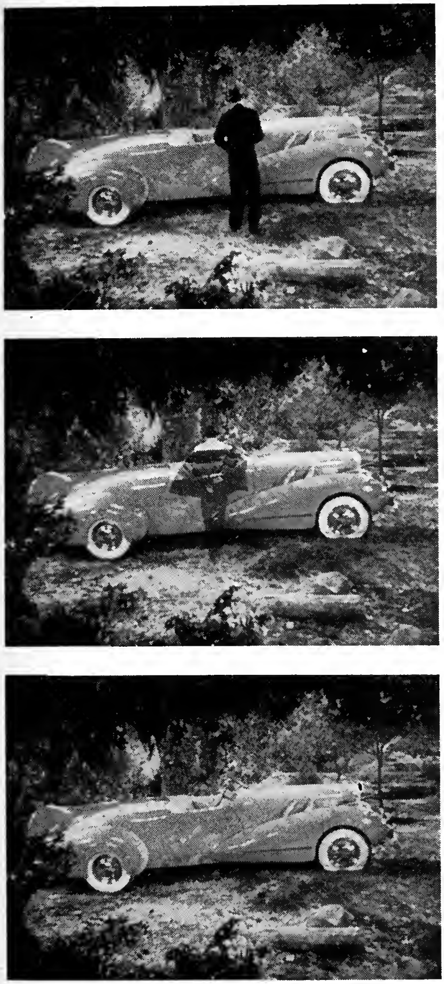


FIG. 2.

The scene showing Mr. Grant disappearing as he approaches the automobile (Fig. 2) is a lap dissolve from the scene showing him walking away into the set. The door of the car was then opened by an operator inside the car. The changing of the tire (the scene following that shown in Fig. 2) involved various types of animation, manipulating wires and concealed operators. For instance, the jack was manipulated by an operator in a pit under the car and the car let down by another operator.

FIG. 3.

The scene in which Constance Bennett "zips" herself out (Fig. 3) was projected and mattes animated to follow the action of her hand. Miss Bennett got up and ran off the set as soon as her action was finished and Mr. Young held his position until she was clear. The length of film necessary to get her off the set was then cut out, and by use of the animated matte, plain background was made to replace Miss Bennett as the "zipping" action progressed.

The shot at the elevator where Miss Bennett and Mr. Grant disappear while holding up Mr. Young, was a simple lap dissolve. After they had decided that they should disappear, they held their position for a sufficient footage to cover the dissolve, then releasing Young, they ran off the set while Young continued with his action of swaying back and forth. The scene was then dissolved as they faded away, shortening the amount of footage it took them to run out of the scene. Young's action matched up and he was dissolved back in again.

FIG. 4.

The shot of Miss Bennett with the vase of flowers (Fig. 4) was a split screen, lap dissolve, and wire shot. Young played the scene alone until after the box on the desk had been moved with wires, after which Miss Bennett entered the scene and, taking her position on the corner of the desk, lifted the vase. An operator watched the action through an anchored still camera, following the action of the vase and marking it on the ground-glass. The set was then cleared and from the same set-up the vase was lifted with wires as closely as possible in the path and at the same speed as Miss Bennett had lifted the vase. What discrepancy there was between the two actions of the vase was corrected optically on the lavender positive print and a split screen dupe made immediately in front of Young in which the clear set with the vase on wires was substituted until the vase started up at which time the set was dissolved out and Miss Bennett dissolved in.

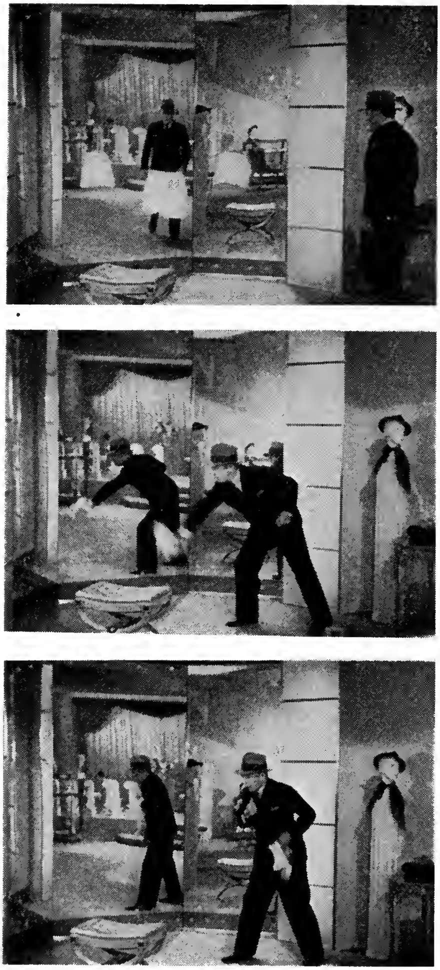


FIG. 5.

The bit of feminine apparel walking by itself without visible means of support (Fig. 5) was photographed against black velvet on a girl wearing a black velvet suit. The shooting continued up to the point where they were snatched off and put into the background by a rather involved process known as subtractive matting, in which the whole of a developed and fixed print is converted back to silver bromide and re-sensitized, after which the background printed into the heavy deposit of silver representing the black velvet. Snatching the pants off was a case of matched action. In one take—that is, in the one in which the pants walked—Roland Young snatched at them in an empty set. From the same position he snatched a real pair from a wire—and the scenes were cut in action.

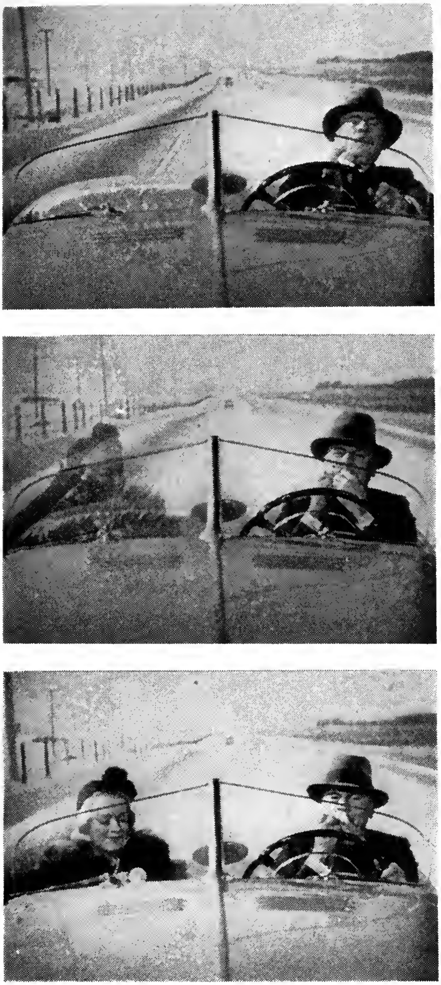


Fig. 6.

Perhaps the most daring shot from a standpoint of braving possible technical troubles was the shot of Miss Bennett materializing in the roadster (Fig. 6). This was a split screen shot against a projection background. Actually no difficulties were experienced as precautions were taken to prevent them. The Mitchell camera taking the shot was, of course, equipped with precision pins. The lavender positives were printed tails first, on a Bell & Howell printer which uses the same perforations for registry as the Mitchell. A special shuttle was built for the optical printer registering pins at the bottom, so that throughout the whole process, the same perforations were used for registry.

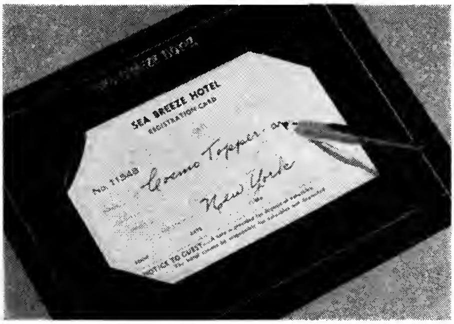


Fig. 7.

The pen writing by itself (Fig. 7) in the close shot was straight animation. The pen was equipped with a pin in the point which was stuck into the blotter holding the pen upright as the animation progressed. The long shot was done with wires.

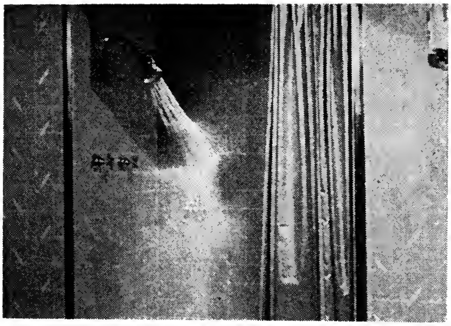


FIG. 8.

The shower-bath sequence (Fig. 8) was a composite of four shots. Efforts to photograph a person in a black suit under a shower proved surprisingly unconvincing. The effect finally was achieved by playing several jets of air against the water in front of a black velvet drop. The steam and the action of the soap were also taken against black velvet and the three shots doubled in over the shower-bath set. The fixtures were worked from the opposite side of the partition. Miss Bennett's materialization after the shower was a simple split screen and lap dissolve.

FIG. 9.

The following shot, however, in which she snuffs her cigarette out after she has dematerialized (Fig. 9) came dangerously near to being complicated. She was dematerialized in a split screen-lap dissolve, substituting the empty set in her half until she had time to run out of the original scene. The position of her cigarette which had been located on a still camera ground-glass, was matched and the cigarette carried down to the tray with wires. This bit of action then had to be substituted for the empty set. The last puff of smoke was then shot coming through a hole in black velvet and doubled in where Miss Bennett's face was last seen.

The scene in which Grant materializes back of Eugene Pallette's arm (Fig. 10) depended more upon acting for its success than upon trick photography. Pallette struck his position in the alcove and held it without moving while Grant ran in and took his place behind Pallette's arm. After allowing sufficient footage for the transition, they both picked up the action and continued the scene. In the dupe it was only necessary to shorten the scene with a lap dissolve the amount of footage it took Grant to get to his place.

FIG. 10.

Fig. 11.

The scene in the cafe where both Miss Bennett and Grant disappear (Fig. 11) is what technically is known as a "headache," the necessity of keeping the background action consistent being the principal problem. In this scene, which was a double split screen-lap dissolve, instead of dissolving the characters into an empty background, they had to be replaced by people, many of them moving. Perhaps it should be said that the shot was made by the "perseverance" method.

FIG. 12.

The stairway scene (Fig. 12) was made by the same method with slight variations. It may have been noticed that Young crossed to Grant's side of the screen the moment Grant disappeared. From the technician's standpoint it was a moment too soon, for Mr. Grant had not yet run off the set. As a consequence, it was necessary to animate the split screen matte which had been introduced to dissolve Grant out of the scene ahead of Young as he advanced, and re-animate the opposite matte which printed in the plain background without losing that almost imaginary line that makes a perfectly blended match.

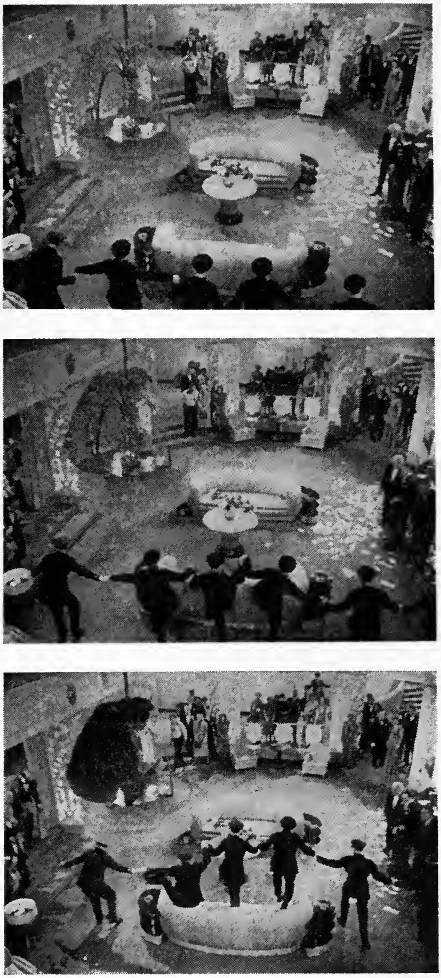


FIG. 13.

Grant's sitting on the chandelier (Fig. 13) was a split screen-lap dissolve. The only difficulty was that the closeness of the actors below necessitated a very sharp blend and an unusually shaped matte.

LATENT IMAGE THEORY AND ITS EXPERIMENTAL APPLICATION TO MOTION PICTURE SOUND-FILM EMULSION*

W. J. ALBERSHEIM**

Summary.—*In a previous paper the writer attempted to show that the latent photographic image is formed in two distinct and separate steps. In the present paper this theory is compared with recent physical research. The writer concludes that each of the photographic steps consists of the attraction of one electropositive silver ion to a sensitizing speck on the grain surface which has previously captured an electron.*

The reciprocity law failure at high intensities is explained by the minimum time required for the attraction of a silver ion. The reciprocity law failure at low intensities is explained by assuming that a sensitizing speck which has attracted only one silver ion is unstable and that the number of grains activated by a single capture decreases exponentially with time.

From these physical theories the writer deduces mathematical relations governing the photographic characteristics. H&D curves and reciprocity failure curves computed from these relations are in good qualitative agreement with experimental curves.

The assumption of an unstable intermediate state of insufficiently exposed grains implies certain effects of delayed fogging and delayed development which are verified by experiments.

In a previous paper[1] by the writer, it was deduced from the shape of the photographic H&D curves that a grain of motion picture film must be hit by at least two photons in order to become developable. At that time, no physical explanation of this "double hit" theory was attempted and hope was expressed that the theory would be supplied by research physicists.

There is, of course, no lack of research nor of physical theories in this field. On the contary, one is overwhelmed by an ever-increasing wealth of literature; in fact, the writer's attention was called to some important contributions after completion of the analytical studies which form the basis of the present report.

Unfortunately, the various investigators do not agree even in some of the most fundamental assumptions. While most of them assume

* Presented at the 1938 Spring Meeting at Washington, D. C.

** Electrical Research Products, Inc., New York, N. Y.

that the latent image consists of silver atoms, recent work carried out in the Eastman-Kodak Research Laboratories[2] suggests that the solarized image alone forms a metallic silver cluster which is amenable to chemical-physical development only, whereas the latent image, being subject to chemical development, must be differently constituted. A further divergence of opinion exists with regard to the number of photons required for latent image formation. Some of the earlier research[3] showed that in single halide crystals the ratio of metal atoms reduced by light to the number of absorbed photons, *i. e.*, the photochemical quantum-efficiency lies between one-quarter and one. Other workers stated[4] that a film grain in a photographic emulsion must absorb about 100 quanta in order to become developable, whereas a recent series of tests[5] proved that for various negative and positive emulsions the number of quanta incident upon an average sized photographic grain needed for formation of a latent image is of the order of 50. Since the grains are transparent and absorb only a fraction of the incident photons, their photographic quantum-efficiency must be considerably greater than $^1/_{50}$.

We begin our survey of experimental knowledge with the photographic toe characteristic. As shown in the previous paper,[1] the shape of the characteristic curve requires for the activation of the film grain by light, two separate physical steps which were mathematically represented in that paper by differential equations *49* and *72*. It must be understood, however, that these two steps are not necessarily to be identified with two single photons of light. They only mean two processes initiated by illumination in which the occurrence of the second process depends upon the completion of the first, so that the probability (or average quantum-efficiency) for the formation of a latent image by a photon is the product of the separate probabilities for the two steps taken singly. The absolute number of photons required for the completion of each step affects the photographic inertia rather than the toe shape of the characteristic which depends only on the *ratio* between the 2 efficiencies. This toe shape at low exposures is difficult to analyze from ordinary logarithmic H&D curves. It has been investigated by many authors but, in most cases, with sources of illumination quite different from visible light.

Silberstein and Trivelli[6] as well as Jauncey and Richardson[7] found that the density of the developed photographic image originating from weak x-ray exposures grows in linear proportion to exposure.

Silberstein and Trivelli also proved that the number of developable photographic grains is equal to the number of photons impinging upon the grain surface. For these x-rays therefore a "single step" theory is established. However, x-ray photons have an energy content which is many thousand times greater than that of the visible light photons used in sound recording. Since a double step process is claimed for visible light, there must be an intermediate range of wavelengths at which a transition from the single to the double step occurs. This seems to be actually the case:

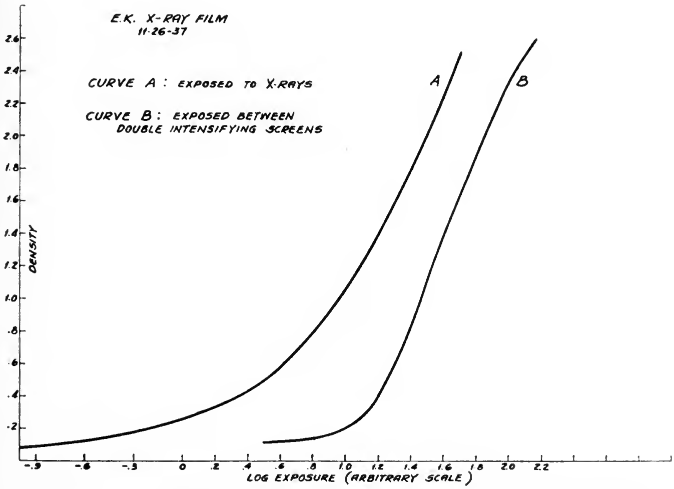


FIG. 1. Characteristics of film exposed to x-rays and between double intensifying screens.

Hirsh[8] showed that, although in images formed by hard x-rays the density increases proportionally to irradiation, the density-exposure characteristic begins to curve upward when the x-rays are softened to a wavelength of over six Ångström units.

This curvature means that the probability of latent image formation is proportional to a power greater than one of irradiation so that on the average more than one photon per grain is needed for the latent image formation.

In order to free the comparison between x-rays and light from the influence of the types of emulsion used, the writer asked the Eastman Kodak Laboratories to supply information regarding the different photographic characteristics of one and the same emulsion when exposed to x-rays and to visible light. Mr. Wilsey of the Eastman Kodak Physics Department very kindly supplied the characteristics which are shown in Fig. 1 of this paper. Curve *A* of this figure is produced by x-ray exposure and shows a long sloping toe which in the previous paper[1] was shown to correspond to the "single hit" theory and incidentally to high transparencies of the emulsion. Curve *B* is obtained by exposing the same film between double intensifying screens. These intensifying screens are fluorescent surfaces which emit a great number of visible light photons when hit by a single x-ray photon. As stated by Mr. Wilsey "when the exposure is made with intensifying screens, practically the whole photographic effect is due to the fluorescent light from the screens so that the H&D response

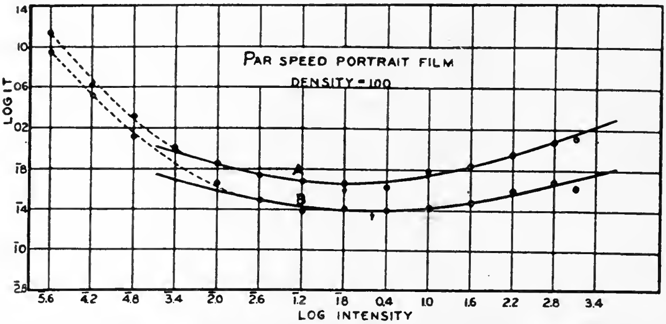


FIG. 2. Constant-density curves for different development times. *A*—5 minutes' development, *B*—30 minutes' development.

is essentially that due to exposure to light on both sides of the film." It is evident that the toe of Curve *B* shows a much greater sharpness than that of Curve *A* corresponding to an exponent greater than one and therefore consistent with the double hit theory. (*A* three-step process can not play any important part in sound-film emulsions because it would cause a toe-curvature greater than that found under actual conditions.)

If one accepts the two separate steps of exposure as a fact, what are the known properties and time requirements assignable to these steps? This information may be derived from a comprehensive series of tests conducted chiefly by Jones, Webb, and other physicists of the Eastman Kodak Laboratories on the subjects of "Reciprocity Law Failure" and "Intermittency Effect," which are closely linked to each other. The main features of the reciprocity failure effect may be illustrated by our Fig. 2 which is a reproduction of Fig. 9 of a paper by Jones and Hall published in 1929.[9] In this figure the logarithm of exposures required to produce given densities is plotted against the logarithm of intensity. The reciprocity law assumed that the photographic effect depended only on the total number of photons impinging on the film grain; that is, on the total exposure. If this were true the curves of Fig. 2 should be horizontal lines. Actually, the lines "fail" to be horizontal and curve upward at very low and very high intensities. Kron and Halm[10] reported that this curvature can be approximated by a catenary relationship, which in Fig. 2 is illustrated by solid lines. However, at the left side of this figure one sees dashed lines breaking away from

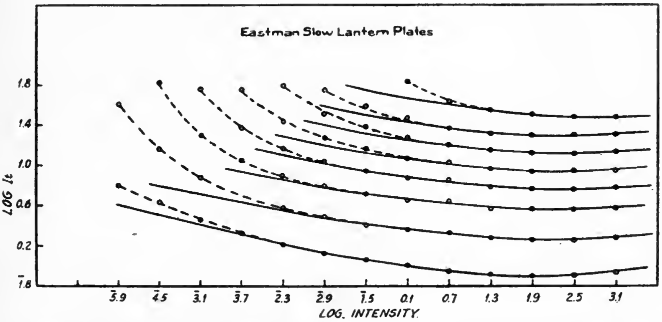


FIG. 3. Constant-density curves for slow emulsion showing low-intensity departure from catenary equation. Top curve, density = 4.2; bottom curve, density = 0.20.

the catenary and rising at an angle of about 45° which limits the curve fitting range of the catenary and deprives it of physical significance. Another series of such curves is shown in Fig. 3 which is a reprint of Fig. 11 of the above-mentioned paper. In these figures, the logarithm of intensity is used as abscissa axis in accordance with historical precedent. This historical usage seems to the writer to be an unfortunate choice which has for a long time beclouded the underlying physical relations. When one talks of a greater intensity in a physical process, such as a baseball hit, one thinks of greater speed or greater muscle tension. But when one talks of intensity of illumination with light of a given color, all the little baseballs, that is, the photons of light, hit their objective with the same speed and with the same energy of impact. What is meant by "intensity of illumination" is actually the number of photons per second, and denotes a quantity rather than a quality. The physical dimension of this "intensity" is energy times sec.$^{-1}$. Since the scale is logarithmic, it is only necessary to reverse the sides of the diagram in order to plot as abscissa axis the logarithm of the reciprocal factor; that is, of the average time interval between successive photon impacts upon a film grain.

This slight difference in the interpretation of the abscissa axis might have greatly speeded up the progress of research, for the impact time interval has recently been shown by J. H. Webb[5] to be a most important factor in the reciprocity law failure effect. In his investigation of the relation between reciprocity failure and the intermittency effect, Webb discovered that intermittent exposures are equivalent to continued exposures with an equal total number of photons radiated and equal total duration, provided that the interruption cycle is completed within the average time interval between successive photon impacts upon one and the same grain surface.

Webb defines reciprocity law failure as the effect produced by the time distribution of quanta reception by a photographic grain (in agreement with our double step theory).

This theory accounts for the reduced efficiency at both extremes of intensity, or rather of exposure time in the following way: Reciprocity failure at high intensities means that the first step requires for its completion a small but definite average time interval, before the second step can take place: If a new photon hit, or group of hits, occurs before the "step," *i. e.*, the physical process initiated by the previous photon hit (or hits) has had time to be completed, the additional hits just "do not count" and very short exposures can not utilize all received light quanta for the production of developable photographic grains.

Disregarding for simplicity's sake the statistical variations in the time requirements of the first step, we note for incorporation into our mathematical picture, that *the effective time interval between successive photon impacts upon a film grain exceeds the actual time interval by a fixed minimum time* which hereafter is called the "blocking time."

In order to account for the reduced efficiency of the photographic process at very low intensities, that is, very long exposure times, it is necessary to make an additional assumption: The configuration produced by the first step of latent image formation must be electrically or chemically unstable, a stable latent image being only obtained by the completion of the second step. The simplest form of this assumption is that *grains activated by completion of the first step fade back to the unexposed state according to an exponential time function*, as if the activated grains were a radioactive substance re-emitting the stored light energy in random manner. Some of this released energy may be detectable by photographic or other methods. The time after completion of exposure in which the number of activated grains is reduced by a factor e will be introduced into our equations as the "fading time."

However, before attempting the mathematical analysis of this delayed step-by-step mechanism, an attempt should be made to find a plausible physical explanation for the somewhat involved process of image formation which we deduced from two such well established every-day characteristics as the H&D curve and the reciprocity failure curve!

As previously mentioned, the research of Przibram, Smakula, Hilsch, and Pohl[3] shows that in single silver halide crystals the photochemical action consists of a liberation of silver atoms from their crystal bonds to the halide ions, the number of atoms thus reduced being proportional to the number of photons absorbed. This suggests that the two photographic steps are related to the number of deposited silver atoms rather than to the number of incident photons. This interpretation is made more probable by the above-mentioned fact that one and the same emulsion has entirely different characteristics when exposed to x-rays and to visible light. The powerful x-ray photons blast the required number of silver atoms out of the halide crystal in a single hit, whereas the weaker light photons can only displace them one at a time. The double step hypothesis is thus narrowed down to a "double atom" hypothesis. It implies two claims which must be substantiated: (*a*) That in spite of the low quantum efficiency of grain exposure, two silver atoms deposited at the right place are necessary and sufficient to make a photographic grain developable; and (*b*) that the deposition of these two atoms proceeds in separate steps.

Considerable light is shed upon the minimum size of development nuclei by the research of W. Reinders and his associates.[11] These investigators condensed extremely thin films of silver on glass plates and developed them in solutions containing a mixture of chemical developing agents and free silver salts. The minimum developable silver density turned out to be $^1/_{500}$th of that corresponding to a single atomic layer. The authors assumed that the deposited silver atoms combine into groups if they are condensed within a mutual distance, no larger than that which separates them in a metallic silver crystal, and they computed the probability of various group sizes. The observed minimum density was found just sufficient to permit the occurrence of four-atom groups. Hence it was concluded that aggregates of four or more silver atoms can serve as nuclei of development.

It has been well established by the work of Sheppard and others[12] that development starts at so-called sensitizing specks which seem to consist of silver sulfide molecules. Reinders found that sulfide molecules can act as centers of development just as well as silver atoms. Reinders and his associates then applied their probability calculus of group formation to the amount of silver sulfide present in photographic emulsions. They found that according to Sheppard's reports there are several hundred silver sulfide molecules available for each grain; that each grain is likely to have on its surface (and perhaps in its interior) several groups consisting of two sulfide molecules each; but that on only a small percentage of grains (less than 10 per cent) aggregates of three sulfide molecules will be formed. Now one may "put two and two together:" If two units of aggregation are supplied by the sulfide molecules of the sensitizing specks and if aggregates of four are needed to make a grain developable, it is evident that two additional units must be supplied by the photographic process in the form of silver atoms or silver ions.

The manner in which the silver atoms find their way to the sensitizing specks is explained by J. H. Webb[13] and by Gurney and Mott.[14] According to quantum mechanics the primary action of the photon consists in knocking loose an electron from its attachment to a halide ion. If the electron receives sufficient kinetic energy it can travel freely through the previously insulating halide crystal as if the crystal were a metal. These electrons are "captured" at regions of the crystals in which the electrical potential is more positive than average. Such trapping points may consist of small fissures and irregularities in the crystal or, more likely, of impurities, such as the silver sulfide molecules of the sensitizing specks, which will be charged up to a higher negative potential by the captured electron.

Gurney and Mott suggest that at normal temperatures the thermal agitation will throw some silver atoms out of their normal positions in the crystal lattice, producing slightly mobile negative "holes" and and highly mobile positive silver ions. The free silver ions are electrostatically attracted by the electrons captured at the sensitizing specks and move toward them like the ions in a liquid electrolyte. This description fits very nicely into our step-by-step pattern. The union, or at least close association, of a silver ion and an electron completes one photographic step by neutralizing the free charges. Since the net motion of the silver ion in the electrostatic field of an electron is relatively slow, it becomes plausible that the completion of this photographic step takes a measurable amount of time. Before neutralization of the charges the negative potential of the captured electron repels any further electrons which might be liberated by light and prevents them from reaching the same sensitizing speck. This, as discussed above, accounts for the reciprocity failure at high intensities.

After completion of the first step the silver ion is not fully stabilized at the sensitizing speck. Due to thermal agitation there exists during each time interval a small probability that the electron which attracted it is thrown off or "evaporated." In that case the electron begins to travel freely through the crystal and is either captured by another sensitizing speck or by a crystal irregularity, or it may recombine with the positive electron hole created when it was first knocked out of the crystal by the impact of the photon. This leaves a single silver ion unattached and it in turn resumes a random thermal motion through the crystal, probably being recaptured by a negative hole in the lattice. If, however, two steps are completed, that is, two silver ions and their electron mates are united at the sensitizing speck, they presumably form a silver molecule which is more stable than a single silver atom and much less likely to give up an electron by heat evaporation. By assigning silver atoms to the small nuclei of chemical development this mechanism differs from the view of Evans and Hanson[2] who attribute metallic nature only to the solarized nucleus. Possibly the discrepancy can be solved by assuming that in small nuclei containing very few silver atoms, these atoms remain closely embedded in the crystal structure so that chemical development can spread out from the sensitizing speck into the crystal. When the number of silver atoms grows due to overexposure, they exert an increasing mechanical pressure upon the surrounding crystal. Finally this pressure will tear the silver cluster loose from the silver halide. The cluster can be physically developed by silver deposition but it is physically and chemically divorced from the halide crystal which reverts to the "unexposed" state minus a sensitizing speck.

The above physical interpretation follows closely the viewpoint of Gurney and Mott and differs from it mainly by assuming that the deposition of two silver atoms suffices to make a grain developable, whereas the said authors imply that a greater number is necessary. If two atoms only are required and if a single photon has sufficient energy to liberate an atom, why is it that on the average dozens and in some emulsions even hundreds of photon impacts strike a grain surface before it becomes developable? The reason may be found in a relatively great number of sensitizing specks per film grain. Assume, for instance, that the grain contains ten sensitizing specks of which

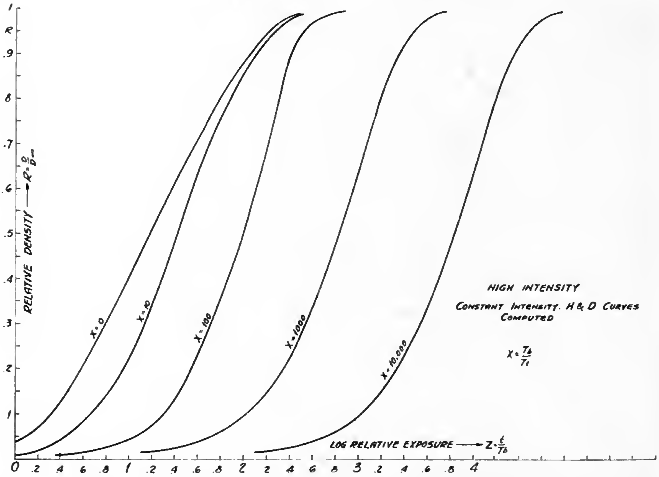


FIG. 4. Showing the reduction of photographic efficiency produced by an increase in the intensity of light.

nine are located in the inaccessible interior of the grain and only one on the surface where it can be reached by the developer. Even if there were no other trapping possibilities but the sensitizing specks, the probability for a liberated silver ion to reach a sensitizing speck on the surface of the grain would be only $^1/_{10}$th. The probability of a second silver ion's reaching the accessible sensitizing speck previously reached by the first ion would also be $^1/_{10}$th, so that the combined probability for the formation of a developable grain would be $^1/_{100}$th for two photon impacts, or $^1/_{200}$th per photon.

The above-described mechanism accounts for the known experimental facts in a qualitative manner. As a next measure, therefore, it was brought into a simplified mathematical form. The differential equations governing the two steps and their solutions are given in the mathematical appendix attached to this paper. The equations differ from the double hit equations of the previous paper[1] by the blocking time required between the first and second step and by the gradual decay of film grains in which the first step only was completed. At the limit of zero blocking time and infinite decay time which is approached for medium intensity, the new equations coincide with the old ones. The H&D curve at this medium intensity has been plotted as the extreme condition in the curves of Figs. 4 and 5. Fig. 4 shows the reduction of photographic efficiency produced by

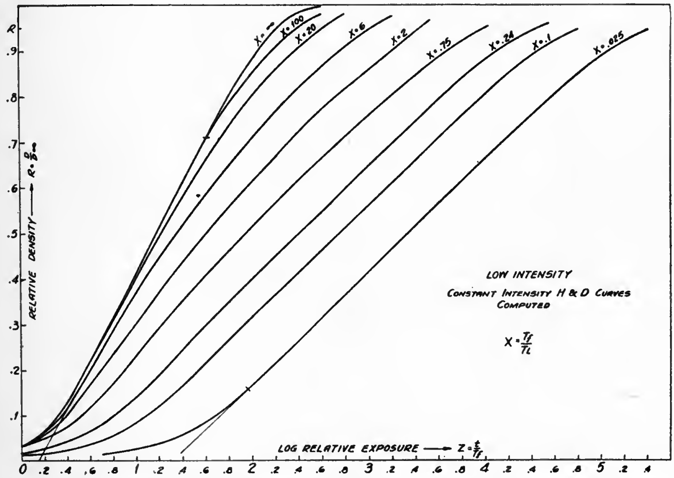


FIG. 5. Computed H&D curves for long exposure times at decreasing intensities.

an increase in the intensity of light. At extremely high intensity levels shown at the right side of Fig 4, the shape of the H&D curves approaches that of the x-ray characteristic, Curve A, in Fig 1. One reason for this is that the efficiency is at a minimum at the front surface of the emulsion where the excess of photons is greatest so that there is little difference between the photographic effect in front and rear of the emulsion: the effective penetration increases. Furthermore, due to the abundant supply of freed electrons a second electron will reach every sensitizing speck and initiate the second step immediately after completion of the first step. This makes the photographic process a function of the first step only, *i. e.*, the equivalent of a single-step process. The time-scale gamma increases with intensity due to the high penetrating power, and the straight-line portion of the H&D curve is shortened.

In Fig. 5, a similar series of H&D curves has been computed for long exposure times at decreasing intensities. The photographic effect falls off first at the rear of the emulsion where a long time interval between successive photon impacts allows the end products of the first step to fade away before a second photon is received. Consequently, the effective penetrating power decreases, producing at extremely low intensities a reduced gamma and a straight-line portion of the H&D curve extending high up toward the shoulder. Whether this idealized relation is followed under practical conditions may be

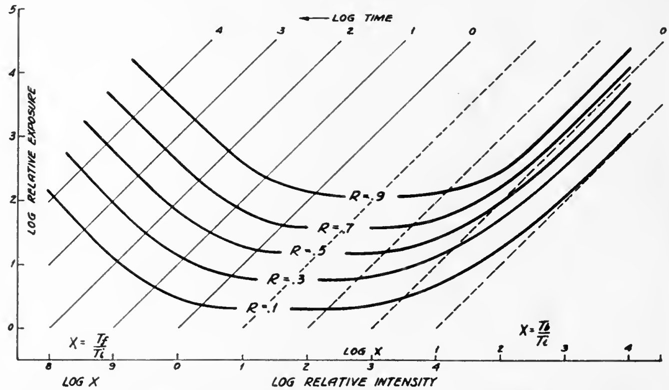


FIG. 6. Constant density curves, computed: "reciprocity failure."

doubted. The great effective absorption requires extreme exposures in the front of the emulsion to obtain a reasonable overall density and this may lead to solarization and loss of density in the shoulder region.

All characteristics of Figs. 5 and 6 are "time-scale" curves. The intensity-scale curves deviate increasingly from these for the more extreme exposure ranges: As shown in the Appendix, the ratio of time-scale gamma to intensity-scale gamma is a function of the slope of the reciprocity failure curve.

By picking points of equal density on the various curves of Figs. 5 and 6 and plotting their exposure logarithm as function of the intensity logarithm, one obtains "reciprocity failure curves" as shown in Fig. 6. Comparing these curves with the experimental curves of Figs. 2 and 3, one notes the similar character although the rise of the computed constant density curves at the high and low ends is somewhat too sudden. The shape of the measured reciprocity failure curves can be explained by considering that actual film emulsions do not have grains of uniform size and composition as assumed in our simplified calculations, but that they consist of a wide range of grain sizes containing different numbers of sensitizing specks. In a smaller grain it will, on the average, take less time for the silver ion to reach the electrified sensitizing speck, hence its blocking time is shorter. On the other hand, the statistical fluctuations are smaller in a smaller grain, thus reducing the probability for electrons to evaporate from the sensitizing speck and increasing the decay time.

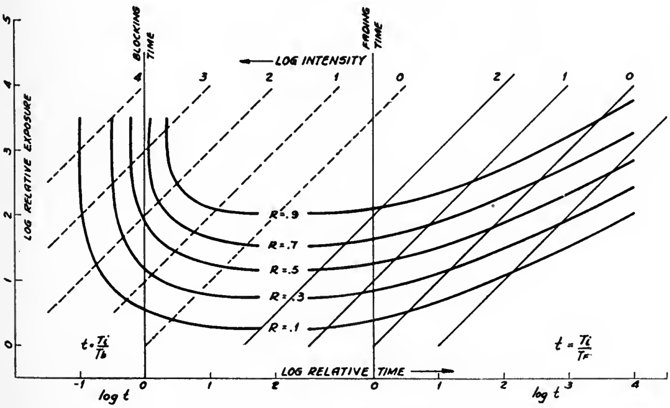


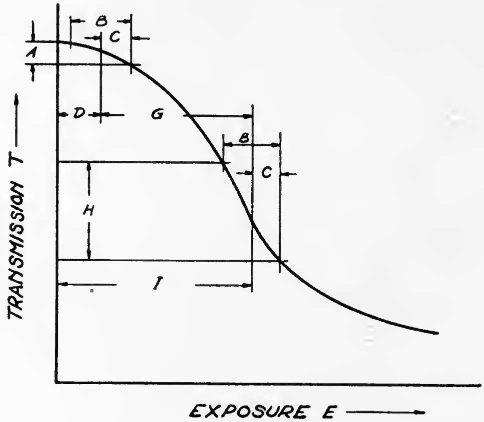
FIG. 7. Constant density curves, computed: "reciprocity failure."

Hence, actual reciprocity failure curves will be produced by the superposition of a great number of contributing curves which are transposed laterally. There will therefore be on each side of the curves an intermediate range of reduced and fairly constant slope, depending upon the statistical distribution of grain sizes.

In Fig. 6, lines of equal exposure time have been drawn, in the form of thin straight lines rising at an angle of 45 degrees toward the right in a manner which seems to have first been used by Jones and Webb.[15] Since the reciprocity failure is determined by two *time* constants, namely, the blocking time and the decay time, it would be more instructive to plot the logarithm of the total irradiation (It) as a function of log T rather than of log I. This has been done on

Fig. 7. It is seen that the photographic process is completely inefficient at exposure times shorter than the blocking time. At somewhat longer exposure times the required irradiation reaches a minimum, and at extremely long exposure times, exceeding the decay time, the required irradiation for constant densities increases with the square root of exposure time.

Having thus verified that even in its simplified mathematical form the two-step theory fits the facts that led to its adoption, we considered it necessary to put it to an experimental test by checking new



A: ΔT contrast without fogging.
B: $2\Delta E$.
C: ΔE-1000 cycle single amplitude.
D: E_1-D.C. component of signal.
G: E_2-Fogging.
H: ΔT contrast with fogging.
I: $E_1 + E_2$.

FIG. 8. Increase of contrast by fogging.

facts which can be predicted from it. The most significant of these facts seems to be connected with the claimed instability of the activation produced by the first photographic step. In the under-exposed toe region of the characteristic the irradiation produces relatively very few grains in which the two steps of latent image formation are completed, but a much greater number, in which one step only has taken place, that is, one silver atom transported to a sensitizing speck on the grain surface. After development these under-exposed pictures show negligible contrast. However, their contrast can be increased by superimposing to the picture a constant illumination.

This is known as "fogging," and depending on whether the superimposed d-c. exposure takes place before or after the under-exposed modulated exposure, one speaks of "pre-fogging" and "post-fogging." The purpose and effect of fogging are illustrated by Fig. 8. According to our view, fogging can only be efficient if the time interval between the two superimposed exposures is smaller than the decay time so that the activated "single-step" grains do not have time to fade out. This theory was verified by the following "fading test": A soundtrack was exposed to a thousand-cycle signal with very low intensity of illumination, E_1 (Fig. 8) producing a specular density of only 0.07. Upon this weak signal exposure we superimposed a uniform fogging exposure E_2 with about three times greater average light intensity. One part of this fogging exposure was applied ten minutes before the signal, a second part one-half hour after the signal, and

TABLE I

Fading Test

Hours between Signal and Fogging	Relative Level (Db.)	Specular Density
No fogging	−17.4	0.069
−0.2	0.0	0.168
+0.5	0.0	0.172
+1.0	− 0.05	0.164
2.0	− 0.2	0.165
4.0	− 0.5	0.160
6.0	− 0.75	0.158
21.5	− 2.1	0.142

further parts after increasing time intervals up to 21.5 hours. The result of this test is tabulated in Table I and shown on Fig. 9. It shows that fogging applied within ±0.5 hour of the signal improves the a-c. output by 17 db. and that with increased time intervals this benefit was reduced by about 0.1 db. per hour. During the test time of 21 hours, the total average density decreased from 0.17 to 0.14. This decrease in density would have increased the level by 0.6 db. if the modulation had remained constant. The actual decrease of modulation therefore amounts to about 2.7 db. Since without fogging the signal level was negligible, the modulation loss can only be explained by a fading of the partly exposed grains in the time interval between signal and fog exposures.

The change of average density, however, may have a double explanation: In addition to the fading effect proved by the signal loss, there may exist an increase of the quantity of fully exposed grains available for development with time. Such an "intensification effect" has been mentioned in the literature. In the discussion of a paper on dry hypersensitization before this Society,[16] Mr. J. I. Crabtree of the Eastman Kodak Company stated, "It is well known that you may get effective hypersensitization or growth of the latent image by merely storing the latent image." The two-step theory leads one to expect such an intensification from the following reasoning: Assume that a film grain has ten sensitizing specks and that due to an insufficient

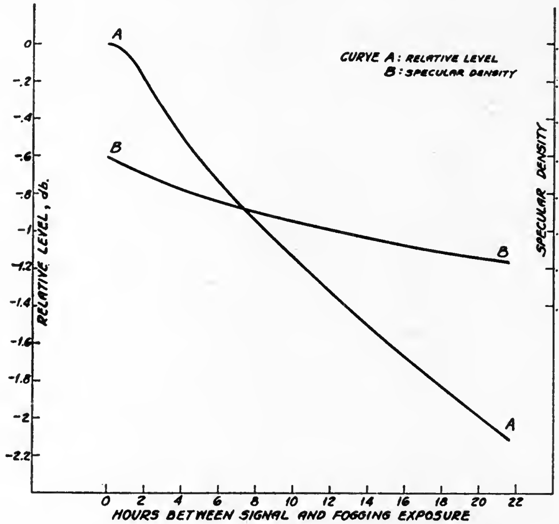


FIG. 9. Fading test; E. K. emulsion *1359*.

exposure five of these specks have received one silver atom each, but that in none of these specks the latent image has been completed by the absorption of a second silver atom. According to Gurney and Mott's theory, some of these specks will give up electrons by evaporation and these free electrons will move through the crystal just as if they had been liberated by an additional photon of light. There exists, therefore, a certain probability that one of these electrons will be captured by an "activated" sensitivity speck which has already received one silver atom. The capture of this additional electron and the subsequent attraction and absorption of a second silver ion will complete the second step for this grain and make it stable and developable. This process is, of course, much more likely to occur after weak exposures, when the number of partly exposed grains exceeds that of fully exposed grains. The intensification process will occur mainly in the toe region of the H&D curve. In a modulated sound-track exposed in the straight-line region of the H&D curve, the effect will be a considerable darkening of light portions and a small darkening of the darker portions, that is, a net loss of modulation.

This theory was put to the test in the following manner: Alternate sections of film were exposed with unmodulated light, 500-cycle

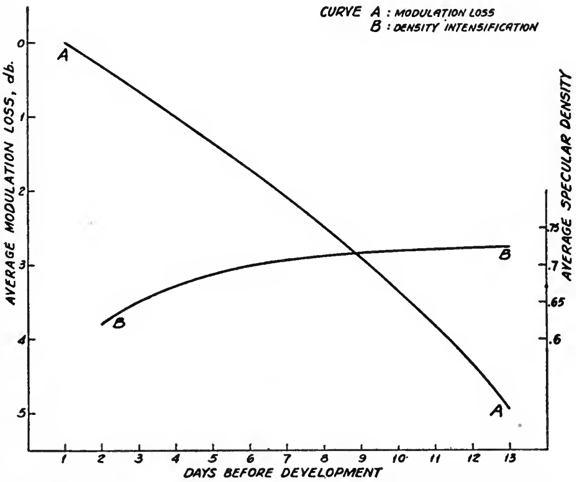


FIG. 10. Intensification test; E. K. emulsion *1359*.

modulation and with 8000-cycle modulation, and portions of all three types of exposures were developed after storing times increasing from 1 to 13 days. The comparison of high-frequency and low-frequency signals was included because it had been suspected that some of the electrons liberated in the fading process might have sufficient energy to expose an adjacent grain and thus to produce an image diffusion recognizable as a high-frequency loss. The results of this test are given in Table II and Fig. 10. After correcting for the daily variations in development characteristics, there was an increase in the average density of the modulated as well as of the unmodulated sound-tracks amounting to about 0.01 per day and a loss of modulation amounting to about 0.35 db. per day. The small increase in the density of the unmodulated sound-tracks shows that the loss of modulation must be nearly entirely due to an intensification of the low-density portions. These findings explain why the motion picture studio operators dislike recording films on the last day of the working week and storing them over the week-end before development.

TABLE II

Intensification Test

Days between Exposure and Development	Relative Modulation (Db.) 500~	8000~	Average Modulation Loss (Db.)	Average Specular Density
1	0.0	− 0.7	0.0	0.62
5	−1.4	− 8.3	1.35	0.69
8	−2.4	− 9.4	2.4	0.71
13	−5.1	−11.8	4.95	0.725

Fortunately, the fading time of commercial emulsions at normal temperatures is so long that the photographic result is not noticeably impaired, provided development takes place within a day of exposure. For professional motion picture work, it does therefore not seem necessary to include the time loss of modulation due to low-density intensification into the analytical expressions for latent image formation which are cumbersome enough without this added complication! From the experimental point of view, however, the positive result of the fading and intensification tests has encouraged us to present the "step-by-step" or "two-atom" hypothesis as a small contribution to the comprehensive quantum theory of the photographic image formation built up by so many research workers and culminating at the present time in the work of Webb and of Gurney and Mott.

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ANALYTICAL APPENDIX

COMPUTATION OF PHOTOGRAPHIC CHARACTERISTICS

(1) Physical assumptions and definitions

(*1.1*) A latent image is formed by the deposition of two or more silver ions at a sensitizing speck located on the grain surface and accessible to the developing agent. A grain in which this image formation is completed is called "exposed."

(*1.2*) Silver ions are transported to the sensitizing specks by the electrostatic attraction of electrons liberated by photons from the halide crystal and trapped by the sensitizing speck; this transportation takes a measurable average time called the "blocking time," t_b. The union of silver ion and electron neutralizes the free electron charge and completes a photographic "step."

(*1.3*) Before completion of the photographic step the electron charge repels any further electrons and prevents them from being trapped by the same sensitizing speck.

(*1.4*) A grain in which only one photographic step is completed, is in an unstable "activated" state. An electron and subsequently the silver ion attracted by it may be lost by thermal agitation. The time constant of this loss, *i. e.*, the time in which the number of activated grains is reduced by the factor ϵ, is called the "fading time," T_f.

(*1.5*) An "exposed" grain per 1.1, is stable and remains developable. (The fact that an excessive amount of deposited silver atoms may "solarize" the grain and make it inert to chemical development, is of no importance in the exposure range of motion picture sound-films.)

(*1.6*) The grains are distributed at random throughout the photographic emulsion.

(*1.7*) Due to absorption the light intensity decreases nearly exponentially with depth of penetration. The absorption constant μ is defined as the reciprocal of the depth at which the number of photons per second is decreased by the factor ϵ.

(*1.8*) *Effective Electron Time Interval.*—The average time interval between photon impacts on the grain may be called T_p. The absorption factor of single grains for photons is called p_a. The probability that an electron is liberated by the absorbed photon, is called p_e. The probability that a liberated electron penetrates to an unexposed, accessible sensitizing speck is called p_{g_1}. The probability that a liberated electron penetrates to an activated accessible sensitizing speck, is called p_{g2}.

One finds the effective time interval between photo-electrons arriving at an unexposed speck:

$$T_i = \frac{T_p}{p_a p_e p_{g1}} \tag{1}$$

and the effective time interval between photo-electrons arriving at an activated speck

$$T_2 = \frac{T_p}{p_a p_e p_{g_2}} = CT_i \tag{2}$$

(*1.9*) *Additional Symbols* (See list of symbols at the end of appendix).—In order to maintain a connection with the previous paper[1] we define g as the fraction of the grains at a given depth in the emulsion which has been activated but not fully exposed, and r as the fully exposed fraction. Where convenient, we use the fading factor:

$$f = \frac{1}{T_f} \tag{3}$$

and the intensity factor:

$$i = \frac{1}{T_i} \tag{4}$$

(2) *Differential equations for the steps of latent image formation*

(*2.1*) *Equation for the First Step.*—The gross increase of activated grains is proportional to the available number of unexposed grains and to the intensity factor. From this gross increase one must deduct the decrease due to fading and the decrease due to a transformation of activated grains into fully exposed grains. Hence:

$$\frac{dg}{dt} = \frac{1}{T_i}(1 - r - g) - \frac{g}{T_f} - \frac{dr}{dt} \tag{5}$$

or

$$g' = (1 - r - g)\, i - fg - r' \tag{6}$$

(*2.2*) *Equation for the Second Step.*—The increase of exposed grains is proportional to the available number of activated grains, divided by the effective electron time interval plus the blocking time:

$$\frac{dr}{dt} = r' = \frac{g}{t_2 + t_b} \tag{7}$$

Hence

$$g = r'(t_2 + t_b) \tag{8}$$

and

$$g' = r''(t_2 + t_b) \tag{9}$$

(*2.3*) *Solution for a Single Emulsion Layer.*—Introducing the values of *8* and *9* into *6* one finds:

$$r + Ur' + Vr'' = 1 \tag{10}$$

with

$$U = T_i + (t_2 + t_b)(1 + fT_i) \tag{11}$$

and

$$V = (t_2 + t_b)T_i \tag{12}$$

A solution of *10* must have the form:

$$r = 1 + r_1{}^{-k_1t} + r_2{}^{-k_2t} \tag{13}$$

At $t = 0$, both r and g and, in view of (7), r' must equal zero. Hence *13* can be transformed into:

$$r_1 + r_2 + 1 = 0 \tag{14}$$

$$r_1k_1 + r_2k_2 = 0 \tag{15}$$

from this one finds:

$$r_1 = \frac{k_2}{k_1 - k_2} \tag{16}$$

$$r_2 = -\frac{k_1}{k_1 - k_2} \tag{17}$$

and

$$r = 1 + \frac{k_2}{k_1 - k_2}\epsilon^{-k_1t}\ \frac{k_1}{k_1 - k_2}\epsilon^{-k_2t} \tag{18}$$

From *10* one finds for k_1 and k_2 the relation:

$$r_1\epsilon^{-k_1t}(1 - Uk_1 + Vk_1^2) + r_2\epsilon^{-k_2t}(1 - Uk_2 + Vk_2^2) = 0 \qquad (19)$$

from which it follows that:

$$1 - Uk_1 + Vk_1^2 = 1 - Uk_2 + Vk_2^2 = 0 \qquad (20)$$

$$\text{and } k = \frac{i+f}{2} + \frac{.5}{t_2 + t_b} \pm 0.5\sqrt{\left(i + f + \frac{1}{t_2 + t_b}\right)^2 - \frac{4_i}{t_2 + t_b}} \qquad (21)$$

(*2.4*) *General Equation of H&D Curve.*—Equations *18* and *21* describe the formation of the latent image at uniform intensity, and therefore at one given depth in the emulsion. The itensity itself decreases exponentially with depth:

$$i_y = i_o\epsilon^{-uy} \qquad (22)$$

$$T_i = \frac{1}{i} = T_{io}\epsilon^{uy} \qquad (23)$$

$$T_2 = C\,T_i = \frac{C}{i} = T_{2o}\epsilon^{uy} \qquad (24)$$

If R is defined as the fraction of all grains in the emulsion which has become developable, one sees that after uniform development:

$$R = D/D_\infty \qquad (25)$$

where D is the measured density and D_∞, the highest density obtainable with the same emulsion and development. According to definition, R is found as:

$$R = \frac{1}{Y}\int_o^y r\,dy \qquad (26)$$

in which dy denotes a differential emulsion layer and Y the total emulsion thickness. In view of *22:*

$$dy = -\frac{di}{ui} \qquad (27)$$

$$R = -\frac{1}{uY}\int_{i_0}^{\tau_{i_0}} \frac{rdi}{i} = \frac{1}{-\ln\tau}\int_{i_{0\tau}}^{i_0} \frac{rdi}{i} \qquad (28)$$

in which τ is the transparency of the emulsion for the photographically active light. In order to make more clear which factors of *21* are functions of i, it may be transformed into:

$$ky = \frac{i_y + f}{2} + \frac{0.5\,i}{C + t_b\,i_y} \pm 0.5\sqrt{\left(i_y + f + \frac{i_y}{C + t_bi_y}\right)^2 - \frac{4i_y^2}{C + t_bi_y}} \qquad (29)$$

Combining *18*, *25*, and *28*, one finds:

$$D = -\frac{D}{\ln\tau}\int_{i_{0\tau}}^{i_0}\left(1 + \frac{k_2}{k_1 - k_2}\epsilon^{-k_1 t} - \frac{k_1}{k_1 - k_2}\epsilon^{-k_2 t}\right)\frac{di}{i} \qquad (30)$$

Equations *29* and *30* constitute the general solution for the H&D curve as function of the light intensity at the surface and the length of exposure, assuming, however, that all grains are uniform in size and constitution.

(*2.5*) *Evaluation of H&D Characteristics.*—If one introduces the full values of k from *29* into *30*, the integral becomes very complicated and unmanageable for computation. It can, however, be simplified by the following considerations:

The constant C in equations *2* and *29* denotes the decrease in probability of electron capture by the presence at a sensitizing speck of one or more silver ions and electrons which neutralize each other's charges. The additional silver atoms may lower the work function and thus increase the probability of capture so that C would be somewhat smaller than one. However, its magnitude will not differ much from unity and its effect will be about equivalent to a mere change of film speed. C will therefore be considered equal to one in the following computations.

Furthermore, blocking time and fading time are of very different orders of magnitude: The blocking time is measured in microseconds, the fading time in hours. One can therefore regard the one as zero or the other as infinite, according to the intensity range explored. This splits the computation into a high-intensity and a low-intensity range.

(*2.51*) *Computation of High-Intensity Curves.*—Equation *29* is simplified into:

$$k_y = 0.5i\left[1 + \frac{1}{1 + t_b i} \pm \sqrt{\left(1 + \frac{1}{1 + t_b i}\right)^2 - \frac{4}{1 + t_b i}}\right] \qquad (31)$$

Introducing the new variable:

$$t_b i = x \text{ one finds:} \qquad (32)$$

$$k_y = 0.5i\left(\frac{2 + x}{1 + x} \pm \frac{x}{1 + x}\right) \qquad (33)$$

$$k_1 = i \qquad (34)$$

$$k_2 = \frac{i}{1 + x} \qquad (35)$$

$$r_i = \frac{i/1 + x}{i - i/1 + x} = \frac{1}{x} \tag{36}$$

$$r_2 = -\frac{i}{i - i/1 + x} = -\frac{1 + x}{x} = -1 - \frac{1}{x} \tag{37}$$

Introducing the variable:

$$t/t_b = z \text{ one finds:} \tag{38}$$

$$r = 1 + r_1\epsilon^{-k_1 t_b z} + r_2\epsilon^{-k_2 t_b z} \tag{39}$$

$$r = 1 + \frac{1}{x}\epsilon^{-xz} - \left(1 + \frac{1}{x}\right)\epsilon^{-xz(1+x)} \tag{40}$$

In view of *32*

$$\frac{dx}{x} = \frac{di}{i} \qquad \text{and} \tag{41}$$

$$R = 1 - \frac{1}{\ln t}\int_{\tau x}^{x}\left[\epsilon^{-xz} - (1 + x)\epsilon^{-xz/1 + x}\right]\frac{dx}{x^2} \tag{42}$$

$$xz = it = e \tag{43}$$

(*2.511*) *Approximate Solution at Relatively Low Intensities.*—At low intensities

$$\lim x \longrightarrow 0 \tag{44}$$

The integral of *42* can be rewritten:

$$\frac{dx}{x^2}\epsilon^{-e}\left[1 - (1 + x)\epsilon^{ex/1 + x}\right] \tag{45}$$

For small x values this approaches:

$$\frac{dx}{x^2}\epsilon^{-e}\left[1 - (1 + x)\left(1 + \frac{ex}{1 + x} + \ldots\right)\right] = -\frac{dx}{x}^{-e}(1 + e + \ldots) \tag{46}$$

For a given exposure time:

$$\frac{dx}{x} = \frac{di}{i} = \frac{de}{e} \qquad \text{hence} \tag{47}$$

$$R = 1 + \frac{1}{\ln \tau}\int_{\tau e}^{e}\epsilon^{-e}(1 + e)\frac{de}{e} \qquad \text{and} \tag{48}$$

$$D = \frac{D_\infty}{\ln \tau}\left[\epsilon^{-e\tau} - \epsilon^{-e} - \int_{\tau e}^{e}(1 - \epsilon^{-ex})\frac{dx}{x}\right] \tag{49}$$

Equation *49* is identical with equation *79* of the previous paper and confirms that at low intensities the blocking time does not have any influence upon the speed or the shape of the H&D curve.

(*2.512*) *Approximate Solution at Extremely High Intensities.*—At high intensities $\lim x \longrightarrow \infty$. This reduces *42* to:

$$R = 1 + \frac{1}{\ln \tau} \int_{\tau x}^{x} \epsilon^{-z} \frac{dx}{x} \tag{50}$$

$$D = D_{\infty} (1 - \epsilon^{-z}) = D_{\infty} (1 - \epsilon^{-t/t_b}) \tag{51}$$

Equation *51* is a function of z alone, indicating that no matter how greatly one increases the intensity, a minimum time proportional to the blocking time is required for the formation of a latent image.

The reciprocity failure curve is determined by the fact that t becomes independent of i. Hence:

$$\frac{d \log t}{d \log i} = 0 \tag{52}$$

$$\frac{d \log e}{d \log i} = \frac{d \log t + d \log i}{d \log i} = 1 \tag{53}$$

Equation *53* defines the reciprocity failure curve as a straight line rising at an angle of 45 degrees.

The shape of the H&D curve for extreme intensity, as expressed by *51,* can be interpreted by comparing equation *51* with equation *50* of the previous paper:[1] *51* is identical with the function resulting from a single step process in a single "layer" of emulsion or in a completely transparent emulsion. That is, the H&D curve at extreme intensities takes the shape of an x-ray characteristic.

(*2.513*) *Strict Solution of High-Intensity Equation.*—Equation *42* can not be completely solved in analytical form. By partial integration, however, it can be stripped down to residual terms of the form:

$$F_e = \int_0^e (1 - e^{-x}) \frac{dx}{x} = e - \frac{e^2}{2.2} + \frac{e^3}{3.3} - \cdots + \tag{54}$$

This function was discussed and used in the previous paper.[1] (See equation *59*, p. 431, and Fig. 5 of that paper.)

Even with this abbreviating symbol, the solution for R or D remains rather complicated:

$$D = \frac{D}{\ln \tau} \Big[(1 - z - \epsilon^{-z}) \ln \frac{1 + \tau x}{1 + x} - \frac{1}{\tau x} \epsilon^{-\tau e} + \frac{1}{x} \epsilon^{-e} + \frac{1 + \tau x}{\tau x} \epsilon^{-\frac{\tau e}{1+\tau x}} -$$
$$\frac{1 + x}{x} \epsilon^{-\frac{e}{1+x}} - z (F_e - F_{\tau e}) - (1 - z)$$
$$\left(F_{\frac{e}{1 + x}} - F_{\frac{\tau e}{1 + \tau x}} \right) - \epsilon^{-z} \left(F_{\frac{-z}{1 + \tau x}} - F_{\frac{-z}{1 + x}} \right) \Big] \tag{55}$$

From this equation, the curves of Fig. 4 were computed.

(*2.514*) *Formulas for Gamma at High Intensity.*—The function for time-scale gamma is nearly as cumbersome as equation *55* because equation *42* does not become integrable by differentiating with regard to *t:*

$$\gamma_t = \frac{d}{d \log t} (RD_\infty) = D_\infty \frac{dR}{d \log z} = 0.434\ D_\infty \frac{z\, dR}{dz} \quad (56)$$

$$\gamma_t = \frac{D_\infty z}{\log \tau} \int_{\tau x}^{x} \left(\epsilon^{-xz} - \epsilon^{-\frac{xz}{1+x}} \right) \frac{dx}{x} \quad (57)$$

The intensity-scale gamma, however, can be freed of the integral sign:

$$\gamma_i = 0.434\ D_\infty \frac{xdR}{dx} = \frac{0.434\ D_\infty}{x} \Big[\epsilon^{-e} - (1 + x)\, \epsilon^{-e/1+x} - \frac{1}{\tau} \epsilon^{-\tau e} + \frac{1 + \tau x}{\tau} \epsilon^{-e\tau/1+\tau x} \Big] \quad (58)$$

(*2.52*) *Computation of Low-Intensity Curves.*—As discussed in the computation of high-intensity curves, the constant *C* of equations *2* and *28* is assumed to approximate the value one. Furthermore, the blocking time is regarded as infinitely short compared to the long exposure times. Thus equation *28* is transformed into:

$$k_y = i + 0.5f \pm \sqrt{(i + 0.5f)^2 - i^2} = i + 0.5f \pm \sqrt{fi + 0.25 f^2} \quad (59)$$

The following new variables are introduced:

$$i/f \equiv x \quad (60)$$

$$ft \equiv z \quad (61)$$

$$q = k/f \quad (62)$$

This transforms *18* into:

$$r = 1 + \frac{q_2}{q_1 - q_2} \epsilon^{-q_1 z} - \frac{q_1}{q_1 - q_2} \epsilon^{-q_2 z} \quad (63)$$

with $$q = x + {}^1/_2 \pm \sqrt{x + {}^1/_4} \quad (64)$$

(*2.521*) *Approximate Solution at Relatively High Intensities.*—lim $x \longrightarrow \infty$.

63 can be written in the form:

$$r = 1 + \epsilon^{-(q_1+q_2)z/2} \Big[\frac{q_2}{q_1 - q_2} \epsilon^{-(q_1 - q_2)z/2} - \frac{q_1}{q_1 - q_2} \epsilon^{+(q_1 - q_2)z/2} \Big] \quad (65)$$

This approaches the value:

$$r = 1 + \epsilon^{-e}\left[\frac{\sqrt{x} - 1}{2}\,\epsilon^{-\sqrt{xz}} - \frac{\sqrt{x} + 1}{2}\,\epsilon^{+\sqrt{xz}}\right] \tag{66}$$

and, due to

$$z\sqrt{x} \ll 1, \tag{67}$$

$$r = 1 - \epsilon^{-e}(e + 1) \tag{68}$$

$$R - = \frac{1}{\ln \tau}\int_{i\tau}^{i} r\,\frac{di}{i} = -\frac{1}{\ln \tau}\int_{e\tau}^{e} r\,\frac{de}{e} \tag{69}$$

$$D = RD_{\infty} \doteq \frac{D}{\ln \tau}\left[\epsilon^{-e\tau} - \epsilon^{-e} - F_e + F_{e\tau}\right] \tag{70}$$

This equation is again identical with equation *79* of the previous paper, confirming that at high intensities the blocking time does not influence speed or shape of the H&D curves.

(*2.522*) *Approximate Solution at Extremely Low Intensities.*—Under these conditions,

$$\lim x \rightarrow 0 \tag{71}$$

$$q_1 \doteq 1 + x \doteq 1 \tag{72}$$

$$q_2 \doteq x^2 \tag{73}$$

$$r \doteq 1 - \epsilon^{-x^2z} \doteq 1 - \epsilon^{-j} \text{ with} \tag{74}$$

$$j = x^2z \tag{75}$$

$$R = -\frac{1}{\ln \tau}\int_{x\tau}^{x} r\,\frac{dx}{x} = -\frac{1}{2\ln \tau}\int_{j\tau^2}^{j} r\,\frac{dj}{j} \tag{76}$$

$$D = \frac{D}{2\ln \tau}(F_j - F_{j\tau^2}) \tag{77}$$

The density becomes a function of j alone. The reciprocity failure curve is determined by the equation:

$$j = \text{constant} \tag{78}$$

$$d\,(\text{long } x^2) + d \log z = 0 \tag{79}$$

$$2d\,(\log i) = d\,(\log t) = 0 \tag{80}$$

$$d\,(\log e) = d\,(\log i) + d\,(\log t) = -d \log i \tag{81}$$

The reciprocity failure curve becomes a straight line sloping *downward* at an angle of 45 degrees.

The shape of the H&D characteristic *77* approaches that of a *single step process*, but with a low transparency, equal to the square of the actual transparency τ. Accordingly, one sees in Fig. 5 that the toe of the extreme right curve becomes rounded, but that the straight-line portion extends way up toward the shoulder.

(*2.523*) *Strict Solution of Low-Intensity Equation.*—We have:

$$R = -\frac{1}{\ln \tau}\int_{\tau x}^{x}\frac{dx}{x}\left(1 + \frac{q_2}{q_1 - q_2}\epsilon^{-q_1 z} - \frac{q_1}{q_1 - q_2}\epsilon^{-q_2 z}\right) \qquad (82)$$

$$R = 1 - \frac{1}{\ln \tau}\int_{\tau x}^{x}\frac{dx}{x}\,\frac{q_2}{q_1 - q_2}\epsilon^{-q_1 z} + \frac{1}{\ln \tau}\int_{\tau x}^{x}\frac{dx}{x}\,\frac{q_1}{q_1 - q_2}\epsilon^{-q_2 z} \qquad (83)$$

In the first integral of *83* substitute $q_1 = m^2$ (*84*)

One finds:

$$x = m^2 - m \qquad (85)$$

$$dx = 2m - 1 \qquad (86)$$

$$q_2 = (m - 1)^2 \qquad (87)$$

In the second integral of *83* substitute $q_2 = n^2$ (*88*)

One finds:

$$x = n^2 + n \qquad (89)$$

$$dx = 2n + 1 \qquad (90)$$

$$q_2 = (n + 1)^2 \qquad (91)$$

This transforms *83* into:

$$R = 1 - \frac{1}{\ln \tau}\int_{0.5+\sqrt{0.25+\tau x}}^{0.5+\sqrt{0.25+x}}\frac{m-1}{m}\epsilon^{-m^2 z}dm + \frac{1}{\ln \tau}\int_{-0.5+\sqrt{0.25+\tau x}}^{-0.5+\sqrt{0.25+x}}\frac{n+1}{n}\epsilon^{-n^2 z}\,dn \qquad (92)$$

These simplified integrals can not be solved completely. But by partial integration they can be stripped to integrals of the above-mentioned type $F_{(e)}$ and to probability integrals defined as:

$$P_{(x)} = \frac{2}{\sqrt{\pi}}\int_{0}^{x}\epsilon^{-x^2}dx \qquad (93)$$

which can be found in tables.

The solution becomes:

$$D = -\frac{D}{\ln \tau}\left[\sqrt{\frac{\pi}{4z}}\left(P_{a_2} - P_{a_1} - P_{b_2} + P_{b_1}\right) + {}^1/_2\left(F_{a_2^2} - F_{a_1^2} + F_{b_2^2} - F_{b_1^2}\right)\right] \qquad (94)$$

in which equation:

$$a_1 = \sqrt{z}\,(0.5 + \sqrt{0.25 + x}) \tag{95}$$

$$a_2 = \sqrt{z}\,(0.5 + \sqrt{0.25 + \tau\, x}) \tag{96}$$

$$b_1 = \sqrt{z}\,(-0.5 + \sqrt{0.25 + x}) \tag{97}$$

$$b_2 = \sqrt{z}\,(-0.5 + \sqrt{0.25 + \tau x}) \tag{98}$$

(*2.524*) *Gamma at Low Intensity.*—The time-scale and intensity-scale gammas can be found by differentiation of equation *82* with respect to log t and log i, in a manner analogous to that shown under *2.514*. The calculations have been omitted from this appendix because in motion picture sound recording the exposure range is generally not in the low-intensity part of the reciprocity failure curve.

(3) *Equations of Reciprocity Failure Curve*

The concepts of blocking time and fading time were introduced into the theory in order to account for the reciprocity law failure. It will therefore be shown by the following derivation that, and how, the reciprocity failure curve is determined by the H&D curve *29*.

For a given emulsion and development, D_∞, τ, t_b, and T_f are constants. k is a function of i_y, and the integral *29*, a function of i_0 and t only. (The suffix of i_o will be omitted below where no misunderstanding is possible.)

Reciprocity curves are plotted with log e, that is, log (it) as ordinate and log i as abscissa. The density is held constant for any given curve. Since log i and log t are the only independent variables the constancy of D is expressed by:

$$dD = \frac{\delta D}{\delta \log i}\, d \log i + \frac{\delta D}{\delta \log t}\, d \log t = 0 \tag{99}$$

Hence:

$$d \log t = -\, d \log i\, \frac{\delta D/\delta \log i}{\delta D/\delta \log t} \tag{100}$$

$$d \log e = d \log (it) = d \log i + d \log t \tag{101}$$

$$d \log e = d \log i \left[1 - \frac{\delta D/\delta \log i}{\delta D/\delta \log t}\right] \tag{102}$$

Equation *102* is the required relation between ordinate and abscissa of the reciprocity failure curve.

(4) *Reciprocity Curve and Intensity—to Time-Scale Gamma Ratio*

In the "straight-line" region of the H&D curves, the partial differentials are defined as:

$$\delta D/\delta \log i \equiv \gamma_i \text{ (intensity-scale gamma)} \qquad (103)$$

$$D\,D/D \log t \equiv \gamma_t \text{ (time-scale gamma)} \qquad (104)$$

Hence *102* may be rewritten in simplified form:

$$\frac{d \log e}{d \log i} = 1 - \gamma_i/\gamma_t \qquad (105)$$

The slope of the reciprocity failure curve equals one minus the ratio of intensity-scale gamma to time-scale gamma. *At high intensities,* such as used in sound-film recording, this slope is positive; hence *the intensity-scale gamma is smaller than the time-scale gamma.*

SYMBOLS

Symbol	Definition	Dimension
C	$= t_{2i} = t_2 T_i$	
D	= Density	
D	= Saturation density	
e	$= it$ = relative exposure	
f	$= 1/T_f$ = fading constant	sec.$^{-1}$
$F_{(x)}$	$= \int_0^x (1 - e^{-x})\, dx/x$ = integral function	
g	= fraction of activated grains in an emulsion layer	
i	$= 1/T_i$ = relative intensity	sec.$^{-1}$
p	= probability factor	
P_x	$= \frac{2}{\sqrt{\pi}} \int_0^x \epsilon^{-x^2} dx$ = probability function	
r	= fraction of exposed grains in an emulsion layer	
R	= fraction of exposed grains in the entire emulsion	
t	= exposure time	sec.
t_b	= blocking time	sec.
t_2	= electron time interval for second step	sec.
T_f	= fading time	sec.
T_i	= electron time interval for first step	sec.
u	= absorption constant	cm.$^{-1}$
y	= extension into depth of emulsion	cm.
Y	= total thickness of emulsion	cm.
$a, b, k, j, m, n, q, U, V, x, z$	= auxiliary symbols, explained in appendix	
ϵ	= basis of natural logarithms	
τ	= transparency of emulsion	
δ	= partial differential	

DISCUSSION

MR. ALBURGER: What is the mechanism by which the electrons deposit the silver atoms on the crystal surface?

MR. ALBERSHEIM: I am not a physicist; I can only guess that every atom in the molecular or crystal array has a certain electrical field surrounding it, and we know that unless the electron has a certain speed it will be captured. A sharp corner produces a strong electric field; in ordinary wire we have corona effects that we would not have if the wire were round and polished. Something like that happens in the crystal, and at points of physical or chemical irregularity the electric field becomes strong enough to capture and retain the electron. When it is captured the excess electron will be attracted to the silver and rip it loose from the bond to the adjacent chlorine atom, and deposit it no longer as an ion but as a silver atom. The bromide shifts, and if it finds a resting place in the adjacent gelatin matrix it will probably come to rest there.*

MR. GOLDSMITH: If a fully exposed negative is wound up on a reel over a negative of a much less brightly illuminated subject, and the entire negative is preserved some little time before development, is there found to be any trace of image transfer due to light re-emission from one end of the film to the other?

MR. ALBERSHEIM: I have not found it in the literature, but by word of mouth it has been reported to me that such is the case, that under some conditions a picture can be transferred from one emulsion to an adjacent one. It may be that this effect is not as dangerous as it seems, because the re-emitted electrons have a threshold value and it is possible that it might be easier to obtain the effect if the second emulsion has been sensitized to infrared.

MR. DAVIS: I think the transfer of the picture from one film to another is the work of Sir William Abney, of England, some years ago, who made this experiment. He coated a plate and exposed it, and coated another emulsion on top; then after developing, he stripped the coat and found a picture on the second coating. This probably was a development effect and not a *bona fide* latent image transfer.

MR. FRAYNE: In view of the fact that the energy of the bullets you speak of is directly proportional to the frequency of the light, is the shape of the catenary curves dependent upon the frequency of the light that is used?

MR. ALBERSHEIM: The influence of color is surprisingly small. I thought there would be such an effect, but this was disproved by the Kodak Research Laboratories. Webb made an investigation of the influence of color from green, yellow, and reddish light, so far as the emulsion would take to ultraviolet of 3600 Å, and the curves, while they came to different densities, were surprisingly close to parallelism. The curve seems just to shift in intensity, but not in character.

MR. FRAYNE: Then in this case how do you explain the change of gamma with wavelength?

MR. ALBERSHEIM: That is probably due to a resonance effect. The emulsion is most sensitive to a certain wavelength, from 4000 to 4400 Å. So long as the impinging light falls within that range nearly every grain will be exposed, and high ultimate densities and high gammas result. If we go down to 3500 Å, many grains will not be exposed at all, so the emulsion acts as if it had fewer grains. We get lower gamma and lower ultimate density, and a coarser grained picture, relatively speaking. The grains are as big but there are fewer available.

MR. GOLDSMITH: Would you assume that the re-emitted light is of the same wavelength as the original light producing the image? In other words, if a colored object is photographed, would a colored image be released?

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* Experiments conducted after the date of this discussion showed trace of this effect.

MR. ALBERSHEIM: I believe not. No matter how hard the light the electron will probably lose some energy, and when it is finally absorbed it is absorbed with just enough energy to liberate the silver atom. The excess is dissipated, then, perhaps as light or heat, so when the electron is re-emitted it will probably be re-emitted nearly monochromatically.

MR. JONES: At the ultraviolet end, at least, the exposing radiation is absorbed by the thin layers, so you are working with a thinner and thinner emulsion, which of course gives a lower gamma. That is purely absorption. You do not have to invoke resonance to explain that.

MR. ALBERSHEIM: If the emulsion were exposed to ultraviolet of sufficient density you would finally penetrate through, so that the ultimate density at very high exposures would still be the same. It would take very much more light to penetrate to the bottom, and I believe there must be some other effect involved because the ultimate gamma is lower. Also, if you expose with red light or greenish light, which penetrates all the way through the emulsion, you still get the lower gamma. There may be a superposition of two effects there.

MR. SANDVIK: If the change of gamma with wavelength is a resonance phenomenon, how would you explain the change in gamma when you use yellow dye in an emulsion and use blue light?

MR. ALBERSHEIM: That would probably be due to the absorption effect that Dr. Jones has mentioned. However, the resonance effect is present because there is a fairly narrow absorption band in most emulsions. A single silver halide crystal exposed to light has a resonance frequency at about 4000 Å where it absorbs the maximum number of photons and is photographically most effective.

MR. SANDVIK: It does that no matter what wavelength radiation is lost. The gamma is greatly decreased to the extent that the absorption takes place with the wavelength that is used.

MR. ALBERSHEIM: I am glad to hear so. In that case we do not need ultraviolet for the sound-films to obtain reduced gamma. We can use the yellow dye, which we have been preferring all along.

THE EVALUATION OF MOTION PICTURE FILMS BY SEMIMICRO TESTING*

J. E. GIBSON** AND C. G. WEBER†

Summary.—*Test methods for the evaluation of motion-picture film for permanent records require test specimens too large to be removed from certain archival films. To assist those charged with the preservation of such films in determining the quality and checking the condition of them, suitable semimicro methods were developed for acidity, viscosity, and residual hypo content. Specimens as small as 7 mg. in weight, removed from the film with a small hand punch, gave satisfactory results for the purpose.*

(I) Introduction
(II) Experimental testing
 (*1*) *Acidity*
 (*2*) *Specific viscosity*
 (*3*) *Residual hypo*
(III) Summary and conclusions

(I) INTRODUCTION

Certain repositories, such as The National Archives and some film libraries, are called upon to preserve films which can not be tested by the methods usually recommended for the evaluation of film for permanent records. From these films it is not possible to obtain test specimens of sufficient size for the usual tests without destroying some of the photographic images or making the film unserviceable otherwise. It is important that the condition of such films be determined. The nitrate films are chemically unstable, and successful preservation of records contained on them requires that they be examined periodically so that disintegration can be anticipated and duplicates made of the records before they are impaired by visible deterioration. Good acetate film is stable, but it should be tested before placing it in storage to find if it was properly made and processed. Also, subsequent testing of it may be desirable, particularly

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** The National Archives, Washington, D. C.

† National Bureau of Standards, Washington, D. C.

if it should be exposed to unfavorable storage conditions. The semimicro methods described in this article were developed to permit the testing of such films without removing test specimens large enough to impair the film as regards legibility and serviceability.

(II) EXPERIMENTAL TESTING

In studies[1] of the stability of photographic films, tests for copper number, viscosity, acidity, residual hypo (sodium thiosulfate), and flexibility were found to be of value. These tests were recommended[2] for the evaluation of film for permanent records. Hence, the micro methods developed were modifications of some of these methods. The value of each of the proposed methods was determined by testing films that had been subjected to accelerated aging at 100°C in oven-dry air for various periods of time. The data are thus comparable with those obtained by Hill and Weber[1] with test specimens of normal amount. The micro tests were made with test specimens weighing only 7 mg. each, which were removed from the films with a $^1/_4$-inch hand punch without causing appreciable damage to the film. The value of the micro test was judged by comparing the results of them with results obtained with the usual methods. The micro methods developed were for acidity, viscosity, and residual hypo.

(*1*) *Acidity.*—The acidity of the film was determined in the following manner. A single punching (wt. 0.007 g.) of film, including both base and emulsion, was transferred to a test tube and 5 ml. of acetone, containing 10 per cent of water by volume, was added. After complete dispersion of the film base, the acidity in *p*H units was determined by means of a commercial micro *p*H-meter. The results are shown in Fig. 1 in comparison with *p*H values obtained with the same apparatus for seven punchings of film weighing 0.049 gram in 5 ml. of acetone containing 10 per cent of water by volume.

The water and acetone were purified by distillation and the combined solvent had a *p*H of 7 ± 0.4. Duplicate determinations on the film agreed within 0.1 *p*H unit.

(*2*) *Specific Viscosity.*—A punching of film (wt. 0.007 g.) was transferred to a test tube and dissolved in 5 ml. of acetone measured at 30° ± 0.02°C. After solution of the film base was complete and the mixture homogeneous, 3 ml. of the solution was transferred to an Ostwald viscosity pipette immersed in a constant-temperature bath (30° ± 0.02°C), and allowed to stand until temperature equilibrium was reached. The time of flow of the solution through the capillary of the pipette was measured with a stop-watch which could be read to one-fifth second. The time of flow of the pure solvent was also measured. Not less than three or four determinations were made for each solution, the values agreeing within two- or three-tenths of a second. The relative viscosity was then calculated as the ratio of the time of flow of the solution to the time of flow of the solvent.

Fig. 2 shows the results of these measurements compared with results obtained by Hill and Weber with one-gram samples. The different scales were necessary because different values are obtained by the two methods.

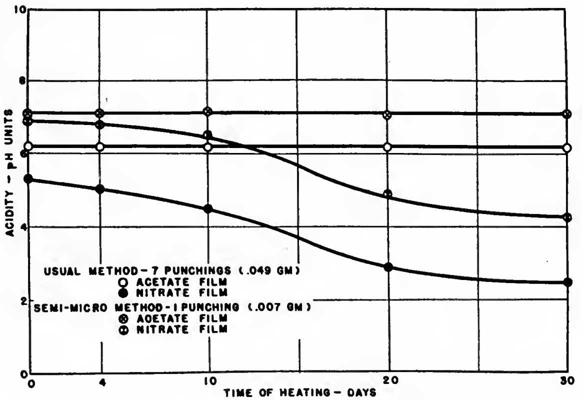

FIG. 1. Effects of accelerated aging on *p*H of cellulose acetate and cellulose nitrate films; results obtained by the semimicro method compared with those obtained on larger test specimens.

(*3*) *Residual Hypo.*—The method used for detecting the presence of residual hypo (sodium thiosulfate) in films is a modification of the test proposed by Crabtree and Ross.[3] The method as modified consists in placing a single punching of film on a glass slide, adding two drops of mercuric chloride test solution to the specimen in such a manner that the solution flows over the specimen and onto the glass, and observing any turbidity that develops in the solution. The test solution contains 25 grams of mercuric chloride and 25 grams of potassium bromide in a liter of aqueous solution. The film is placed on the glass with the emulsion side up, and is allowed to stand for 2 or 3 minutes after the addition of the test solution. It was found that any turbidity of the solution can be best detected with the unaided eye when the glass is held in the light so that the angle of incidence is approximately 90 degrees.

If sodium thiosulfate is present, it reduces mercuric ion, and an insoluble mercurous compound is formed which causes turbidity. If no thiosulfate is present, the solution on the glass remains clear, although the silver image is bleached white. Positive tests were obtained in this manner on single punchings taken from film that contained less than 0.05 mg. of hypo per square-inch. Positive tests

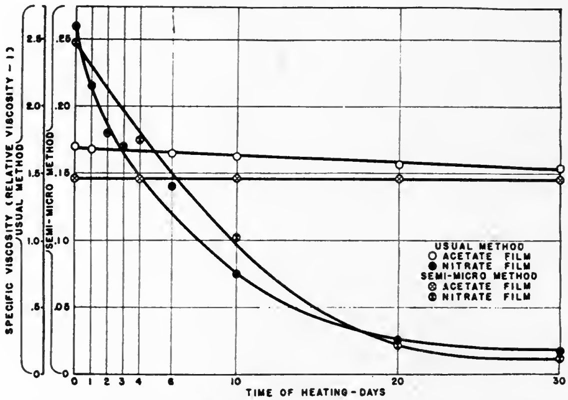

FIG. 2. Effects of oven aging on viscosity of cellulose acetate and cellulose nitrate films as determined by the semimicro methods and by the usual methods.

were also obtained with solutions containing 10 parts of hypo per million parts of water when a large drop of the solution was added to a drop of the test solution.

(III) SUMMARY AND CONCLUSIONS

Motion picture films that can not be sampled for testing by the usual methods can be tested by the semimicro methods. The approximate quality and condition of the film can be determined by tests for acidity, viscosity, and residual hypo, using specimens weighing only 7 mg. each, which can be taken from the film by means of a small hand punch without appreciable damage to the film. These methods are not recommended for use in selecting permanent record film. However, they are recommended to archivists and librarians for determining the condition of finished films given them for custody.

With these tests, the approximate condition of the films can be found, and the necessity of making duplicate copies can be determined before the damage to the films by deterioration is serious enough to be visible. The values obtained by the semimicro methods will differ somewhat from those obtained by the usual methods, but they appear to show the extent of deterioration under accelerated aging equally well. When absolute values are used in judging the condition of a film in question, those obtained by the semimicro methods should be compared with values obtained for new film by these methods.

REFERENCES

[1] *J. Research, Nat. Bur. Standards,* **17** (1936), p. 871; RP950.

[2] *Musc. Pub. Nat. Bur. Standards,* M158 (1937).

[3] CRABTREE, J. I., AND ROSS, J. F.: "A Method of Testing for the Presence of Sodium Thiosulfate in Motion Picture Films," *J. Soc. Mot. Pict. Eng.,* **XIV** (April, 1930), No. 4, p. 419.

DISCUSSION

MR. CRABTREE: Our recent researches have indicated that the milky compound formed by reaction of the mercuric chloride with hypo is not mercurous chloride but, rather, a double compound of mercuric sulfide and mercuric chloride having the formula $2HgS\ HgCl_2$. Such a compound has been described by H. Rose (Poggendorff, *Annalen der Physik,* **13:** 59, 1828) and by Th. Poleck and C. Goercki (*Berichte,* **21:** 2412–2417, 1888).

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.

Journal of the Acoustical Society of America

10 (Oct., 1938), No. 2

- Absorption of Sound in Carbon Dioxide and Other Gases (pp. 89–97) — V. O. Knudsen and E. F. Fricke
- Measurement of Absorption in Rooms with Sound Absorbing Ceilings (pp. 98–101) — J. R. Power
- Absorption Effects in Sound Transmission Measurements (pp. 102–104) — P. E. Sabine and L. G. Ramer
- Absolute Sound Measurements in Liquids (pp. 105–111) — E. Klein
- Theory of the Chromatic Stroboscope (pp. 112–118) — R. W. Young and A. Loomis
- Adjustable Tuning Fork Frequency Standard (pp. 119–127) — O. H. Schuck
- Recent Advances in the Use of Acoustic Instruments for Routine Production Testing (pp. 128–134) — B. Foulds
- Frequency Ratios of the Tempered Scale (pp. 135–136) — C. Williamson
- Harmonic Structure of Vowels in Singing in Relation to Pitch and Intensity (pp. 137–146) — B. Stout
- Apparatus for Direct-Recording the Pitch and Intensity of Sound (pp. 147–149) — J. Obata and R. Kobayashi

American Cinematographer

19 (Oct., 1938), No. 10

- Flashes Across Nearly Sixty Years (pp. 403–404) — J. Gevaert
- Dunning Has Three-Color Process Now Ready to Go (pp. 406, 416)
- Mole-Richardson Introduces Duarc, New Automatic Broadside (pp. 407, 416)
- Ingenious Accessories Simplify Making of Special Effects Shots (pp. 408, 410) — G. Teague
- 100 Watter Throws 150—and Whiter (p. 411)
- American Cameramen Lead. . . Pasternak (pp. 412–414) — J. Pasternak

American Cinematographer

19 (Nov., 1938), No. 11

What's Wrong with Cinematography? (pp. 449, 457)

Reeves Single System Sound Fits Any Camera (pp. 454–455)

New Berndt-Maurer Sound Tract (pp. 456)

20th-Fox Installs New Make-Up Lamps (p. 479)

British Journal of Photography

85 (Sept. 9, 1938), No. 4088

Aluminum as a Photographic Base (pp. 568–570) — H. W. GREENWOOD

Journal of the British Kinematograph Society

1 (Oct., 1938), No. 3

Modern Electric Discharge Lamps and Their Application to Kinematography (pp. 158–174) — W. R. STEVENS

Volume Range Expanders (pp. 175–187) — J. MOIR

Manufacture of Motion Picture Film (pp. 188–204) — A. E. AMOR

An Optical System for Sound Reproduction (pp. 209–213) — J. H. MCLEOD AND F. E. ALTMAN

Bulletin de la Société Française de Photographie et de Cinématographie

25 Serc. 3 (Sept., 1938), No. 9

Sur L'Obtention de Negatifs Photographiques á Grains Fins á Partir d'Émulsions ou d'Images á Gros Grains. (Obtaining Fine Grain Negatives Starting with Large Grain Emulsions or Images) (pp. 145–150) — A. SEYEWETZ

Educational Screen

17 (Sept., 1938), No. 7

Motion Pictures—Not for Theaters, Pt. I (pp. 211–215) — A. E. KROWS

17 (Oct., 1938), No. 8

Motion Pictures—Not for Theaters. Pt. II (pp. 249–253) — A. E. KROWS

Preparing Sound Film Strips (pp. 254–256) — C. R. THOMAS

Electronics

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A Laboratory Television Receiver—IV (pp. 16–19) — D. G. FINK

A Shielded Loop for Noise Reduction in Broadcast Reception (pp. 20–22) — S. GOLDMAN

Squeeze or Matted Track (p. 23) — J. K. HILLIARD

An Electric Timing Device (pp. 28–29) — R. W. CARLSON

Ideal Kinema

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The Stableford All-Metal Screen, How It Is Constructed (p. 33)

Kinematographic Weekly

259 (Sept. 29, 1938), No. 1641

Metals as Base for Picture Film (p. 36)

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Technicolor Expands (p. 9)

Projection-Revision of SMPE Standards (pp. 24–27) — C. N. BATSEL

Kinotechnik

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Sicherheitsfilm im Normalformat (35 Mm. Safety Film) (pp. 255–256) — J. GRASSMAN

Bildfilm und Magnetton (Magnetic Sound Recording on Film) (pp. 256–257) — H. PETERSEN

Methoden zur Messung des photographischen Gleichrichtereffektes (Method of Measuring the Photographic Rectifying Effect) (pp. 258–264) — A. NARATH AND W. VOX

Zwei neue Aufnahme-Materialen; Agfa Superpanfilm und Agfa Ultrarapidfilm (Two New Films; Agfa Superpan and Agfa High-Speed Film) (pp. 264–267) — A. SCHILLING

Moderne Wiedergabegerate für 16-Mm.-Tonfilm (Modern 16-Mm. Sound-Film Projectors) (pp. 268–269) — WEINBERGER

International Projectionist

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Advance Preparations Minimize Sound Emergencies (pp. 7–10) — A. NADELL

Television and Its Effect Upon the Motion Picture Theatre) (pp. 12–14) — F. WALDROP AND J. BORKIN

A Higher-Efficiency Condensing System for Tungsten-Filament Projectors (pp. 14–16) — F. E. CARLSON

Projection Possibilities of Mercury Vapor Discharge Lamp (pp. 17–18) — R. H. CRICKS

Photographische Korrespondenz

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Fortschritte der Kinematographie im Jahre 1937 (Progress of Photography in 1937) (pp. 164–167) — H. PANDER

SPRING, 1939, CONVENTION

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Headquarters

Headquarters of the Convention will be the Hollywood-Roosevelt Hotel, where excellent accommodations are assured. A reception suite will be provided for the Ladies' Committee, and an excellent program of entertainment will be arranged for the ladies who attend the Convention.

Special hotel rates, guaranteed to SMPE delegates, European plan, will be as follows:

One person, room and bath	$ 3.50
Two persons, double bed and bath	5.00
Two persons, twin beds and bath	6.00
Parlor suite and bath, 1 person	8.00
Parlor suite and bath, 2 persons	12.00

Indoor and outdoor garage facilities adjacent to the Hotel will be available to those who motor to the Convention.

Members and guests of the Society will be expected to register immediately upon arriving at the Hotel. Convention badges and identification cards will be supplied which will be required for admittance to the various sessions, the studios, and several Hollywood motion picture theaters.

Railroad Fares

The following table lists the railroad fares and Pullman charges:

City	Railroad Fare (round trip)	Pullman (one way)
Washington	$132.20	$22.35
Chicago	90.30	16.55
Boston	147.50	23.65
Detroit	106.75	19.20
New York	139.75	22.85
Rochester	124.05	20.50
Cleveland	110.00	19.20
Philadelphia	135.50	22.35
Pittsburgh	117.40	19.70

The railroad fares given above are for round trips, sixty-day limits. Arrangements may be made with the railroads to take different routes going and coming, if so desired, but once the choice is made it must be adhered to, as changes in the itinerary may be effected only with considerable difficulty and formality. Delegates should consult their local passenger agents as to schedules, rates, and stop-over privileges.

Technical Sessions

The Hollywood meeting always offers our membership an opportunity to become better acquainted with the studio technicians and production problems, and arrangements will be made to visit several of the studios. The Local Papers Committee under the chairmanship of Mr. L. A. Aicholtz is collaborating closely with the General Papers Committee in arranging the details of the program. Complete details of the program will be published in a later issue of the JOURNAL.

Semi-Annual Banquet and Dance

The Semi-Annual Banquet of the Society will be held at the Hotel on Thursday, April 20th. Addresses will be delivered by prominent members of the industry, followed by dancing and entertainment. Tables reserved for 8, 10, or 12 persons; tickets obtainable at the registration desk.

Equipment Exhibit

An exhibit of newly developed motion picture equipment will be held in the *Bombay and Singapore* Rooms of the Hotel, on the mezzanine. Those who wish to enter their equipment in this exhibit should communicate as early as possible with the general office of the Society at the Hotel Pennsylvania, New York, N. Y.

Motion Pictures

At the time of registering, passes will be issued to the delegates to the Convention, admitting them to the following motion picture theaters in Hollywood, by courtesy of the companies named: Grauman's *Chinese* and *Egyptian* Theaters (Fox West Coast Theaters Corp.), Warner's *Hollywood* Theater (Warner Brothers Theaters, Inc.), Pantages *Hollywood* Theater (Rodney Pantages, Inc.). These passes will be valid for the duration of the Convention.

Inspection Tours and Diversions

Arrangements are under way to visit one or more of the prominent Hollywood studios, and passes will be available to registered members to several Hollywood motion picture theaters. Arrangements may be made for golfing and for special trips to points of interest in and about Hollywood.

Ladies' Program

An especially attractive program for the ladies attending the Convention is being arranged by Mrs. N. Levinson, *hostess*, and the Ladies' Committee. A suite will be provided in the Hotel, where the ladies will register and meet for the various events upon their program. Further details will be published in a succeeding issue of the JOURNAL.

Points of Interest

En route: Boulder Dam, Las Vegas, Nevada; and the various National Parks.

Hollywood and vicinity: Beautiful Catalina Island; Zeiss Planetarium; Mt. Wilson Observatory; Lookout Point, on Lookout Mountain; Huntington Library and Art Gallery (by appointment only); Palm Springs, Calif.; Beaches at Ocean Park and Venice, Calif.; famous old Spanish missions; Los Angeles Museum (housing the SMPE motion picture exhibit); Mexican village and street, Los Angeles.

In addition, numerous interesting side trips may be made to various points throughout the west, both by railroad and bus. Among the bus trips available are those to Santa Barbara, Death Valley, Agua Caliente, Laguna, Pasadena, and Palm Springs, and special tours may be made throughout the Hollywood area, visiting the motion picture and radio studios.

On February 18, 1939, the Golden Gate International Exposition will open at San Francisco, an overnight trip from Hollywood. The Exposition will last throughout the summer so that opportunity will be afforded the eastern members to take in this attraction on their convention trip.

SOCIETY ANNOUNCEMENTS

ELECTION OF SECTION OFFICERS

Results of the election of officers and managers of the Mid-West and Pacific Coast Sections of the Society are as follows:

(*Mid-West*)

*S. A. Lukes, *Chairman*

C. H. Stone, *Past-Chairman*	*J. A. Dubray, *Manager*
*G. W. Baker, *Sec.-Treas.*	**O. B. Depue, *Manager*

(*Pacific Coast*)

*L. Rydee, *Chairman*

J. O. Aalberg, *Past-Chairman*	*C. W. Handley, *Manager*
*A. M. Gundelfinger, *Sec.-Treas.*	**W. Miller, *Manager*

* Term expires December 31, 1939.

** Term expires December 31, 1940.

Elections of officers and managers of the Atlantic Coast Section are now in progress and will be announced in the next issue of the Journal.

ATLANTIC COAST SECTION

At a meeting of the Section held on December 13th at the studios of RCA Photophone, Inc., New York, a paper was presented by F. C. Gilbert and E. S. Seeley of the Altec Service Corporation, New York, on the subject of "The Adjustable Equalizer as a Tool for Selecting the Best Response Characteristics." This equalizer is a device that can be inserted into theater reproducing systems for determining with a given horn system what characteristic is best in a given house. It is portable and can be carried into the auditorium, and has an extremely wide range of variation.

The paper was presented by Mr. Seeley and aroused considerable interest among the members attending the meeting, as evidenced by the protracted discussion held at the close of the presentation. A demonstration of the equalizer accompanied the presentation.

MID-WEST SECTION

At a meeting held at The Western Society of Engineers, Chicago, on December 6th, Mr. J. Frankenberg presented a paper dealing with "Mechanical Sound Recording of Film." The meeting was well attended and the presentation was discussed at considerable length.

Announcement of the officers and managers of the Section for the year 1939 was made as listed above.

PACIFIC COAST SECTION

On December 15th a meeting of the Section was held at the Walt Disney Studios in Hollywood, at which time a demonstration of the recording spectrophotometer and the Disney multiplane camera was given by the technical staff of the Walt Disney Studios. On account of limited accommodations, the meeting was open to only members of the Society and was well attended. The presentation elicited much interest and discussion.

CONVENTION ACKNOWLEDGMENTS

Acknowledgment is due to many companies and persons for their coöperation in arranging and conducting the Detroit Convention, held on October 31st–November 2nd, with headquarters at the Hotel Statler. General facilities of the Convention were arranged by Mr. W. C. Kunzmann, *Convention Vice-President;* Messrs. H. Griffin, J. Frank, Jr., and G. Friedl, Jr., in charge of projection facilities; Mr. K. Brenkert, *Chairman of the Local Arrangements Committee;* A. J. Bradford and J. F. Strickler on the *Local Arrangements Committee;* Mrs. J. F. Strickler, hostess in charge of the Ladies' Committee; Mr. J. Haber and F. Johntz of the Publicity Committee; and Mr. E. R. Geib, *Chairman of the Membership Committee.*

Credit for the papers program and technical arrangements are due to Mr. J. I. Crabtree, *Editorial Vice-President,* and Mr. G. E. Matthews, *Chairman of the Papers Committee.*

Among the companies contributing equipment and service to the Convention were the following: International Projector Corporation, National Carbon Company, National Theatre Supply Company, Raven Screen Company, Eastman Kodak Company, Bausch & Lomb Optical Company, RCA Manufacturing Company, Brenkert Light Projection Corporation, Jam Handy Pictures Corporation, and the Detroit Local 199 IATSE.

The Society is indebted to the following companies for the films loaned for the motion picture performance held on the evening of Monday, October 31st: RKO Radio Pictures, Paramount Pictures, Inc., Eastman Kodak Company, Technicolor Motion Picture Corporation, March of Time, and Walt Disney Productions, Ltd.

Acknowledgment is due also to the United Detroit Theaters Corporation and the Fox Detroit Theater for supplying passes to members and guests during the week of the Convention.

ADMISSIONS COMMITTEE

The following applicants have been admitted by vote of the Board of Governors to the Active grade:

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SAWYER, C. R.
6601 Romaine St.,
Los Angeles, Calif.

WALKER, H. S.
1620 Notre Dame St. West,
Montreal, Canada

JOURNAL
OF THE SOCIETY OF
MOTION PICTUTE ENGINEERS

Volume XXXII **February, 1939**

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JOURNAL
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Subscription to non-members, $8.00 per annum; to members, $5.00 per annum, included in their annual membership dues; single copies, $1.00. A discount on subscription or single copies of 15 per cent is allowed to accredited agencies. Order from the Society of Motion Picture Engineers, Inc., 20th and Northampton Sts., Easton, Pa., or Hotel Pennsylvania, New York, N. Y.

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SOME TELEVISION PROBLEMS FROM THE MOTION PICTURE STANDPOINT*

G. L. BEERS, E. W. ENGSTROM, AND I. G. MALOFF**

Summary.—*Certain of the characteristics of television have their counterparts in motion pictures, and motion picture film and motion picture practice are applicable to television. Some of the problems and limitations pertaining thereto are outlined, and the following television-image characteristics are briefly discussed: (1) Number of scanning lines and the relationship to image size and viewing distance; (2) number of frames; (3) interlacing.*

The effect of film and optical system limitations on reproduced television images is illustrated by photographs, and curves are given showing the spectral characteristics of Iconoscopes. The screen color characteristics of Kinescopes are also discussed, and the overall range and gamma characteristics of a television system are reviewed.

The prime objective of television, in common with other pictorial arts, is to create an illusion. There are certain limitations on how good the illusion can be; some inherent and others dependent on the state of the art. Many of these limitations have a counterpart in motion pictures and it is the purpose of this paper to review and compare some of these mutual restrictions.

PICTURE DETAIL

Picture detail in motion pictures is ultimately determined by the optical system and the resolution of the film. The factors determining picture detail in television are more complex. The frequency band width limitations imposed by a single-channel communication system suitable for television broadcasting makes it necessary to divide the scene arbitrarily into elemental areas and transmit the information representative of light and shade, area by area and line by line until the entire scene has been scanned. With such a television system the basic factors determining picture detail are the number of scanning lines, the size of the scanning spot, the frequency-band width, and the optical system. In practice the first two factors are definitely

* Presented at the 1938 Fall Meeting at Detroit, Mich.; received December 12, 1938.

** RCA Manufacturing Co., Camden, N. J.

related, since the size of the scanning spot is commensurate with the distance between centers of scanning lines. In the television standards of the Radio Manufacturers Association scanning is expressed in terms of the total number of lines from top to bottom from the beginning of one frame to the beginning of the next frame. Since in a practical television system both spot size and frequency-band width are chosen on the basis of the number of scanning lines, the

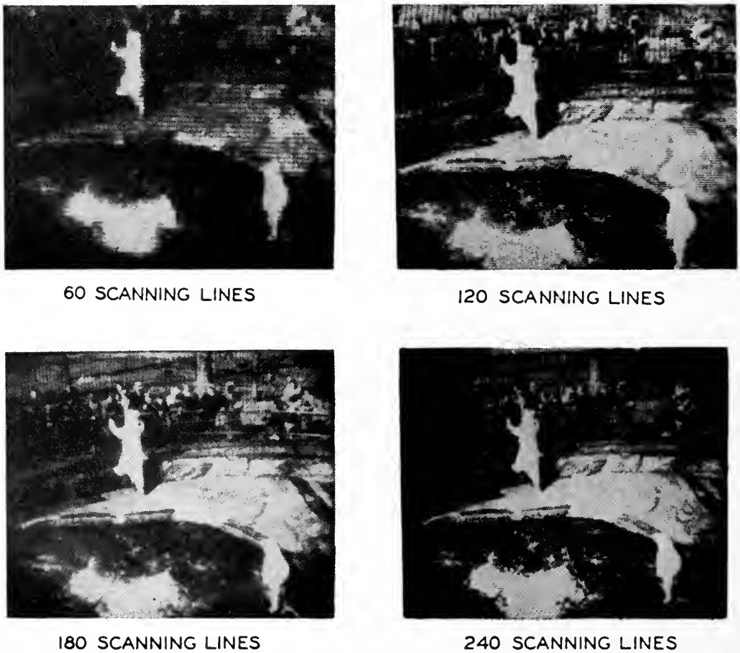

FIG. 1. Pictures depicting characteristics representative of television images for several numbers of scanning lines.

inherent resolution of a television system may be expressed as the number of scanning lines per frame.

Information has been presented previously to indicate the degree of entertainment possible for television images of various numbers of scanning lines.[1] A summary of this will be presented here as the first step in our analysis of how good the television illusion will be. First, we may consider Fig. 1 which is made up of four repetitions of the same subject with detail equivalent to 60, 120, 180, and 240 scanning lines. From images of this type of motion picture film, from related tests, and from experience with television systems Fig. 2 has been made. This chart shows the relationship between number of scanning lines and picture size for several viewing distances. These curves indicate what the average eye demands for satisfactory images to produce the illusion expected of television.

Another means for evaluating the resolution of a television system is to estimate its ability to tell a desired story in comparison with 16-mm. home movie film and equipment. The result of such a comparison by a number of observers is that a 400- to 500-line television system compares favorably with 16-mm. home movies in permitting observers to understand and follow the action and story. The scanning standard adopted by the Radio Manufacturers Association is 441 scanning lines per frame.

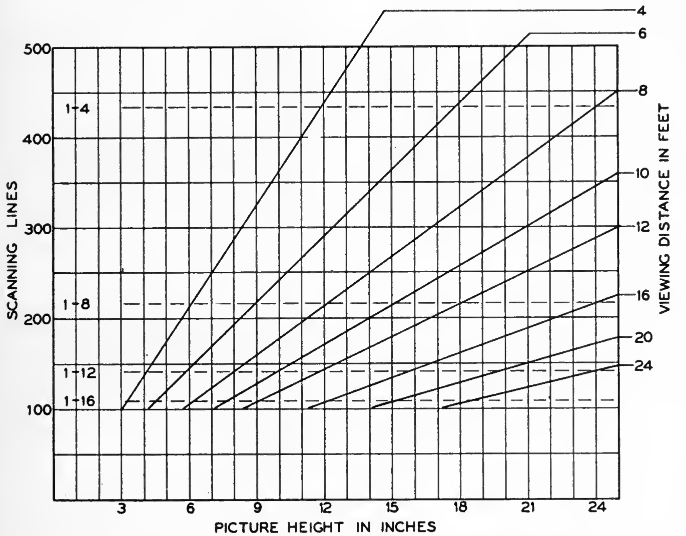

FIG. 2. Relationship between the number of scanning lines and picture size for several viewing distances.

FRAME FREQUENCY AND FLICKER

Television images consist of rapidly superimposed individual frames much the same as motion pictures. In the case of motion pictures a group of time-related stills is projected at a uniform rate, rapid enough to form a continuous picture through persistence of vision. By present methods, each frame of a television image is built up element by element in some definite order and these time-related frames are reproduced at a rapid rate.

In motion pictures the frame frequency determines how well the system will reproduce objects in motion. This has been standardized at 24 frames per second. In television other factors than the ability to reproduce motion have made it necessary to use a frame frequency of 30 per second.

Motion picture projectors commonly used are of the intermittent type. The usual cycle of such a projector is that at the end of each projection period the projection light is cut off by a shutter, the film is then moved a step so that the succeeding frame registers with the picture aperture, and the shutter then opens, starting the next projection period. This is repeated 24 per second. Since projection at 24 light-pulses per second with the screen brightness levels used in motion pictures causes too great a flicker effect, the light is cut off also at the middle of the projection period for each frame for a time equivalent to the period that it is cut off while the film is moved from one frame to the next. This results in projection at 24 frames per second with 48 equal and equally spaced light-pulses. Such an arrangement provides satisfactory results from the flicker standpoint.

In television, because of the manner in which the image is reconstructed, a continuous scanning process, it is not practicable to break up each light pulse further by means of a shutter in a manner similar to that used in the projection of motion pictures. We therefore have in an elementary television system a flicker frequency corresponding with the actual frame frequency. This is satisfactory at very low levels of screen brightness but becomes increasingly objectionable as the screen brightness is raised.

In motion pictures the projector shutter opening in terms of degrees for each frame has an important effect on the flicker characteristics. Cathode-ray tubes—Kinescopes— are at present the preferred means for television image reproduction. In the Kinescope each element of the image on the luminescent screen, when excited by the electron beam, fluoresces and assumes a value of brightness corresponding with the value of the electron-beam strength. Upon removing the excitation this brightness then decays (phosphoresces) in an exponential manner and at a rate dependent upon the screen material. The phosphorescence or persistence of the image screen aids the persistence of vision of the eye in viewing the reproduced image. This characteristic for one screen material is shown in Fig. 3. However, a previously stated, far too much flicker is present at 24 or 30 frames per second for the desired levels of screen brightness.

A particular method of scanning is therefore used to modify the overall image flicker. This is possible because scanning is a continuous process. Scanning may be in equal horizontal strips or lines from top to bottom in numerical order of lines *1, 2, 3, 4,* . . . . (progressive scanning). This results in one overall light-pulse for each frame. If the procedure is modified so that scanning is for the first half of one frame period in the order of lines *1, 3, 5, 7, 9,* . . . . . ., from top to bottom of the frame and for the second half of the frame period in the order of lines *2, 4, 6, 8, 10,* . . . . , from top to bottom

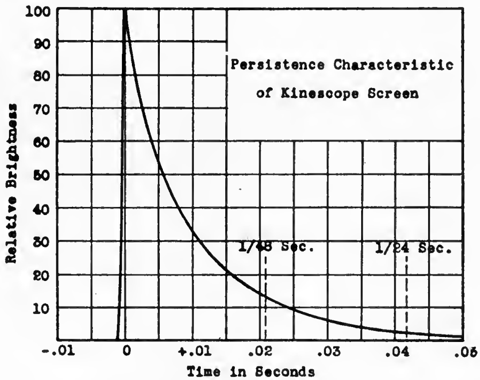

FIG. 3. The phosphorescence characteristic of a Kinescope screen.

of the frame (interlaced scanning), then the flicker effect of the reproduced image is changed. This method of scanning is shown diagrammatically in Fig. 4. Each frame now consists of two portions (two *fields*) with respect to time: each field composed of a group of alternate lines, and the two sets of alternate lines are properly staggered to form a complete interlaced pattern. In progressive scanning each line flickers once per frame and neighboring lines differ in time relation only by the time required for scanning one line. There is, therefore, no noticeable inter-line effect. In interlaced scanning also each line also flickers once per frame, but neighboring lines differ in time relation by one-half a frame period. This results in two flicker effects, an overall effect and an inter-line effect.

As previously stated a frame frequency of 30 per second with progressive scanning produces an intolerable flicker. A frame frequency of 60 per second is certainly satisfactory from the flicker standpoint but the frequency-band width required for transmission is doubled. With interlaced scanning at 30 frames, the overall flicker effect is the same as with 60 frames progressive scanning, and no increase in frequency-band width is required. Each line flickers at the rate of 30 per second and adjacent lines flicker with respect to each other, since they are scanned with a time-difference of $^1/_{60}$ of a second. At optimum viewing distances for television images and for practicable levels of screen brightness this inter-line flicker is not noticeable.

A frame-frequency effect peculiar to television is encountered in the operation of cathode-ray television receivers from an alternating-

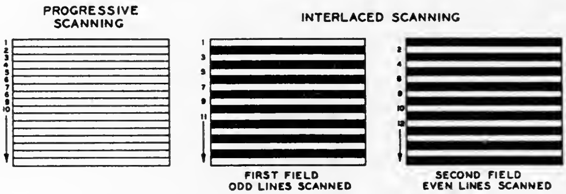

FIG. 4. Diagrammatic illustration of progressive scanning and interlaced scanning.

current power-supply system. The effects of ripple voltages and fields appear in the reproduced image in a variety of forms and from numerous sources. If the frame-frequency differs from the power-supply frequency, that is, differs except in terms of integral multiples or sub-multiples, then these effects move across the image at rates dependent upon the time-difference between the frame-frequency (multiple) and the power-supply frequency. This moving ripple pattern is almost as disturbing as flicker and the visual effects are about the same. Also for interlaced scanning these ripple effects cause moving displacements in the position of alternate sets of lines and tend to destroy the interlaced pattern. If the frame-frequency has an integral ratio to the power-supply frequency, 30 frames for a 60-cycle source, then the effects are stationary on the image and very much less pronounced, thus making it possible to obtain satisfactory performance when using comparatively inexpensive apparatus.

On the basis of these factors the Radio Manufacturers Association has standardized interlaced scanning with a frame-frequency of 30 per second and a field-frequency of 60 per second.

Motion picture film is one source of program material for television. With electronic scanning methods it is usual to project an image of the film moving or stationary on to some element of the electronic translating device. This may be accomplished by the use of an intermittent type of projector, a continuous projector having an optical intermittent, or a system in which the film moves continuously with a compensating motion of film-image and scanning. The particular method used is partly determined by the type of electronic scanning device. The use of 24-frame motion picture film to produce

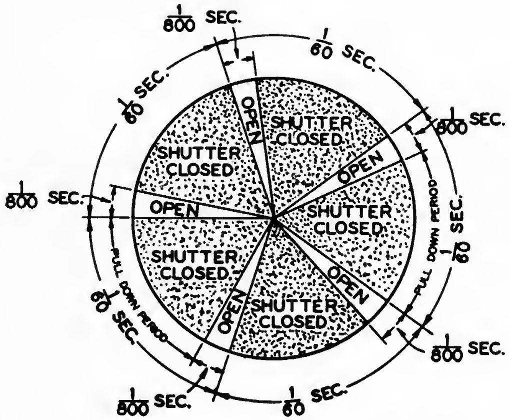

DIAGRAM OF ONE COMPLETE CYCLE OF OPERATION OF TELEVISION FILM PROJECTOR
ENTIRE CIRCLE IS $\frac{1}{12}$ SECOND

FIG. 5. Diagram illustrating the 3:2 ratio of pull-down periods in a special television film projector.

30-frame television with interlaced scanning presents certain special problems.

In using an Iconoscope as the electronic translating device it has been customary to use an intermittent type of projector. By utilizing the storage properties of an Iconoscope, the film-image may be projected on to the photosensitive mosaic during the time between the completion of one field scanning and the beginning of the next. Scanning then may take place and electrical signals may be obtained from the mosaic while it is dark. Since the field scanning-frequency is at the rate of 60 per second, this means a short period of projection 60 times a second and of a duration of approximately $^1/_{800}$ second.

With 60 projections per second we may hold one frame for three projection periods—$^3/_{60}$ second; the next for two projection periods—$^2/_{60}$ second; the next for three projection periods—$^3/_{60}$ second; the next for two projection periods. . . . Thus by a 3:2 ratio of pull-down periods in an intermittent and by the use of a shutter that is open only during the vertical return time of the scanning, we may derive program material for a 30-frame television system from standard 24-frame sound motion picture film, retaining the standard film speed. This 3:2 ratio of pull-down periods is illustrated diagrammatically by Fig. 5. Fig. 6 is a photograph showing two television film projectors having these characteristics.

EFFECT OF FILM AND OPTICAL SYSTEM LIMITATIONS ON REPRODUCED TELEVISION IMAGES

In order to verify previous conclusions regarding the relative picture detail capabilities of a 441-line television system and home motion pictures, a test-target was photographed and reproduced on 35-mm., 16-mm. and 8-mm. film. A second purpose of making these films was to determine the merits of the several film sizes as sources of television program material.

The test-target used in making the films consisted of twelve substantially identical major squares arranged in three horizontal rows to form a rectangle having a 4:3 aspect ratio. Each major square included four minor squares of equal size but different patterns. Each major square contained a complete vertical wedge of thirteen tapered bars (7 black and 6 white) which started in the upper right-hand minor square with a resolution calibration of 100 "resolution bars" and increased to 200 at the bottom at that minor square. The wedge continued in the lower left-hand minor square with 200 at the top and 300 at the bottom. The bars of the wedge were slightly curved so that a linear relation between distance along the wedge and resolution could be obtained, facilitating intermediate readings. The horizontal wedge was similar, beginning with 100 at the left-hand side of the upper-left minor square and finishing with 300 in the lower-right square.

The area surrounding the wedge in the two lower minor squares of each major square was divided into four smaller areas which were cross-hatched to produce the effect of different halftones from black to white.

The test-films were not intended to show the maximum resolution capabilities of the film but to indicate the picture detail obtained through present commercial methods for providing duplicate films. The 16-mm. and 8-mm. films were made from the 35-mm. negative by means of an optical reduction printer. Two 16-mm. and two 8-mm. prints were made. One print of each was made with the customary processing to give the proper halftone reproduction. The other prints were made to accentuate the detail in the wedges at some sacrifice in halftone gradation.

Each of the five films was separately used to produce a television image by projecting the test pattern on each film on to the mosaic of an Iconoscope in an experimental 441-line television system. The

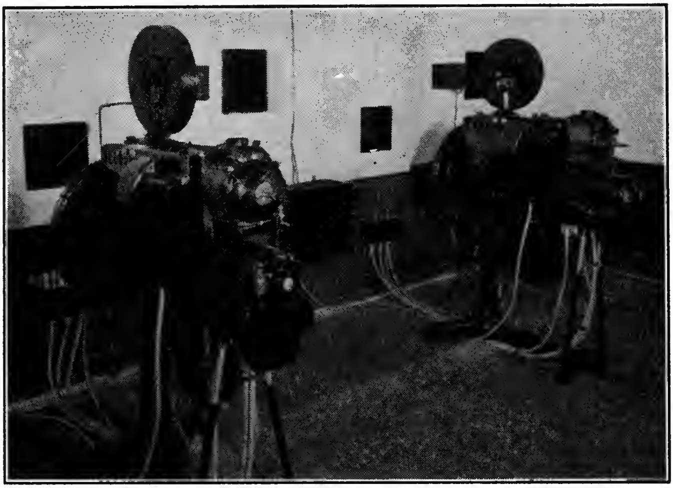

FIG. 6. Two special television film projectors.

video-frequency band employed by this system was from 30 to 3,500,-000 cycles, and the single side-band transmission this band-width is well within the channel limits that have been tentatively assigned for television broadcasting. For each of the five films a photograph was taken of the television-image reproduced on the screen of the Kinescope. These photographs are shown in Figs. 7, 8, 9, 10, and 11. Fig. 7 shows the result obtained from the 35-mm. film. Figs. 8 and 9 illustrate the images secured from the 16-mm. film and Figs. 10 and 11 give the corresponding results with the 8-mm. film.

It will be noted that there is a slight reduction in detail from the image reproduced from the 35-mm. film to that obtained from the

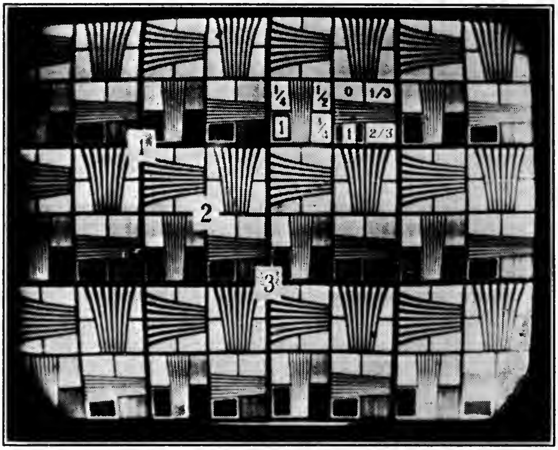

FIG. 7. Television image obtained from a test-chart on 35-mm. film.

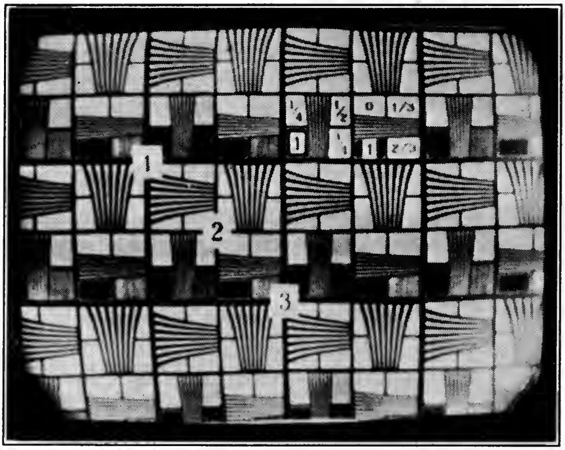

FIG. 8. Television image obtained from a test-chart on 16-mm. film with special processing.

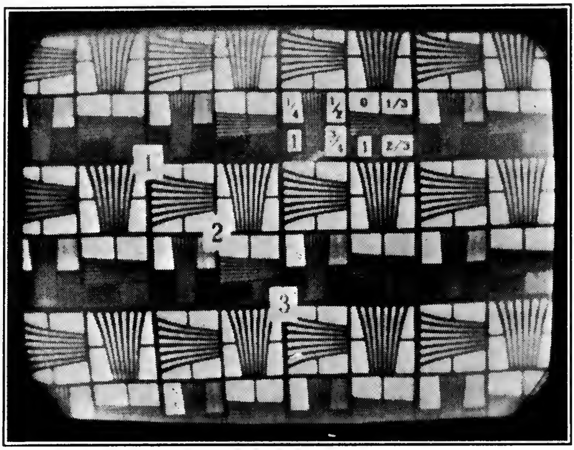

FIG. 9. Television image obtained from a test-chart on 16-mm. film with normal processing.

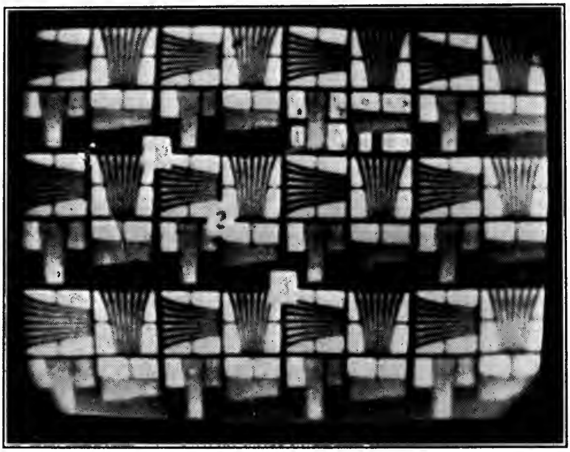

FIG. 10. Television image obtained from a test-chart on 8-mm. film with special processing.

16-mm. films. The loss in picture detail when the 8-mm. films are used is, however, quite serious.

From these tests it seems reasonable to draw the following conclusions: In picture-detail capabilities a 441-line television system compares favorably with 16-mm. home movies. If motion picture film is used to provide television program material, satisfactory results may be expected from 35-mm. film; a slight loss in picture-detail will result from the use of 16-mm. film, and the resolution capabilities of a high-definition television system will not be utilized if 8-mm. film is used.

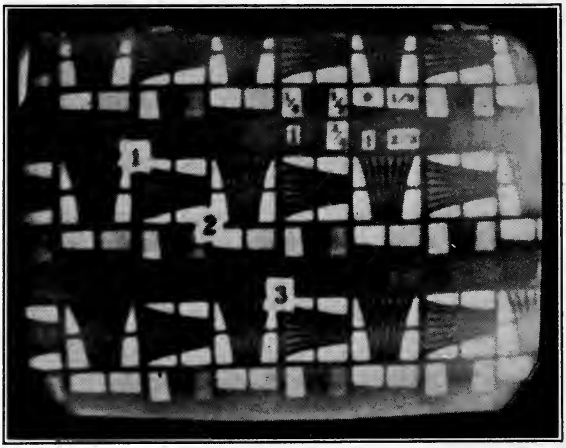

FIG. 11. Television image obtained from a test-chart on 8-mm. film with normal processing.

SPECTRAL CHARACTERISTICS OF THE ICONOSCOPE

In motion picture work studio lighting and make-up technic are dependent upon the color-response characteristics of the film. In television the spectral response characteristic of the Iconoscope controls these factors. This characteristic of an experimental Iconoscope is shown in Fig. 12. As indicated by the curve this Iconoscope gave maximum sensitivity in the blue end of the spectrum. The most desirable Iconoscope spectral characteristic for a given application is dependent upon the light-source used to illuminate the scene. An Iconoscope having the characteristic shown in Fig. 12 tends to compensate for the high red output of the incandescent lamps used in studio lighting. For outdoor pick-up work a characteristic more nearly approximating that of panchromatic film is desired. The spectral characteristic of the Iconoscope can be varied to a considerable extent by the sensitization procedure employed. Various spectral-response characteristics obtained in experimental Iconoscopes have indicated that characteristics can be provided that are comparable to those of panchromatic and other films.

SCREEN-COLOR CHARACTERISTICS OF KINESCOPES

The high-intensity arc commonly used as a light-source for motion picture projectors produces an image that has satisfactory black-and-white characteristics. In the initial stages of cathode-ray television

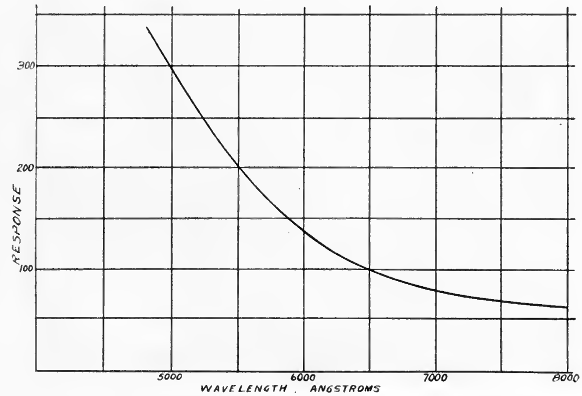

FIG. 12. Spectral characteristic of an Iconoscope.

development, so many serious limitations were present that the green color of the image reproduced on a willemite screen was not considered to be particularly undesirable. As television development progressed and picture-detail and screen brightness improved, the green color of the reproduced image became more objectionable and development work on luminescent materials to produce a black-and-white image was started. Kinescopes having luminescent screens giving black-and-white pictures of adequate brilliance are now a commercial reality. In Fig. 13 the emission spectra of two screen materials are shown. Screens of both materials will be judged as white if viewed separately, but when compared one to the other one will be called blue-white and the other ivory-white. Individual opinions vary greatly as to which is the best white for television screens since the apparent whiteness of a television image is influenced by such factors as the image brightness and the background lighting in the room in which the image is viewed. One thing is certain, and that is that purchasers of television receivers will demand substantially black-and-white images.

GAMMA AND RANGE IN TELEVISION

Those engaged in motion picture work are quite familiar with two terms that recently have been given serious consideration in television, *i. e.*, *gamma* and *range.* Three typical characteristic curves of pictorial reproducing systems are shown in Fig. 14. Curve (*a*) is for a

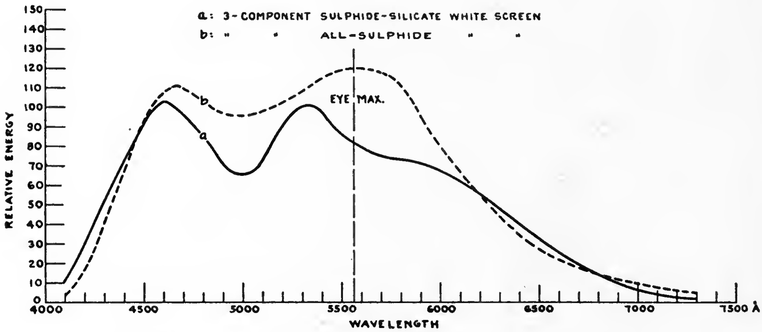

FIG. 13. Emission spectra of two screen materials.

contrast or gamma of unity, while curves (*b*) and (*c*) are for a gamma of 0.5 and 2.0, respectively. The ranges available for the image and ranges of the object that the system can cover are indicated in the figure. In black-and-white motion picture technic, it has become standard practice to make the overall object-to-image contrast between 1.4 and 2 in order to compensate for the lack of color. Television is also a monochromatic system, and it therefore seems desirable to follow the experience of the motion picture industry and produce television images with a similar increase in contrast.

The "object brightness *vs.* output signal" characteristic of the Iconoscope has been measured and found to vary with the amount and distribution of light in the object. However, it may be stated that in general the Iconoscope is a low-gamma device—the value varying between 0.7 and 0.9 for most of the cases encountered in practice. The Kinescope has an inherent contrast or gamma of approximately 1.5 but the saturation effect in the screen material reduces this to the neighborhood of 1.2. The overall gamma of the television system, so far as the Kinescope and Iconoscope are concerned, is therefore substantially unity. This is quite satisfactory when motion picture film is used to provide program material, since the contrast has already been raised to a proper value by an experienced photographer. An overall gamma of unity is probably insufficient when transmitting scenes picked up directly by the Iconoscope. In motion picture work gamma is controlled by the film

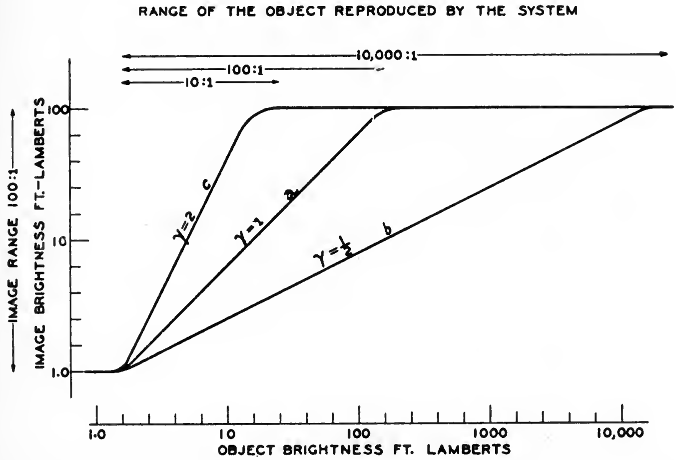

FIG. 14. Three typical characteristic curves of pictorial reproducing systems.

emulsion and the method and time of development. In television any desired gamma can be obtained by varying the characteristic of one of the signal amplifiers in either the receiver or transmitter.

Although the brightness range in television images may be limited in several portions of the system the present practicable limit is in the Kinescope. The bulb shape of the Kinescope is determined by the physical characteristics necessary to withstand atmospheric pressure. For this reason the screen of a conventional Kinescope has a certain curvature, thus permitting illuminated parts to throw light directly on non-illuminated parts. Reflections may occur also from other portions of the inner surface of the bulb. In addition to these reflections, a certain amount of light is totally reflected from the glass-air boundary and introduces a reduction of range in details by halation. These effects have been reduced by blackening the inside walls of the bulb and by introducing a small amount of light-absorbing material in the glass wall. Conventional Kinescopes have an available range of about 50 to 1 for large areas and 10 to 1 in details. Experimental Kinescopes have been built in which the luminescent screen is deposited on a thin sheet of glass which is mounted inside a transparent glass bulb. Such tubes are capable of a considerably greater range between large areas and in details.

REFERENCE

[1] ENGSTROM, E. W.: "A Study of Television-Image Characteristics," *J. Soc. Mot. Pict. Eng.*, **XXII** (May, 1934), p. 290.

DISCUSSION

MR. CRABTREE: When televising an outdoor subject, what is the threshold light-intensity necessary for reproduction, as compared with that necessary when photographing with an $f/2$ lens in combination with the high-speed film emulsion we now have available?

MR. BEERS: With various standard and special pick-up tubes, we can get pictures under any lighting conditions in which you can take pictures on film.

MR. CRABTREE: In other words, you can reproduce satisfactorily a football game about half an hour after sunset on a rainy day?

MR. BEERS: Yes. We have obtained recognizable pictures in which the subject had a surface brightness of 1 or 2 foot-candles.

MR. CARVER: I do not understand whether you have a flicker blade or not or whether it is or is not necessary.

MR. BEERS: There is no flicker blade, as such. A flicker blade is not necessary in television, due to the way in which we reconstruct the image. We produce on the end of the tube a certain number of images a second, and that controls the flicker. Nothing in the projector has anything to do with the manner in which the images are actually reproduced.

MR. CARVER: What do you do when the film is being pulled down? There is no picture on, and there must be a dark space.

MR. BEERS: You are actually seeing the picture when the film is being pulled down. During the pull-down we scan the electrical image that remains on the mosaic of the Iconoscope. That is when we see the image at the receiver. The picture is projected when nothing is seen at the receiver. That is the interval in which we transmit the synchronizing signals.

We have two choices in television. One is to attempt to scan the picture on the mosaic of the Iconoscope during the time the picture is actually being projected there. That means then that we have to pull down the next frame of film during the time we transmit our scanning signals, which is approximately $^1/_{800}$ of a second. That imposes some physical requirements on a projector we have not been able to meet. We have not been able to conceive of a projector on which the frame can be pulled into place in $^1/_{800}$ second without tearing the film. The easier way is to pull the film into place in the gate during the long interval of time and to project it on the Iconoscope mosaic during the short time interval; and then to scan it, while the optical image is no longer on the mosaic, using the electrical image that is stored there.

MR. FRIEDL: With relation to standardization, it appears from these papers that standards are set on the basis of electronic scanning, determined by frame frequency, screen persistency, halation, and so on—all of which result in the broad frequency-band which we can admit is a limitation to the general application of direct television.

Reference was made to mechanical systems in England and the speeds with which these systems operate. Can someone throw some light on the question of mechanical systems *vs.* the electronic systems?

MR. GOLDSMITH: The electronic systems offhand seem to be most appropriate because electrons are weightless and are readily controlled in flight and form a sort of "air-brush" for painting pictures which can be moved rapidly and readily. The only mechanical system that seems to be seriously considered commercially today, at least in England, is the one Mr. Kaar mentioned, the Scophony system, in which essentially there is a storage capacity, because of a diffraction phenomenon of standing waves of supersonic frequency in liquid, actuated by a vibrating quartz crystal. In this system one may scan a half line at a time (about 200 picture elements).

This system, however, as Mr. Kaar pointed out, employs a motor running at some 30,375 revolutions per minute for the high-speed or line deflection of the spot, and a smaller motor, running at a lower speed, for the frame scanning, two mirror systems, the supersonic cell, some lenses, and a mercury-vapor capillary lamp for the light-source. The picture produced is 18 × 24 inches in size.

The competitive devices in England are, for example, the Phillips receiver which produces an 18 ×24-inch picture by projection from approximately a 3-inch projection type cathode-ray tube.

The prices on the British market today are $850 for the Phillips receiver producing the 18 × 24-inch picture, and something over $1100 for the comparable Scophony receiver, but nobody has given reliable data as yet as to the relative performance, life, and economics.

The receivers in England run in the price range from $125 to $150 (for the picture only) in a chair-side type. Receivers for larger pictures run up to $300 or $400, with top figures of $1200 for very large pictures (18 × 24 inches) with sound and all sorts of extra attachments, phonographs, and the like.

MR. BEERS: If it were economically possible to use 24 frames in television it would be done. It is theoretically possible, but the increased amount of filtering and shielding necessary in the receiver to make it perfectly satisfactory from the standpoint of eliminating the moving images resulting from the 60-cycle power-supply system make it economically impracticable.

MR. ROBERTS: When scanning 24-frame motion pictures at 60 or 30 cycles, do you get any time-distortion in the presentation of the picture? Would there be any unexpected effect as a result of seeing one frame longer than the one before it?

MR. BEERS: We have noticed no more distortion than is normally noticed in motion pictures.

MR. CRABTREE: Do you think the trend will be to record directly by means of television scanning, or that the subjects will be photographed on motion picture film previously to scanning? What are the relative merits of the two processes—direct scanning and transmission at the scene, as against photographing the scene and then bringing the film to a central transmitting station?

MR. BEERS: That is a program problem. Either can be done. The scene may be taken on motion picture film and then converted into television program material; or, as you know, we have a mobile unit, which can be taken out to the scene and there televise it and transmit its picture directly by relay to the transmitting station.

MR. CRABTREE: When we met in New York we gained the impression that the actors in the studios had to work under high temperatures, with fans blowing on them and the make-up melting on their faces. In other words, it seemed to be a terrible ordeal to be a television actor. Would it not be simpler to photograph the scene and then to transmit it?

MR. GOLDSMITH: That condition has been markedly improved.

MR. BEERS: The sensitivity of the electronic pick-up device is being constantly improved, and as it is improved, of course, this high-temperature condition that you mention is reduced. From what little contact I have had with motion pictures, I am not sure that conditions in that respect are so vastly different. The advantage in motion pictures is that you can shoot a scene and then take time to cool off; but in television, if we wish to keep a continuous program on the air, the actors have to stay under the lights and suffer. However, as I said, as the sensitivity of the pick-up device is improved the heat to which the actors are subjected will decrease.

MR. SCHLANGER: Am I to understand that the television picture is equal in quality to a 16-mm. picture, projected with a 250-watt lamp and of comparable size and viewing distance?

MR. BEERS: From the standpoint purely of picture detail they would be comparable. I stated that the film was processed to produce duplicate films. If you take standard home motion pictures on reversible film, you will have somewhat better detail, but with ordinary commercial processing of duplicate films, I think that the picture detail of the two will be comparable.

SOME PRODUCTION ASPECTS OF BINAURAL RECORDING FOR SOUND MOTION PICTURES*

W. H. OFFENHAUSER, JR., AND J. J. ISRAEL**

Summary.—*The binaural effect, while of great importance in our day-to-day life, has been an unexplored field in our conventional monaural sound motion picture which, despite our other technical advances, remains incapable of the quality called sound "perspective."*

To achieve the missing quality, it is important that controllably variable perspective effects be attainable for the release print from an original having different perspective quality. This is necessary not only to make the sound recorded on a three-walled set simulate the sound from a six-sided room, but also to make the recorded sound correspond satisfactorily with the view portrayed by the camera.

A new system is described that not only fulfills these fundamental requirements, but also is capable of controllably producing at will the various perspective and quality-change effects in a simple dubbing operation from a source having no perspective characteristics such as a conventional monaural sound-track. The new method may be introduced step by step into our present production system without material obsolescence of either films or equipment.

There is a very simple test that anyone can make that should conclusively answer the question, "Why binaural?" As someone speaks to you, hold a finger to one ear so as to prevent sound from entering that ear. You will notice a marked difference in the sound; it now seems hollow, and, if you close your eyes, the voice that was so intimately near but a moment ago has changed and now seems to have a different aspect which causes it to appear indistinct; and, you are now somewhat confused as to the true location of the speaker. If, with your eyes still closed, you remove the obstructing finger so as to hear normally through both ears, the voice of the speaker again becomes distinct and takes on all the characteristics that you regard as natural; and your speaker again seems human to you.

Despite the fact that we are aware that monaural systems are quite incapable of that quality called perspective, all our commercial sound recording and reproducing systems in use in motion pictures

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** New York, N. Y.

today are monaural or one-eared systems. Technical development of monaural systems has been pushed ahead by the industry at full speed; the success of these efforts has been reflected in renewed energy in the development of the newest advance which no doubt will soon take its place commercially in the industry—binaural sound recording and reproduction. Binaural recording, like stereoscopic pictures, has a long history of achievement as well as disillusionment. The difficulty encountered in approaching both subjects has the same character; it is necessary for us to understand human reactions before we can attempt even to consider technical solutions. This analysis of the human phase at first glance seems simple; yet, closer inspection reveals that the more we look into the subject, the less we appear to comprehend.

Before any methods or apparatus can be considered, it is necessary to approach the problem in the manner in which we approach any problem of evaluation; we must first determine our hypotheses and our axioms; and only after these are fully decided upon may we approach our theorems. This must be done with fear and trembling; every step in the formulation of the hypotheses and axioms must necessarily involve compromise as it will be found that no two workers in the field can agree completely upon either the premises or the objectives.

We must leave to the psychologists the problem of evaluation of human reactions. In every step of our reasoning we must keep in mind the fact that a motion picture audience is a group of customers who take nothing tangible home with them despite the fact that they pay something tangible for what they receive. It is the purpose of the motion picture to create an illusion by whatever means, and the most successful motion picture is the one that creates the best illusion.

Our psychologists have pointed out for centuries that reality and our concepts of it may have little to do with one another. We have been told repeatedly that only the abstract can be perfect: the more real (in the sense of physical reality) a thing becomes, the more noticeable are its flaws. The same may be said to be true of motion pictures.

This point has been amply demonstrated time and again. In the recording of sound, for example, we would not always care to have the noise of a collapsing building reproduced for us in our theaters at its original volume, particularly if, after the building collapsed we wished to hear dialog between two of our principal characters. The perfect picture would be one that would create the illusion of the falling building without causing the physical discomfort that would result if we were to hear the noise in all its original intensity.

In motion pictures it is the illusion produced by the facile and artistic combination of *both* picture and sound that is the desideratum of a "good show." This is forcefully pointed out when we consider a hypothetical case that could well take place. Suppose one were to make a sound record, without picture, of the waves breaking on the beach at Atlantic City. For the sake of illustration let us boldly assume that we are able both to record and reproduce this sound without any loss of fidelity whatever. We will project this sound under ideal conditions for a group of Iowa Agricultural College students, most of whom have never been to the seashore. What will be the reactions of this audience after a long afternoon spent in the hot sun studying Japanese beetle control? There is only one answer: our recording accomplished with such technical perfection is nothing more than a meaningless noise that is at first quite boring, and, after a few seconds, a plain nuisance from which our students will seek escape.

Binaural recording is something that we ought to have in motion pictures today. It will immeasurably enhance the illusion when properly applied, as has been indicated by the remarkable sound illusions produced by the engineers of the ERPI and allied groups. A motion picture director with an imaginative mind would revel in the delightful possibilities of creating illusions with even today's commercial motion picture and today's demonstrated results in binaural sound transmission. With stereoscopic color pictures and binaural recording, our director could well indulge in an artistic orgy.

Motion pictures with binaural sound can hardly be considered visionary today: many years before sound was introduced commercially into our motion picture theaters, patents had been granted to far-seeing inventors on the combination of motion pictures with binaural sound. The binaural patent that is the forerunner of them all is that of Rosenberg, applied for in Great Britain on October 25, 1911 (Brit. Pat. No. 23,620). Rosenberg's appreciation of the problem is truly remarkable and his clarity can well be considered a model for others to follow.

It is doubtful that Rosenberg's reduction to practice consisted in much more than the filing of his patent application. Surely there was little that he could do at the time in making models of his invention. The vacuum tube was practically unknown outside of a very few research laboratories. The quality possible with existing microphones and loud speakers was such as to discourage any inventor with far-reaching ideas. It is indeed a tribute to the man's confidence in his ideas that he prosecuted his patent to a successful conclusion, and a tribute to the British Patent Office that his patent was passed to issue.

If one reviews the advance of the art since Rosenberg, it does seem fair to say that most inventions since then have been primarily adaptations of currently existing mechanisms to the art as disclosed by him. There has been little of theoretical value added unless it be the concepts of Kuechenmeister dealing with the delay effect. (Brit. Pat. No. 238,372; applied for Aug. 12, 1924.) This currently popular concept as applied to binaural recording on film is shown in Kuechenmeister British patent 258,864, which had a convention date of Sept. 22, 1925. Certain other inventions may be classified as frequency characteristic variation; still others have shown multiplicities of microphones, multiplicities of amplifiers, multiplicities of recording means, and multiplicities of loud speakers; others disclose dummy heads and their equivalents with microphonic ears. All these things have been combined with motion pictures, television, radio, phonographs, broadcasting, as well as an almost infinite variety of other things worthy of passing mention. In the motion picture field, these have even been combined with "wandering" sound-tracks and other inventions of similar nature.

The improvement that has occurred in the art of motion picture production since sound was first introduced commercially, can be summarized briefly as an improvement in technic. In the physical stages of production, there exist both shooting and editing, and it can truly be said that today a picture is *made* in the cutting room. The editing aspect is almost daily acquiring greater and greater importance.

The addition of anything new to sound motion picture production must consider the adaptability of the new element to the editing process as well as to the shooting process. If the new added element involves little or no added complexity in the shooting process, so much the better. Stage time costs money as all producers know only too well. If the new added element further involves but a small added complexity in the editing process, it can be introduced readily provided the scheduled editing time and expense are not unduly increased. This is important since the present tendency is to limit stage operations and to delegate more and more work to the editing process. H. G. Tasker's description of the production process given to the Society at the last Hollywood meeting points out indirectly the importance of editing when the procedure he described is compared with what we now consider the antiquated methods of 1928 and 1929 when pictures were, for the most part, made on the shooting stage.

At first glance, the application of binaural recording to motion pictures would seem to hold unknown terrors for the production supervisor. It would seem that there would be no assurance that the desired effect could be produced at all even if it were accurately defined; and, for that reason, shooting delays would seem almost certain to occur due to the introduction of the new technic, resulting in prohibitive shooting costs.

Let us consider such a simple scene as that of a talking actor passing through a doorway. Our actor performs in a three-walled set located on a shooting stage. It is difficult to record scientifically "perfect" sound for such a sequence. In the first place, the sound heard must correspond with the picture seen; the picture is dependent upon camera location and lens size. In the second place, even assuming that we could make the sound and picture correspond, it would still be impossible to produce by usual straightforward methods a sound record having the characteristics of a six-sided room when the recording is actually made in a three-wall set. A director would "throw up his hands" as soon as the actor started through the doorway; the extremely rapid swinging of the microphones suspended on the boom necessary to produce a suitable acoustic spatial effect would be entirely impracticable in a set of present-day construction. Under the circumstances, it is rather impracticable to attempt scientifically "perfect" recordings especially when it is an illusion that we are trying to produce, and we are already aware that reality and our concept of it may differ radically.

The tricks of the sound-effects men are a case in point. It is indeed a revelation to the average movie-goer to view the various gadgets used by these artists in the production of their convincing sound illusions. In spite of our innate desire for scientific truth, we do not exhibit to the public gaze the props that form such an important part of our artistic legerdemain; our attitude, rather, is to produce the best illusion we know how and to ignore entirely the means of its production. The mechanical contrivances backstage would not add to the illusion if they were exposed to public view; we go even so far as to conceal them willfully.

Why, then, in the case of an actor going through a doorway, is it necessary for us to swing microphones at a prodigious rate merely to create a scientifically "perfect" recording, when it is possible not only to produce the desired illusion by far simpler means but also to do it without any especially serious change in shooting technic? This is all the more forcefully pointed out when it is realized that our scientifically "perfect" recording can at best produce only the *wrong* illusion, because we are recording in a three-walled set.

Suggestions have appeared in the prior art[1,2,3,4] from time to time that a procedure is possible for moving sound around in reproduction without any movement of the sound on the shooting stage. A typical instance is Jones in U. S. Pat. No. 1,855,146 and the various divisions of the invention there disclosed. In the vernacular, Jones may be said to disclose "the wriggling of microphonic ears in a dummy head." Regardless of the means, there has been little serious consideration of this feature of moving sound around artificially in test and other stereophonic and binaural films that have been exhibited as samples of the binaural art. If the binaural art is to be fitted into everyday sound motion picture production, it must consider for the release print the production of acoustic effects that were not produced on the shooting stage.

Rosenberg clearly described the requirements:"—the necessity for communicating to the spectator an impression of constant coincidence between the actual and the visually apparent sources of a train of sounds as reproduced is due to the fact that . . . the perfection of the illusion will be impaired unless those sounds which represent the voice of the performer are at each instant made to appear as if they actually proceeded from whatever spot the speaker is himself visually represented as momentarily occupying."[5]

Jones[6] has suggested that the apparent location o a sound in space can be shifted about by the "wriggling" of the microphonic ears in the dummy head that he disclosed. His theory is based on the delay concept that Kuechenmeister[7] has aptly described—"means intended to convert into sound the record optically produced on the talking film are so arranged with respect to the said record on the film that the sound reproducer or reproducers connected to the said means will repeat the sound at a small interval of time." Kuechenmeister did describe this delay effect as a phase-difference and expressed his phase difference as "being about $^1/_{30}$ to $^1/_8$ of a second." Jones describes his delay effect as a phase-difference also, only he measures his delay in what he calls "sound-inches"; a coined term to indicate the time-interval required for sound to travel a distance of one inch.

Investigators in the field are not agreed as to whether phase-difference has something to do with the problem or not; the point at issue seems to be the definition of phase-difference as applied to this particular problem. A number of investigators are quite definite and state with apparent assurance that phase-difference has nothing whatever to do with the case and that it is amplitude-difference that is the crux of the question. Other investigators state with apparently equal assurance that phase-difference is the crux of the question, despite the fact that much of the prior art has accepted the amplitude-difference theory. Still others straddle the fence and propose the conversion of phase-differences into amplitude-differences, particularly in the low-frequency portion of the audio spectrum. To an impartial student, such a condition is indicative of lack of agreement upon hypotheses. As Mark Twain put it, "An argument arises when people use the same words to describe different things or when they use different words to describe the same thing."

It looks as if we engineers are stepping out of our field a bit at this stage in attempting to define phase-difference. We are not specific as to whether our aural impressions are air-borne through a common medium or whether the binaural impressions are separately conveyed. In the motion picture business we are of course interested in the former; the research man has primary interest in the latter as a step in the fuller understanding of the former. It is not our privilege to decide how the two impressions received at the two ears are integrated in the brain. That is the province of the physiologist and the psychologist and we are getting ourselves into a limitless morass unless we approach this problem in the same scientific manner in which we approach our other technical problems.

Our purpose is to create an illusion and the most successful motion picture is the one that creates the best illusion. Let us then put aside for the time being, at least, the question of phase-difference *vs.* amplitude-difference and do a bit of listening with our ears. When we have once decided what creates the illusion we want, let us then again attempt to analyze the means of its production, after the psychologists have told us what we are now in dire need of knowing.

There are, of course, a number of points of agreement. We can agree that two-eared hearing as we experience it in everyday life is better than one-eared hearing. We can also agree that in one-eared hearing, reverberation plays an important part in conveying the depth impression. We can also agree that if we have one sound record and reproduce it as Kuechenmeister did through two channels, controlling the delay of one channel with respect to the other, certain effects are produced that to many persons are pleasing. We can also agree that the practical demonstrations of auditory perspective given by the ERPI engineers produced sound results that were as desirable as they were startling. All that remains is to apply these effects to the production of sound motion pictures in a practicable and economic manner.

If we ignore for the moment reverberation effects, it can be fairly said that it is our present practice—and a very desirable one—to record all our sound with relatively close microphone placement. It is in this manner that we are able to reduce extraneous noise to a minimum. If, then, we can continue so to record and later produce in the dubbing room the desired perspective and spatial effects without any increase in noise-level other than that due to the addition of the usual re-recording step in the production of the final print, we then have a system which from an engineering viewpoint is ideal, in that it allows the highest signal-to-noise ratio and also the attainment of the desired dramatic perspective and spatial effects in the dubbing room, where the cost of retakes is so small relative to those of the shooting stage that it is possible to avoid compromise with quality in the sound portion of the presentation.

With the system to be demonstrated, it is possible not only substantially to achieve these desiderata but also to produce quite similar effects using only a standard single channel in recording, and nevertheless effecting the perspective control in the dubbing room much in the manner of a binaural recording. As is to be expected, the quasi-binaural system, as we may call it, is not quite as convincing as the full binaural system. When the illusion is aided by the picture, however, it is doubtful whether the average audience would notice the difference, particularly if the quasi-binaural films were released in the transition period from monaural to binaural.

The change from monaural to binaural films in reproduction can be made without difficulty. In projecting binaural films, we can select either one track or the other or possibly mix the two by scanning both with the same light-beam in a conventional monaural projector.

Thus a film printed for binaural release can be projected satisfactorily on a conventional projector and at the same time be suited to projection on a binaural projector. There is no technical reason why all films should not be printed for binaural release.

In the production studio, the change to binaural can be made with equal facility. Since it is possible to dub a monaural recording for binaural release, films on the shelf are not made obsolete merely because a new improvement in sound recording has arrived.

The stage-shooting technic for binaural recording requires no serious change from the present technic since the perspective control portion of the process is to be effected primarily in the dubbing room. On the sound-stage, the sound may be recorded much as it is today with the possible modification that somewhat less microphone manipulation may prove desirable. As the experience gained in production increases, the advantageous deviations from the present procedure may be studied and later introduced as their peculiarities become better understood. The change to the new system requires no drastic revisions of either operating technic or apparatus other than the eventual introduction of the necessary second channel.

There seems to be but little agreement upon the acoustic effects desired. If we consider the requirements as defined by Rosenberg we can, in all likelihood, agree that left-right movement is desirable; that some convincing impression of the distance of a sound-source from the scene represented is likewise desirable; and that possibly some impression of the directness with which the sound is presumed to approach the listener is desirable. On the other side of the Atlantic, this last is known as the "round-the-corner" effect. As in the past, our procedures will, no doubt, best be worked out by rule of thumb.

The system to be demonstrated is not limited to motion pictures; it may be applied in any field where it is desired to transmit impressions by means of sound. Some of the effects that have been produced with the system include variation of the apparent recording room size from very small, say, 1000 cubic feet, to very large, say, 500,000 cubic feet. Also important is the simultaneous yet independent movement in reproduction of one sound-source with respect to another. Essentially independent left-right movement as well as close-up and distant perspective has also been attained. All these effects were produced in reproduction without movement of the actual sound-sources with respect to the microphones. In motion pictures, the application of such a system can appreciably increase editing latitude and improve dramatic effectiveness.

The authors then proceeded to demonstrate the system. A conventional single-channel disk reproducing turntable was connected to the perspective-control device at the rear of the room. Two channels from this device fed independently to two loud speakers placed side by side on a platform directly before the audience. No movement of the speaker with respect to the microphone or the surroundings occurred when the record was made; the perspective or binaural effect was produced entirely by the manipulation of the prespective control in the rear of the room. The sounds appeared to move from one side of the room to the other, upward and downward, or backward and forward, as the controls were manipulated.

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DISCUSSION

MR. OFFENHAUSER: There is one feature in particular to which we would like to call your attention and that is the fact that it is now possible to make the sound appear to come from a point some distance beyond the physical limits of the loud speakers themselves. This, to the best of our knowledge, has never been accomplished before and is a feature that should open up a new wealth of dramatic possibilities through the increase in editing latitude of which we spoke. It is particularly significant that this effect can be produced not only by a binaural (two-channel) input but also by a monaural input of the everyday variety, as has just been demonstrated. Another important fact is that the point from which the sound appears to emanate can be shifted about in space at the will of an operator even though the original record is of the constant-quality conventional monaural type. It is now possible to provide by this method variably controllable perspective in binaural release-prints from any conventional sound-track as a source.

MR. GOLDSMITH: Did the same sound come from each loud speaker?

MR. OFFENHAUSER: There are two different loud speakers, one for each output channel.

MR. GOLDSMITH: And you control the amplitude and phase relationships between them?

MR. OFFENHAUSER: The turntable over at the left feeds into our apparatus at the rear of the room. From the output of the apparatus, the system becomes what might be termed a conventional binaural system. The particular application of the quasi-binaural system that we have just demonstrated is to provide perspective in binaural release-prints in sound that had no such perspective as originally recorded.

MR. GOLDSMITH: You take monaural sound and bring it in modified form to two separate speakers which play it back in binaural form.

MR. OFFENHAUSER: That is correct. The system also permits the use of a conventional binaural input which produces other desirable effects not attainable with conventional equipment.

MR. CARVER: Was someone varying the effects while we were listening?

MR. OFFENHAUSER: Mr. Israel, at the back of the room. He was manipulating the controls which produce the effects.

MR. WOLF: What is the relation between the two acoustic sources?

MR. OFFENHAUSER: As mentioned in the paper, there appears to be a difference of opinion as to whether the effects are a result of phase-difference or amplitude-difference or both.

We can offer this as a clue to the answer to the question. In certain tests that we conducted with sounds of complex wave-form, we connected the vertical plates of a cathode-ray tube across the loud speaker leads of one channel and the horizontal plates of the tube across the loud speaker leads of the other channel, and then manipulated our controls as we did in the present demonstration. The trace on the tube screen was a straight line which took different angular positions on the screen as our controls were manipulated. We obtained substantially the same effects demonstrated today, and throughout the variation the trace on the screen remained a straight line. Phase-difference would thus appear to be quite important.

MR. GOLDSMITH: You are asking that we be aural "guinea pigs," and you want to know whether as such we got the effect of distance and of people turning their heads, or moving away, or moving forward, or turning toward a reflecting wall, and the like. It would be interesting to have the members of the audience express their viewpoints, as to whether they got the impression of people moving about and turning their heads away from the audience, and whether the effect approximated the binaural action.

MR. CUTHBERT: The effect was very noticeable. There is one point, however: How much of the effect was actually due to the directional quality of the speakers?

MR. OFFENHAUSER: Possibly the best answer to that question is in our past experience. We made quite a number of extensive tests with all sorts of speakers, and as a result we consider it reasonable to expect that these binaural effects can be reproduced effectively if each of the loud speakers used will cover the area properly as a monaural speaker in the conventional manner.

MR. GOLDSMITH: You mean, then, that the two speakers will operate satisfactorily in the overlapped areas. That would create an acoustic pattern which you are shifting about. I noticed a definite change in acoustic quality and a decided movement of the voice. I had the feeling that the control was somewhat overdone in two or three places. There were times when it was handled with more care and feeling. I noticed some effects I thought were significant, but there were parts, of course, where you were just exaggerating the effects.

MR. OFFENHAUSER: There is one problem that always arises in connection with any binaural sound transmission, and that is the orientation of the listener with respect to the sound being transmitted. We will admit that we tried it out on you. Since there was no picture, we felt that it would be a good test, because if we could produce the illusion with sound alone without the very material aid that a picture gives, there would be no question that the illusion produced by the combination of picture and sound would be heightened to the point where it would be quite satisfactory.

MR. WOLF: There was definitely no lag between the two channels.

MR. OFFENHAUSER: We have only one input channel. There is no electrical time lag in the system.

MR. WOLF: It appears to be nothing more than a phase change.

MR. OFFENHAUSER: Not quite. As we have explained before, it is more like a combination of both phase and amplitude control.

MR. MITCHELL: What difference would it make if the loud speakers were separated, one on each side of the room. I think it is customary to assume that binaural speakers will be placed quite widely separated.

MR. OFFENHAUSER: While wide speaker placement has been found by cut-and-try methods to be most satisfactory in conventional binaural systems, our results seem to indicate no such limitation for this system; in fact, speakers placed side by side, as we have placed them here, produce the most, shall we say, startling effects?

MR. GOLDSMITH: Dramatic effects?

MR. OFFENHAUSER: That is a better description. Of course, in the initial public demonstration of a system of this sort we must try to obtain exaggerated effects in order that you may leave with some lasting impressions. If we were to show this in its true aspect as it would be shown with a picture, the sound demonstration without the picture would not be as impressive. That is entirely psychological, as you are aware.

MR. MACNAIR: This paper, on two channel reproduction, emphasizes again before the Society that our normal equipment is a one-channel system from the sound stage through to the theater, and as such has certain inherent limitations.

I should like to make one appeal, which may seem to many of you here to be a purist's appeal. This is on the use of this word "binaural." Sooner or later, if this type of reproduction becomes common, the Standards Committee is going to be up against the choice of standards and nomenclature and it will ease their work if we pay attention to the exact meaning of the word. Normally a binaural system refers to a system in which the sound is picked up by a dummy or something similar with a microphone to replace each ear. The left ear of the dummy hears sounds that would be heard by the left ear of an observer in that position, and the right ear of the dummy would hear the sound that would be heard by the right ear of an observer in that position.

The word "binaural" has been used to refer to that type of system which, in a very strict way, transfers those two channels to a right and left ear of the ultimate observer. The characteristic of that system is that the sound that is heard by the left ear of the dummy is transmitted *only* to the left ear of the observer, and the sound that is received by the right ear of the dummy is transferred *only* to the right ear of the observer.

I think it would make our discussion easier if the word "binaural" were left for that unique and accurately specified system, and that these other systems, which give a sense of motion of the sound, were referred to by some other name.

MR. OFFENHAUSER: In all the earlier patents and scientific publications such as in the *Physical Review*, the term "binaural" seems to have been adopted as descriptively generic, and we have used the word in that sense as being descriptive of certain effects rather than of certain systems. The dictionary, while not particularly precise, seems to lean in the same direction (binaural—having or relating to two *ears;* involving the use of both *ears: Merriam Webster New International, 1936*).

MR. MACNAIR: I wanted to point out that from the physical and engineering points of view there are more than one kind of system. We ought to admit from the outset that there are basically different kinds of systems, and therefore they should be referred to with different words.

MR. OFFENHAUSER: Until the present time it has hardly been possible to classify such systems since a particular effect produced in any of the previous systems usually had as an inseparable accompaniment other effects, usually undesirable, which were not independently controllable by any suitable means.

There still remains the problem of properly classifying the effects that we do consider desirable. It will require a consensus of opinion to determine suitable and proper classifications, and in order that that may be accomplished, there is required a study of the individual effects of themselves. One example is room echo, or effect, or reverberation.

Let us suppose that this room is an acoustically simple room, without columns but with very hard, flat walls, and a hard flat ceiling. When a person talks in such a room, a listener gets one impression of the room's size. If we block off one-half of the room, as with a plaster block wall, the listener has another impression merely because the size and shape of the room have changed.

We do not at the present time have technical terms to describe accurately the effects that we feel. Unless the effects are segregated, it would seem to me that we are going to have difficulty with any classifications that we may use in analysis.

Let us again consider our acoustically simple room. We shall now modify it by using some absorption material uniformly over all the exposed surfaces. With listener and speaker in the same places as in the "hard" room, the effects will be different. The effect produced when the speaker is walking about in the "hard" room is certainly different from the effect produced when he is walking about in the treated room.

If the room is then further modified so that it becomes a room such as this is acoustically, with its columns and its windows and its partially treated surfaces, the effect produced when the speaker walks about in such a room is certainly different from *any* of the other conditions described.

MR. GOLDSMITH: Yes, you have mobility of the speaker and you have sonority of the surroundings, and you mix the sonority of the surroundings and the mobility of the sound source and get a wide variety of acoustic effects.

MR. OFFENHAUSER: With this arrangement, it is possible to simulate many of these effects in reproduction when the sound-source or sources actually remain stationary with respect to the microphone. It is even possible to take a small orchestra, set up compactly for ordinary pick up and, by the manipulation of our controls, cause the reproduced orchestra to appear to spread out over a large area of, let us say, 1000 square-feet, or to contract into the area in which such a group of musicians would ordinarily perform. In addition to mobility and sonority we also seem to have a characteristic of the apparent source itself which we can call source size. This, too, is a variable.

There is a decided advantage in this particular type of reverberation effect inasmuch as it is synthetic and is not dependent upon the limitations of physical surroundings.

MR. CRABTREE: It was my feeling that you kept switching from one speaker to the other. Would not the test have been better if you had covered up the loud speakers?

MR. OFFENHAUSER: That is a good point. We had considered darkening the room and projecting a picture or some kind of visual color pattern but decided against doing so in order that we might demonstrate the system to you under the worst possible psychological conditions. If we obtain results under these conditions, we can consider this an acid test.

MR. GRIFFIN: Is the particular type of speaker that you are using of necessity a part of the system?

MR. OFFENHAUSER: Definitely not. We have used flat baffle speakers, directional horn speakers, and all sorts of other speakers, and can, to a varying degree, produce the effects with commercial speakers. Loud speakers with good high-frequency response are preferable, however.

MR. ENGL: As I understand it, there are two separate electrical channels connected to the two loud speakers. It might be an interesting experiment to connect both channels to one loud speaker instead of two loud speakers. As far as phase-differences are concerned the result on the audience should be expected to be the same.

MR. OFFENHAUSER: If they were connected to the same loud speaker mechanism, you would get an effect similar to mixing.

MR. ENGL: I mean to use the same mixing system.

MR. OFFENHAUSER: It is impracticable to try it now.

MR. KELLOGG: I should like to second Mr. MacNair's remarks and make a plea for reserving the term "binaural" for a really completely separated channel between two microphones. I believe the use of that term in patents is not as good a criterion as to what is the best usage of language as the scientific writings, because those who write patents may have excellent ideas and a good deal of ingenuity, but as a class they are not as careful probably as those who come along afterward and reduce things to careful analysis and classification. I believe that "binaural" is usually used by scientific writers in the sense of separated channels.

MR. OFFENHAUSER: We have substantially separated output channels here, but our input, as we have described, is a single channel.

MR. KELLOGG: Still it is not a binaural channel in the sense I have just described.

MR. OFFENHAUSER: That is correct; we call it quasi-binaural. We would like to call your attention to the fact, however, that this system is by no means limited to monaural input and may be used with even better results with binaural microphone input. What we have demonstrated is the quasi-binaural system.

MR. KELLOGG: That may be all right. It may be of interest to you that a number of years ago I witnessed a number of tests at our laboratories in Camden, in which we resorted to changes in phase and changes in intensity to shift sound apparently from one source to another, and it appeared that either an advance in phase or an increase in intensity would serve to shift the sound from one source to another. Within moderate limits, phase has preference, for if the intensity is pretty close, the one from which the sound reaches you first is what you consider to be the real source. However, with further increase in the difference in level, you presently reach a point where the louder one seems to be the source. This is when it almost completely subdues the other. Apparently our ears judge, so far as possible, by where the first impulse of sound comes from.

MR. DAVEE: There are one or two points in this system that we should not overlook. The first was mentioned by Mr. Offenhauser and I would like to emphasize it: the possibility of moving the sound outside the limits of the loud speakers.

Second, if each of you should walk about the room as we did last night, you would realize the rather complete coverage of the effect in this auditorium. If you have ever worked with binaural systems before, you know that the effect is usually quite disappointing when you get very far from the loud speakers. With this system, from my observation in walking about the room, the effect is very startling. One can walk about the room to his heart's content and the binaural effect is still there. The word "binaural" appears to me to be an adjective describing an effect rather than the name of a system.

MR. WOLF: This system is definitely not a binaural system in the way we are accustomed to thinking of it. With regard to the phase relations, I thought it was an accepted fact that they did not make any difference in the acoustic or subjective effect.

MR. ENGL: Perhaps I should not have used the term phase-difference, but rather time-difference. In other words, the effect here in question probably depends upon time differences. My idea was that similar effects could be produced with one loud speaker because you can, of course, get two sound waves from one loud speaker with the desired time-difference between them. With regard to the expression "binaural," I think one might propose the term "stereophonic."

MR. GOLDSMITH: In connection with phase delay, what is generally understood is that if the various frequency components of a given sound are altered in phase, the effect is not noticeably detectable. But if you have two complete replicas of a given sound, with all the components shifted bodily, a new effect of an echo occurs.

MR. MITCHELL: What is the effect of the reverberation of the auditorium, comparing a live room with a comparatively dead room with the present set-up?

MR. OFFENHAUSER: With this type of system, we can go into a room where reproduction is practically impossible with commercial conventional equipment and where even direct speech from a live speaker is unsatisfactory, and obtain improved intelligibility; even better in certain cases than the live speaker himself.

There is one other effect we have found that seems to be important and we are going to investigate it much further than we have so far. In the application to public address systems, we were able to adjust our apparatus in such a manner that we could increase the sound level in an auditorium at the feedback point by some 6 or 8 db. At the present time we attribute it to a form of negative reaction effect between the sound projected by the loud speakers and that picked up by the microphone or microphones.

MR. GOLDSMITH: That is probably acoustic degeneration between loud speakers and microphones.

MR. OFFENHAUSER: Quite likely.

COÖRDINATING ACOUSTICS AND ARCHITECTURE IN THE DESIGN OF THE MOTION PICTURE THEATER*

C. C. POTWIN** AND B. SCHLANGER†

Summary.—*In past practice, acoustics has been overlooked as a function of the architectural planning of motion picture theater structures. The need for and the extensive use of sound-absorbing devices in existing buildings have led to reliance upon corrective methods in the planning of new designs.*

The constructive approach to the solution of acoustical problems in new design is achieved only through proper determination of the basic proportions, cubic-foot volume per seat, and detailed form of the auditorium structure.

The purpose of this paper is to show that acoustics can be coördinated constructively with the other primary functions of theater planning to develop a more efficient and more economical design and one that truly expresses modern and creative architecture.

A critical distinction of modern architecture from prior technic lies in a more candid evaluation of *function*. Because of the persistence of superficial ornamentation, however, this fundamental is frequently lost in our conception of what really constitutes modern design. We need not here go into the history of the modern approach to architectonics; suffice it to point out that it assuredly did not have its real origin in ornamentation. Instead, it began as a method of using our standard and new materials for the creation of buildings better suited to our need of them.

Despite widespread digressions, which continue to exalt the purely aesthetic evaluations, modernism in architecture is the offspring of science, not of fine art. Modern science has revised our approach to most things. Giving us knowledge of a thousand venerable mysteries, it has discouraged circumlocution and falsity in our expressions generally. *To be really modern in architecture is to go straight to the purpose of a building, and to develop it in plan and structure according to an honest acceptance of that purpose, providing in the forms and devices that serve it a beauty that is inherent.*

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When the ideal of functional efficiency and proper aesthetic quality becomes our guide in designing a motion picture theater, the precepts of *sound, light,* and *vision* supply the basis for fundamental planning. Fortunately, the insistence upon such a basis has lost much of its radicalism, for which thanks are in a great measure due this Society. Through the efforts of the Projection Practice Committee[1] and of other groups and individuals, definite advances have been made in many engineering phases of theater planning. Correct vision, without obstruction, has been provided in a number of new designs, although much additional work is required in this field. Lighting in the auditorium, coincidental with the picture presentation, is now being given more study. Other provisions for the patrons' comfort and enjoyment, such as air-conditioning, proper seating, and general arrangement and appointments are also receiving much more consideration. Unfortunately, however, practically no attention has been given in previous design practice to the relationship that exists between acoustics and the fundamental plan of the theater. This does not mean that the acoustical problem has received no attention. On the contrary, it has often received thoughtful treatment, but more specifically from what might be termed a *corrective* rather than a *constructive* point of view. In other words, the usual procedure has been first to plan the theater from all other aspects and, in many cases, even to go so far as to determine the decorative treatment of the interior, before considering acoustics. Then, as the final step (in cases where the subject of acoustics is given consideration in planning) sound-absorbing materials are selected with a view to correcting or compensating for acoustical deficiencies in the design—definite assurance being made first that these materials will fit a predetermined decorative scheme.

This corrective approach to the solution of acoustical problems has become common practice because: (*1*) the preliminary basic form of auditoriums has not been planned for best acoustics; (*2*) the total volume of the auditorium structure has not been held down so as to fall within desirable limits, as it might have been in many new designs; and (*3*) the past tendency to follow tradition in architectural design practice has usually made it mandatory to utilize corrective methods. There is one other reason that should not be overlooked. At the time speech and music were added to films, sound-absorbing devices were required for many existing structures having poor acoustical conditions. Perhaps from force of habit, reliance upon these devices has extended into the planning of new theaters. As a result, basic acoustical design has been overlooked as one of the sources of effective architecture.

It is not the purpose of this paper to discourage the use of acoustical materials for the treatment of motion picture theaters. Such materials may be required for the following special cases: namely, for new theaters having very large seating capacities; for existing theaters having fixed forms that produce objectionable sound reflections; and for both new and existing structures having excessive cubic-foot volumes per seat.

It is proposed to show, however, that more efficient and more economical theater structures can be built when basic acoustical requirements are coördinated with the other primary functions of theater planning. There are four outstanding reasons why this constructive approach will produce more successful results: (*1*) today the various elements affecting the control of sound in a design can be studied initially and planned correctly, with the result that very little or no acoustical material need be provided for the wall or ceiling surfaces; (*2*) minimum surface treatment makes for better acoustics, because (*a*) the proper character of reverberation and absorption can be assured, and (*b*) less critical conditions need finally be met in balancing the frequency absorption characteristic of the theater; (*3*) in cases where little or no acoustical material is required, the architect is at liberty to use ordinary, every-day materials, thereby making for greater flexibility in design; and (*4*) when a theater is efficiently planned in this way, substantial economies can be realized not only in acoustical treatment but also in other phases of theater planning.

From the architectural standpoint, planning for proper acoustical conditions in the initial design stage does not preclude the ability to obtain pleasing forms or surface finishes for the auditorium. Actually, creative design is more readily inspired by this approach.

ACOUSTICAL REQUIREMENTS

Two fundamental factors that must be considered as the first step in the functional acoustic planning of a motion picture theater are: (*1*) the preliminary outline or basic form of the auditorium, establishing its proportions of length, width, and height; and (*2*) the volume or cubical content of the auditorium structure in its relationship to the seating capacity.

Actual design practice indicates that the most efficient control of sound reflections and the best distribution of sound energy can usually be obtained in theater auditoriums where the ratios of width to length fall within the limits of 1 : 1.4 and 1 : 2.[2] When the the length becomes greater than twice the width, difficulties arise from a multiplicity of sound reflections occurring between the side wall surfaces. When the ratio of width to length is less than 1 : 1.4, the resulting design becomes an unfavorable one from the standpoints of proper sound distribution and vision. Furthermore, this design creates an unusally large rear wall, which is often a source of objectionable sound reflections.

The limits of ratios recommended above for the floor plan are not meant to suggest that a strictly rectangular outline must be adopted for the fundamental design. These ratios also apply to the average dimensions for the width and length of an irregular basic outline, such as one having a moderate splay in the preliminary form of the side walls or a generally nonsymmetrical arrangement of outline surfaces.

Establishing the ceiling height in its most practicable and best acoustical relationship to the horizontal dimensions is the next element to be considered in fundamental planning. Ceiling height is very important because it affects both the proportions and the structural volume of the auditorium.

From an architectural viewpoint, the determination of ceiling height is governed by three factors, namely: (*1*) sight-line requirements; (*2*) width of the light-beam and its projection angle to the screen; and (*3*) the general appearance of the auditorium.

From the acoustical standpoint, two other important factors should be included in the determination of ceiling height. These are: (*1*) the proper relationship of the ceiling height dimensions to the horizontal proportions; and (*2*) the optimum cubic-foot volume per seat required for a given design.

A ceiling-height ratio can not be fixed that will be adaptable to all designs. The best ratio can be established only by a study of the horizontal dimensions and by a preliminary analysis of the cubic-foot volume requirements for the initial control of reverberation time in a given design.

Excessive ceiling heights are commonly found today in auditorium design practice. The large structural volume per seat and the prolonged reverberation time resulting from this acoustical defect in theater planning have produced a need for corrective materials in many new designs.

The following study will show the variations in basic proportions and structural volume introduced in the planning of a theater auditorium seating 900 persons. This study will also show the reasons for these variations and how they can be minimized.

From an acoustical standpoint, the structural volume of an auditorium seating 900 persons should lie between 120 and 130 cubic-feet per seat. The factors affecting the determination of these limits are: (*1*) the optimum or best times of reverberation at different frequencies for reproduced sound,[3] and (*2*) the fixed and variable sound-absorption required to produce these times of reverberation.

Fixed absorption means the absorption provided by theater chairs, carpets, and interior surfaces of standard furred construction, finished in an ordinary manner. *Variable* absorption is the absorption normally provided by the audience. "Optimum" reverberation times are usually based on an audience condition approximating two-thirds of the house seating capacity.

The chairs constitute the major part of the fixed absorption for a theater initially planned to be acoustically functional in design. To ensure that the variable absorption, that is, the audience, will not effect a major change in the reverberation time, it is very important that these chairs be of an efficient upholstered type. The type commonly used for theater seating today is one having a leather-covered spring bottom and a fully padded mohair or tapestry-covered back. In the standard 20-inch width this chair has a sound absorption value equivalent to more than two-thirds that of the average person. The use of such a chair has been assumed for the following study.

VISUAL REQUIREMENTS

From the standpoint of vision the proportions and cubic-foot volumes of auditoriums vary for three different reasons. These are:

(*1*) The type of seating arrangement used in the horizontal dimension of the auditorium determined by the number of seats and aisles to be arranged across the width of the auditorium. Types in common use are (*a*) 14 seats with a wall aisle on either side of the seating area; (*b*) 2 aisles separating three banks of seats, the middle bank being 14 seats wide and the side banks against the walls being 7 seats wide; (*c*) 2 banks of 14 seats each separated by a single aisle having, in addition, 2 wall aisles; and (*d*) three banks of 14 seats, each separated by two aisles having, in addition, two wall aisles.

(*2*) The type of seating arrangement employed in the vertical dimension of the auditorium, such as (*a*) all seats on a single level; (*b*) a single general level of seats with the rear portion of the seating area somewhat elevated, with a cross-over separating the raised portion from the remainder, this type being commonly called a stadium design; (*c*) a modified stadium design in which the raised portion of seats in the rear is placed high enough so as to cover the cross-over mentioned in the *b* type; and (*d*) use of upper seating levels partially overhanging the seating area of the level below.[4]

(*3*) The inclination or inclinations of the floor for the main or orchestra level, such as (*a*) a steep downward inclination toward the screen; (*b*) a modified downward inclination toward the screen; (*c*) a modified downward and then upward inclination toward the screen; and (*d*) only a slight downward and then upward inclination toward the screen.

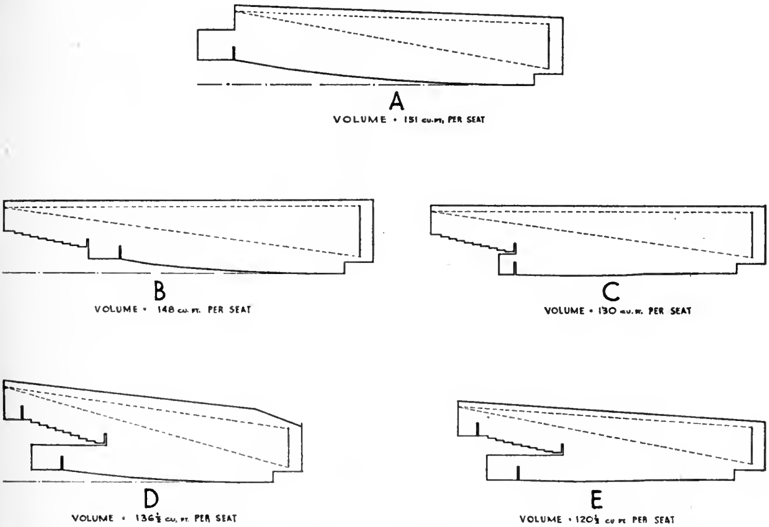

FIG. 1. Longitudinal sections for five values of cu.-ft. volumes per seat.

The degree of inclination of the floor in all cases is affected by the manner in which the seats are placed behind each other. When these seats are arranged in staggered fashion so that the center of any seat is always directly behind the dividing armblock of the preceding seat, the inclination of the floor may be reduced by almost one-half. Variations in floor inclination directly affect the height and inclination of the upper seating levels and the placing of the projection room, thereby the total height of the auditorium.

ANALYSIS OF TYPICAL DESIGNS

The study presented in Fig. 1 has been made to investigate which of the various possible auditorium designs would prove most efficient from both the visual and auditory standpoints, keeping in mind that economy in construction and architectural appearance are also important guiding factors. An auditorium seating 900 persons was selected for this study because this capacity has been found to answer the needs of the average motion picture theater and because a large proportion of the theaters now being erected approximate this capacity.[5]

It is interesting to note in the five theater designs shown that the structural volumes of the auditoriums vary from 108,450 to 134,100 cu.-ft. Furthermore, the required screen width varies from a minimum of $16^1/_2$ ft. to a maximum of 22 ft. due to the increases in maximum viewing distance. Such variations in design are not justified when the seating capacity is the same in all cases, as it is in all the designs here shown.

TABLE I

Design	Cu.-Ft. of Vol. per Seat	Max. Viewing Distance	Screen Width
A	151	104 ft.	20 ft.
B	148	119	22
C	130	105	20
D	$136^1/_2$	89	16 6 in.
E	$120^1/_2$	89	16 6

Ceiling heights have been kept down to a minimum in all five designs, and the seating arrangement in the horizontal dimension is the same in all cases, using the type having two aisles separating three banks of seats, the middle bank being fourteen seats wide and the side banks against the walls being seven seats wide. This arrangement in the horizontal dimension was selected for these studies because it is the most efficient plan for capacities of approximately 900 seats, requiring the least amount of aisle space and thereby effectively reducing the total volume for all the design studies.

Table I shows the resulting characteristics of the five designs shown in Fig. 1.

In the design types *A*, *B*, and *D* shown in Fig. 1, the slope of the orchestra floor is approximately what has been commonly used in past practice. This slope ordinarily does not afford a sufficiently unobstructed vision of the screen. To correct this defect, an increase in the slope in these types would result in a slight increase in the total volume where the volume is already excessive. However, visibility could also be improved in these designs by the use of a stagger system of seating which would effect a slight reduction in the total volume. This reduction would benefit design *D* only. Designs *A* and *B* would still provide excessive volume.

In designs *C* and *E* the staggered system of seating has been used for the lower seating areas. However, a non-staggered plan could also be used which would result in a floor that would pitch downward toward the screen approximately one foot more and pitch upward toward the screen in the front half of the floor to a point about level with the floor behind the seats farthest from the screen. The volume

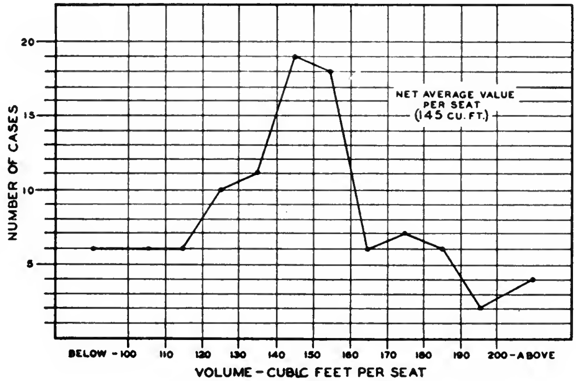

FIG. 2. Volume of 100 theaters seating 800–1000 persons.

added to designs *C* and *E* due to using a non-staggered plan would raise the total volume only a negligible amount.

The designs shown here have horizontal shape ratios varying from 1 : 1.65 in designs *D* and *E* to 1 : 2 in design *B*. Although all these horizontal ratios come within the acoustical limits heretofore recommended, it is particularly significant from the analyses that the proper vertical solution of a design not only results in good basic form but in most cases is the primary factor determining the efficient control of structural volume.

The data given in Fig. 2 provide an interesting parallel to this study and show the variations in volume per seat for one hundred theaters built recently, seating between 800 and 1000 persons. Seventy-one of this number are theaters of the balcony type, whereas only twenty-nine are single-floor houses. It is important to note that the peak of this curve for volume per seat *vs.* the number of cases lies between 140 and 160 cu.-ft., and that the net average value for the 100 cases is 145 cu.-ft. per seat. These data suggest that the greater percentage of present-day theater structures have excessive volumes per seat. This fact is in turn a direct indication of the lack of thought given to coördinating the auditory and visual requirements in fundamental planning, particularly since in the majority of these cases excessive volume was a result of excessive ceiling height.

The advantages to be gained from providing lower ceiling heights than have heretofore been found in general practice are: (*1*) a lower initial time of reverberation, resulting from a smaller volume per seat, (*2*) reduced surface areas to be treated acoustically, permitting more efficient control of sound by shaping the interior surfaces, and (*3*) economies realized in construction costs through the elimination, or reduction in quantity, of acoustic materials usually required, as well as through the use of smaller quantities of ordinary building material.

Two additional advantages result from the proper control of ceiling height and structural volume that should not be overlooked. One is that economies in the size and capacity of sound-reproducing systems are frequently made possible in theater auditoriums having reduced volumes per seat. The other advantage is that excessive power output is not required to compensate for high energy losses frequently caused by the use of acoustic materials on wall or ceiling surfaces.

DETAILED ACOUSTICAL FORM

The final phase of theater planning influencing both the acoustical condition and the architectural treatment is the detailed shaping or styling of the surfaces within the auditorium. This phase of planning is also very important because it functions with the proper determination of basic outline and structural volume to control the character of sound and the destination of sound reflections.

When an auditorium is to be used principally for direct speech or musical presentations it is desirable to plan and arrange the interior surfaces so as to aid in reinforcing the sound produced on the stage. In the motion picture theater, however, where sound is reproduced and adequate power can be provided electrically, the acoustical problem is not one of designing surfaces to gain reinforcement. Rather, the interior surfaces of this auditorium should be shaped and arranged so that they function to break up or disperse sound energy. This result can be accomplished most successfully in cases where favorable basic proportions are maintained and where the initial time of reverberation is efficiently controlled by the structural volume of the auditorium.

Irregularity of surfaces arranged to break up or disperse sound energy may take the form of angular or sloping sections, nonsymmetrical broken offsets, or convex projections. The size of each surface unit, its position and arrangement on a wall or ceiling, and its

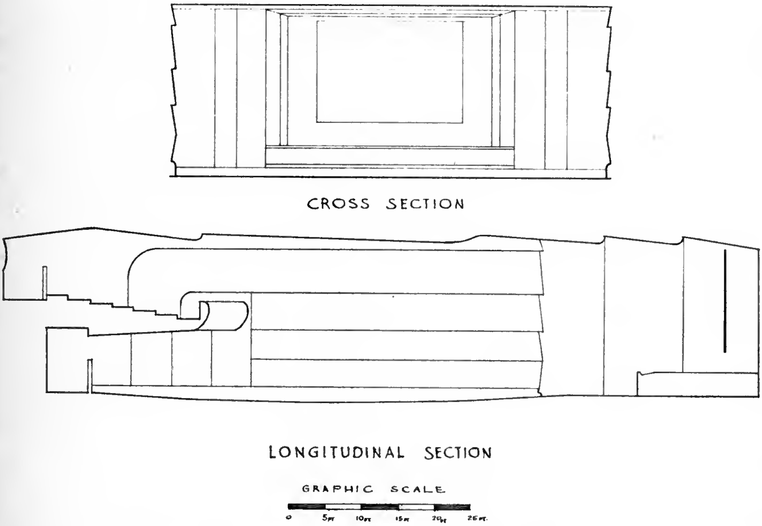

FIG. 3. Theater form showing angular surfaces for controlling sound reflection.

degree of projection from a horizontal or vertical line will depend upon the requirements for control of the destination and dispersion of sound reflections in the individual design. The surface of a major angular or convex projection may in turn be broken into smaller increments if required in special cases for dispersion of the very high frequencies.

AN EXAMPLE OF FUNCTIONAL PLANNING

Fig. 3 shows the longitudinal and cross-sectional views of a motion picture theater planned to seat 900 persons. This theater was recently designed in accordance with the principles outlined in this paper and is now under construction. The horizontal proportions of the auditorium are in the ratio of 1:1.79 and the structural volume is 123 cu.-ft. per seat. No sound-absorbing materials are used on either the wall or ceiling surfaces of this auditorium.

These surfaces are of furred construction and are finished in ordinary hard plaster. The side walls are composed of a series of horizontal angular or sloping sections which vary not only in width but also in their degree of projection from a vertical line. The rear wall area exposed to the incidence of sound is reduced to a minimum and a convex projection is incorporated in the design of the balcony rear wall. The ceiling surface, which takes the form of sloping planes joined by convex sections, is also designed, as are the wall surfaces, to control the destination and dispersion of sound reflections.

CONCLUSION

The authors have attempted to show in this paper that through the proper coördination of auditory, visual, and esthetic requirements, it is possible to plan more efficient and more economical theater structures than have in most cases been designed in the past.

In viewing the various outline forms presented in the foregoing study of typical designs, much is to be said in favor of plans having an upper level of seating. Such a plan usually offers the most efficient solution to the control of horizontal proportions, ceiling height, and volume per seat, assuming that the requirements for correct vision are properly incorporated in fundamental planning. This form of design also introduces a structural break-up at the rear of the auditorium that is initially helpful in controlling sound reflections.

The planning of detailed acoustical forms for the wall and ceiling surfaces offers unusual possibilities for the creation of new modes or styles in the esthetic treatment of the theater auditorium.[6,7] Unquestionably, many highly interesting and altogether unique designs will develop in future planning when the functions of the motion picture theater are in reality adopted as the inspiration for creative and efficient architecture.

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[6] "Acoustical Forms as Decoration," *Architectural Rev.* (London), **LXXXIII** (April, 1938), p. 207.
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DISCUSSION

MR. CRABTREE: This has been an ideal demonstration of a collaboration paper, and likewise, a demonstration of collaboration in presentation. I have long had in mind the idea that the Society should make definite recommendations for architects in regard to (*1*) architectural, (*2*) acoustical, and (*3*) optical features of motion picture theaters. It would seem to be in order to suggest that our President appoint a Theater Construction Committee, which could draw up definite recommendations. We already have the assurance of the architectural societies that after such recommendations have been fully discussed by our own organization they would then publish them and discuss them in their organizations, after which modifications could be made and the recommendations finally drawn up and circulated.

Where is this theater being constructed? If I am in that vicinity I will certainly make a point of going to see it.

MR. SCHLANGER: At Hamden, Conn.

MR. CRABTREE: Are there any in the vicinity of New York City that in any way approach or simulate this one?

MR. SCHLANGER: A theater recently completed in New York and similar in appearance to the small theater on the French Liner *Normandie* has a minimum auditorium height and a floor shape designed in accordance with the latest principles.

MR. POTWIN: In duplicating the architectural treatment of the original *Normandie* theater, the limitations placed on form made the acoustical design somewhat less flexible than the Hamden project. Nevertheless, it was possible to establish a favorable relationship between the structural volume and total seating of the auditorium and to shape and arrange wall and ceiling splays to promote the efficient control of sound reflections. On this basis a minimum amount of acoustical material was used, this material being confined to a very limited portion of the rear wall area.

MR. CRABTREE: In some theaters it is the practice to have intermissions and throw on the lights so one can see the beauty of the decorations; when the show is over they put on the lights again. In this style of theater it would seem almost imperative that the lights never be thrown on, unless a decorative system of color or spotlighting is provided. In other words, there is no question that if the white lights are thrown on, such a theater will appear somewhat like a barn.

MR. SCHLANGER: The simple architectural forms proposed would lend themselves effectively to color lighting.

Mr. Greene: Would it not be possible to use a very simple projected design upon the side walls between pictures, particularly if you are not going to raise the level of illumination high?

Mr. Schlanger: That is an excellent idea and has been done successfully. Certain types of cut outs can be made and placed in front of the light-sources. Variations in the images would make it possible to create more designs per year than could be achieved with any fixed forms of decoration. It can be done from the fascia of the mezzanine, from the projection room, or from hidden spots.

Mr. Crabtree: Perhaps kaleidoscopic changes could be used.

Mr. Schlanger: Yes, that has been thought of.

Mr. Crabtree: With regard to the aisle seats, when the seats are staggered, why is not the end seat in every alternate row made a little wider so the edges of the aisles will be straight?

Mr. Schlanger: If the seats are staggered there is a 10-inch difference between the seat and the aisle line.

Mr. Crabtree: Why not make the end seat about ten inches wider?

Mr. Schlanger: It would be out of proportion. However, we could compromise by making the seat three or four inches wider, so that the indentation would not be so obvious and the width of its arm block could also be increased.

Mr. Crabtree: Some theaters furnish seats for the hard-of-hearing. Why not reserve those seats for the corpulent?

Mr. Schlanger: No doubt those seats would be more comfortable for the extremely corpulent persons.

Mr. Crabtree: Do you think, Mr. Schlanger, that the data are sufficiently far along that the Society would be in position to make definite recommendations if we had a committee as suggested?

Mr. Schlanger: The committee could be formed, but it would have to work in close collaboration with the Projection Practice Committee and the Sound Committee.

Mr. Crabtree: The committees have been assembling data for some time past. Do we have enough data now, or do we have to do more experimental work?

Mr. Schlanger: Naturally, more research work is always in order. However, the new committee could compile its own data and report to the other committees as to what additional data are required from them in order to arrive at the proper conclusions.

Mr. Potwin: Unquestionably with the data now available it should be possible to arrive at definite standards for a number of phases of theater design and construction.

Mr. Crabtree: If the committee did nothing more than prevent the architects from placing lights right under one's nose, I think the effort would be well worth while.

CHARACTERISTICS OF FILM REPRODUCER SYSTEMS*

F. DURST AND E. J. SHORTT**

Summary.—*An analysis of sound-picture reproducing-system characteristics, including electrical and acoustical response data collected in the interest of determining the possibilities involved in obtaining an average characteristic for reproducing various film products with uniform response over several combinations of loud speaker equipment. With the aid of a curve tracer having a long-persistent cathode-ray screen, a photographic record was made of the characteristics, starting with various forms and amounts of equalization and exploring their relationship to the power-handling capacity of amplifiers. Following through the system, this record shows the characteristics of dividing networks under various conditions of load, and finally the acoustical response curves taken for comparison of the loud speaker equipments under study.*

The measurements of loud speaker combinations included various types of units, both permanent-magnet and energized, low-frequency horns ranging from open back baffles to folded horns with specially designed rear-loading compartment, and high-frequency multicellular horns of various configurations and constructional details.

After establishing the natural characteristics of the various equipments involved, careful listening tests were made over an extended period with samples of commercial prints and other recordings. A description follows of the difficulties and problems involved in an effort to obtain one overall characteristic, which would give satisfactory reproduction for all types of material. The final results are shown, with a short discussion of the methods for duplication in other equipment combinations, and conclude with recommendations for future designs and ratings.

Our interpretation of the goal of all organizations concerned with sound in the motion picture industry is to produce in every theater throughout the world the sounds considered desirable by the director or whoever is responsible for the production. In order to achieve this goal, it is obvious that the performance of the equipment must be so well understood, and so well standardized, that the director in his review room can hear his product as his customers will hear it.

It would be very convenient if we could standardize the performance of theater equipment by specifying that it should have a flat

*Presented at the 1938 Fall Meeting at Detroit, Mich.; received November 18, 1938.

**International Projector Corp., New York, N. Y.

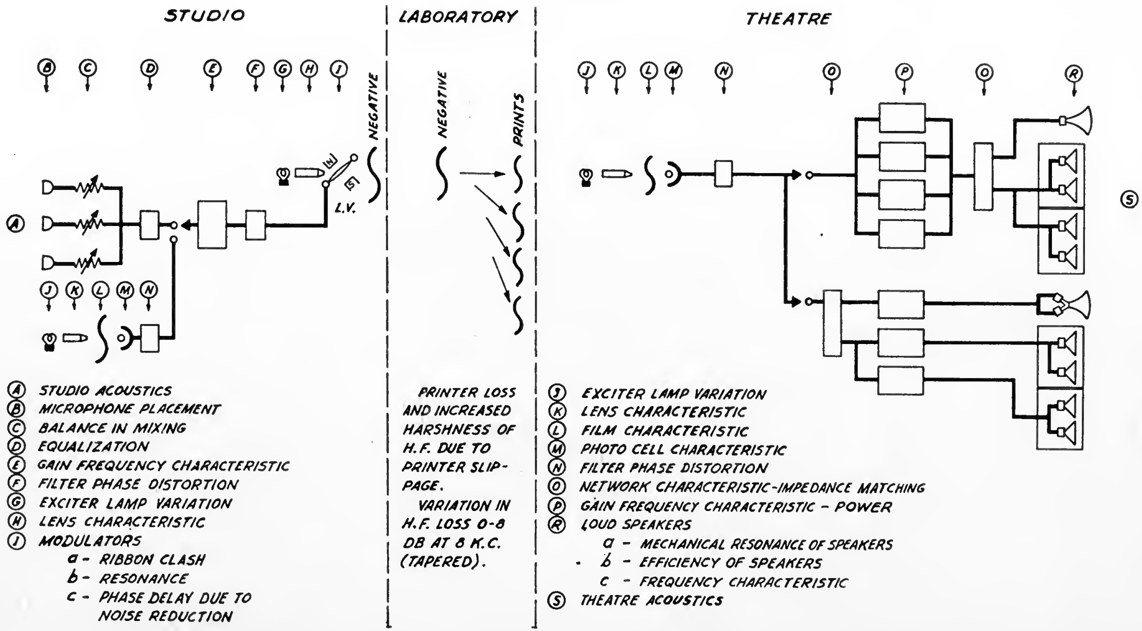

FIG. 1. Diagram of the various steps of the overall recording and reproducing process.

gain-frequency characteristic; that it should introduce no non-linear distortion at any and all levels; and that the distribution should be uniform to every seat in the theater. To adhere even approximately to such a standard would, however, work a hardship on both the theater owner and the producer. It would make the theater owner pay more than is necessary or desirable for him to pay for his equipment, and the best product that the producer could turn out would suffer in signal-to-noise ratio and the general acceptability of the quality.

By using film as a recording method, we accept a medium in which most of the annoyance from noise is concentrated in the high-frequency end of the spectrum. Most of the unpleasant distortion experienced in film reproduction also occurs at the same end of the frequency characteristic. Overall performance can, therefore, be improved by utilizing a reproducing system characteristic in which the response falls off at the high frequencies. If the producer is to use noise-reduction of the type most generally available, the low-frequency response of the reproducing system should be limited so that the listener will not be annoyed by hearing the operation of the noise-reduction device. With this objective in mind, it appears that the reproducing system characteristic should be standardized in such a way as to derive the maximum benefit in signal-to-noise ratio and in the reduction of undesirable distortion, considering at the same time the theater owner's interest in reduced cost of equipment. The Research Council of the Academy of Motion Picture Arts and Sciences, through the work of its Committee on Standardization, has established a basis for the desired attainment. It has brought out the desirability of certain characteristics that must be carefully considered from every angle. In certain instances, some of these characteristics might be misinterpreted unless proper consideration is given to the variable factors involved.

In Fig. 1 an effort has been made to indicate diagrammatically the various steps of the overall recording and reproducing process. It will be noted that variations exist throughout the entire chain. In the recording, consideration must be given to the acoustics of every set. Microphone placement has not only been a point of controversy, but has always been a factor of adjustment in the overall characteristic. The technic of mixing is another vital point which is entirely an adjustable feature. Determination of the proper amount of equalization and the general amplifier characteristics are additional

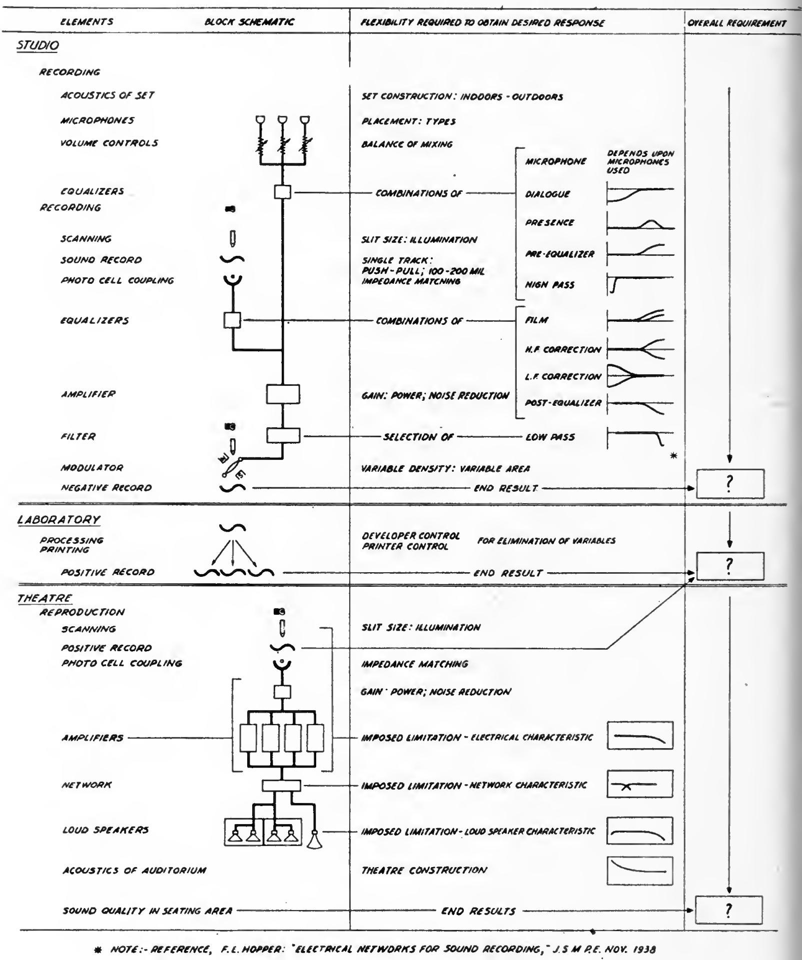

FIG. 2. Flexibility and limitations in recording and reproducing.

tools by which the recording personnel may adjust the final film characteristic to afford the most pleasing and dramatic reproduction in the theater.

In the laboratory is found a situation that contributes further to the variations in film characteristics. It is understood that for extreme conditions high-frequency losses may range from 0 to 8 db. at 8000 cycles. While a considerable proportion of this may be anticipated in the adjustment of recording characteristics, the power ratios for unanticipated variations are important, as they occur in the high-frequency range. Minimizing printer slippage is a very pertinent factor in any attempt to obtain clean and smooth high-end reproduction free from harshness.

The principal variables in reproducing systems may be grouped under the headings of flutter, electrical characteristics, loud speaker characteristics, and theater acoustical conditions. While the electrical characteristics have heretofore been established as extending from film input, including the optical system, to a resistance termination at the output of the amplifier, it is proposed to show here the inadequacy of such standards. Even measurements to voice-coil terminations are not a true indication of the influence of the horn equipment and the acoustical coupling on the aural response that is sold to our customers.

In our interest of standardization in the theater, extensive tests were made with various types of reproducing equipment. If systems generally are manufactured to conform to specified requirements, it must follow that similar results should be expected in the same acoustical environments. The differences actually encountered, and the reasons therefor, were indicative of the present necessity for most careful consideration of the entire program of standardization. While it was disturbing to note the large amount of variation existing in the characteristics of film products today, it is believed that the hope of remedying this situation lies in the establishment of specific end results to which recording, laboratory, and reproducing groups may work.

Fig. 2 shows a tabulation of an outline wherein desirable elements of flexibility are maintained for recording, in direct contrast to the present imposed limitations in the reproducing group.[1] In order to establish a coördinated program for overall betterment, each group must assume its rightful share of responsibility, and be permitted complete control over matters within its own jurisdiction.

In the laboratory, it is suggested that further studies be made, particularly in the interest of reducing the ill effects of printer slippage and of maintaining closer control of high-frequency losses. In the theater field, it is desirable, in the interest of our customers, to be

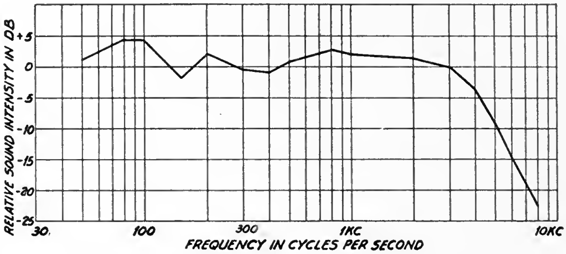

FIG. 3. Overall acoustic characteristic. (Adjusted for most pleasing response.)

allowed freedom from component or sectionalized specifications. End results, not details, are the logical basis for performance specifications.

As a general arrangement, our own tests indicated that a flat overall acoustic characteristic was not always the best. Fig. 3

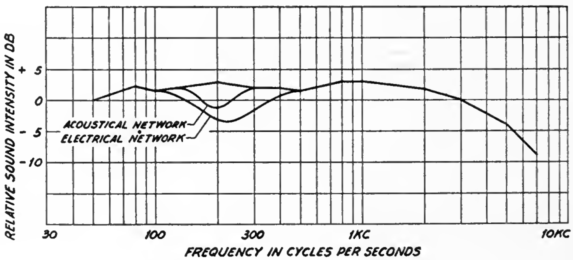

FIG. 4. Overall acoustic characteristic. (Showing acoustic and electrical modifications.)

shows the acoustic characteristic found to be most desirable in this particular theater.

When comparison was made with similar curves, obtained from a number of widely scattered theaters wherein the quality of reproduction has been approved by various technical groups, it was noted that a flat overall acoustic response did not qualify as giving the most pleasing reproduction. It was observed in general that the level in the region of 250 cycles was approximately 6 db. lower than the balance of the characteristics.

Upon analysis it was found that such a characteristic as shown in Fig. 2 creates an impression of roundness or fullness of the bass notes without causing too much heaviness in the region where chest tones become objectionable. From this the natural deductions would point to insufficient dialog equalization in recording, but such conclusions can not be established until the studio review room acoustic characteristics are known. Our analysis was made by direct *A-B* comparison with a system whose overall acoustical response was intentionally made flat through this region, as shown in Fig. 4. This figure shows also the effect of acoustic and electrical networks that may be used to alter the characteristic. In passing, it may be pointed out that the electrical network offers considerable advantage in that it can be made adjustable at very low cost.

It is interesting to observe how this "sway-back" characteristic has been obtained by using component parts which in themselves all have straight lines in the "sway-back" region. A study of these conditions was made, using the RCA curve tracer[2] provided through the courtesy of Mr. L. C. Hollands of the Radiotron Division of RCA in Harrison, N. J. Figs. 5, 6, and 7 show the measured acoustical characteristic of a system wherein the straight-line elements were connected together, each in a different manner. In each case a dividing network,[3] designed to operate between equal impedances, was used, and the high-frequency branch terminated by a load of the proper value. The measured electrical characteristics of this network have been plotted on each curve.

In Fig. 5 the low-frequency units were arranged to provide a matched impedance termination. In Fig. 6 the low-frequency load was changed so that the impedance ratio between the network and the load was 12 to 6. In Fig. 7 the low-frequency units were arranged so that the impedance ratio was 12 to 1.5. These figures show the effect of impedance mis-matching of the network and the loud speakers, and indicate the importance of impedance relationships and the definite necessity of providing standards that are more inclusive than the present form of electrical characteristics which are measured across resistance terminations at the amplifier output. The same overall response can be obtained by redesigns of the net-

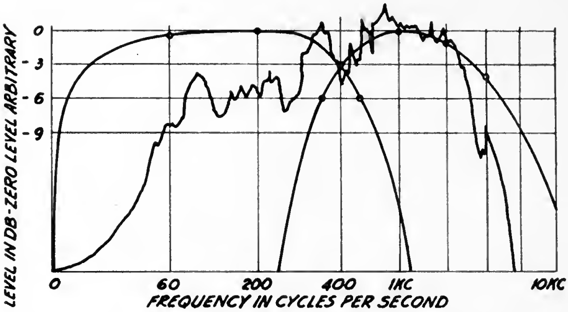

Fig. 5. Overall acoustic characteristic. (Network output 12 ohms, l.-f. load 12 ohms.)

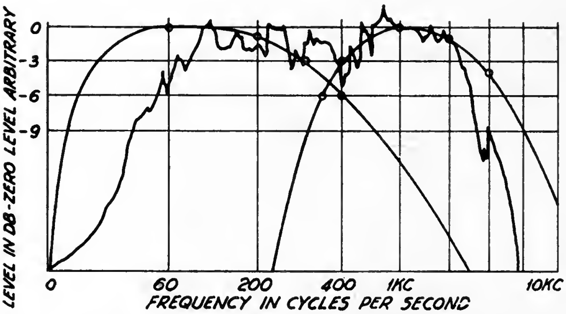

Fig. 6. Overall acoustic characteristic. (Network output 12 ohms, l.-f. load 6 ohms.)

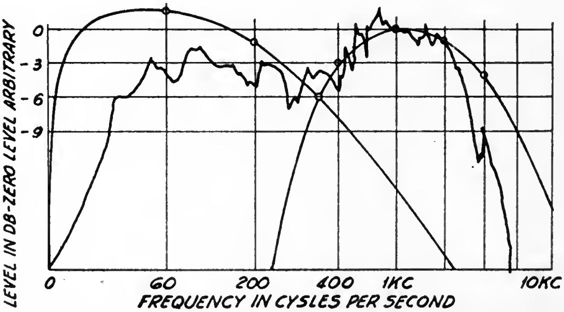

Fig. 7. Overall acoustic characteristic. (Network output 12 ohms, l.-f. load 1.5 ohms.)

work wherein the low-frequency branch is purposely made to have a higher impedance than the load into which it will work, or by reducing the voice-coil impedance of the low-frequency units.

In reviewing numerous acoustical response characteristics, variations in the upper end of the frequency spectrum were noted. The degree of tolerance for highs, the acoustical condition of the theater, the efficiency and response characteristics of the horns and loud speaker units, the effect of printer slippage, flutter, transient distortion resulting from too sharp cut-off filters, resonance conditions, or phase displacements may all have been contributing factors. Our tests disclosed positive differences in the response characteristics of various types of horn equipment.

A substantially flat system[4] is probably the most desirable type to use in the theater for reasons of economy of construction and simplification of general maintenance and tuning-up procedures. It is believed that specifications should not require complicated, costly, or critical designs in theater systems, particularly in view of the flexibility at present available in recording equipment. Furthermore, the cost of modifying recording systems to insert therein any desired characteristics and so maintain a desirable response in the theater would appear to be more economical for the industry as a whole due to the relative number of equipments involved.

Mention has previously been made of the necessity for maintaining the desired characteristic in the theater at any and all sound levels. It will be readily appreciated that this problem lies beyond the scope of this paper as it must include data on various types of amplifier design, involving triodes, beam power tubes, pentodes, with and without feed-back, and various types of feed-back circuits.

With regard to the relationship between power output and frequency response, a composite picture (Fig. 8) was made to show how a given amplifier characteristic was altered when that amplifier was pushed to its maximum output. In this particular instance, both ends of the frequency spectrum were initially raised about 6 db. above the 1000-cycle level. It will be noted that as the output of this amplifier was increased, the characteristic approached a "ceiling" and finally flattened out.

Fig. 9 shows the overdrive characteristic of the same amplifier for various frequencies. It will be observed that in this particular case the various curves show very little departure from each other Overdrive characteristics of another amplifier are shown in Fig. 10.

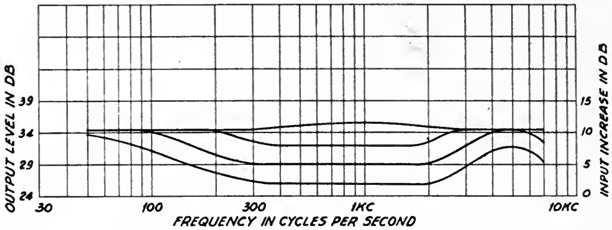

Fig. 8. Frequency response characteristic. (For various output levels.)

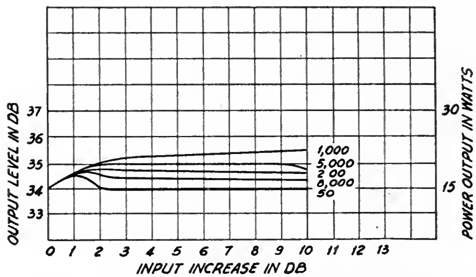

Fig. 9. Overdrive power-frequency characteristics. (Feed-back type.) Abscissas represent input increase in db. above rated load.

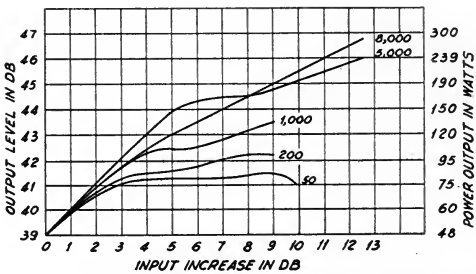

Fig. 10. Overdrive power-frequency characteristics. (Other types of theater amplifiers.) Abscissas represent input increase in db. above rated load.

Here it will be noted that as the input level is increased the low-frequency power output will not increase beyond its compression point, but at the higher frequencies it will continue to deliver more and more power. Under conditions of extreme overdrive, it may be expected that the power delivered by such an amplifier to the high-frequency units may be two to three times the amount that can be delivered to the low-frequency units. With this situation it would be particularly difficult to maintain any predetermined characteristic in a theater at all levels. With demands for increased power output to be provided in order to obtain the proper dramatic effect for various types of recordings, the tendency to overdrive amplifiers will inevitably grow. It appears, therefore, that standards for electrical power must give these factors further consideration.

With respect to power ratings and requirements,[5] attention is called to the block diagram of power amplifiers shown in Fig. 1. In the upper grouping, the amplifiers are paralleled ahead of the dividing network. The total wattage available would naturally be the algebraic sum of the individual amplifiers, and if no attenuation is provided in the dividing network both high- and low-frequency units will obtain that same total amount of power in their respective frequency ranges. In the lower group, where the dividing network is inserted ahead of the power amplifiers, it is common practice to use less power in the high-frequency branch by reason of the relative efficiencies of the high- and low-frequency loud speaker units. It has come to our attention that in discussions of power ratings for volume or seating requirements the total power in these two branches has been used, while in reality the maximum power does not exceed the amount that is diverted in the low-frequency branch alone. This illustration is made as further proof of the possibilities of misinterpretation of standards, and at the same time to indicate additional reasons for adopting acoustical standards throughout.

Without a doubt the feeling exists that acoustical measurements are meaningless, and that adequate test equipment is not now available. Comparison of our own work with the results obtained by others prevent our subscription to this theory in its entirety Improvements can and always will be made, but our work in this field has led us to believe that the present facilities provide a far more accurate indication of comparative response characteristics than any electrical measurements, particularly those of the spot-frequency variety.

In conclusion, it is evident that if our goal of standardized reproduction is to be achieved, investigations should be continued concerning the overall characteristics of reproducing systems. It is firmly believed that to carry this out completely, and to avoid the pitfalls of misinterpreting component part specifications, overall acoustical performance characteristics must be the criteria, and final acceptance tests and tune-up procedure must be based upon the use of the warble film and acoustical measurements, rather than sectionalized response tests. It is believed, in this connection, that the manufacturer should be allowed to decide the methods by which he will provide this final characteristic. Basically, the problem resolves into determining the best overall acoustical characteristic to which film producers can most readily and consistently adjust their product, at the same time keeping the cost to exhibitors at a minimum. Last but not least, it is essential that the listening facilities of both patrons in the theaters and the producers in their review rooms be made equivalent in order that they may obtain the same reactions.

Appreciation for his coöperation is expressed to Mr. J. B. Sherman of the RCA Radiotron Division, Harrison, N. J.

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[1] HOPPER, F. L.: "Electrical Networks for Sound Recording," *J. Soc. Mot. Pict. Eng.*, **XXXI** (Nov., 1938), p. 443.

[2] SHERMAN, J. B.: "An Audio-Frequency Curve Tracer," *Proc. I.R.E.*, **26** (June, 1938), No. 6, p. 700

[3] "Dividing Networks for Loud Speakers," Technical Bulletin (March 3, 1936), *Academy of Motion Picture Arts & Sciences*, Hollywood, Calif. (*cf.* Fig. *d*, p. 23).

[4] "Standard Electrical Characteristics," Technical Bulletin (June 8, 1937), *Academy of Motion Picture Arts & Sciences*, Hollywood, Calif. (*cf.* p. 3).

[5] "Procedure for Projecting 'Hi-Range' Prints in the Theater," Technical Bulletin (Nov. 24, 1937), *Academy of Motion Picture Arts & Sciences*, Hollywood, Calif. (*cf.* p. 5).

DISCUSSION

MR. GOLDSMITH: It is very obvious from these interesting curves which have been presented with unusual completeness that engineering compromises must be made in reproducing-equipment design in order to give reasonably uniform results in the theater for all types of product and on an economic basis. If the engineer were to specify "perfect" acoustics from zero cycles to the highest frequency which we hear, it would require that the theater be correct architecturally and acoustically, that the film be kept in immaculate condition to eliminate all film noises, and that other ideal conditions must hold. Inasmuch as the conditions which are encountered in actual practice can not approach the ideal, broad compromises must be made. It would be interesting to know whether these performance curves have been selected as a matter of engineering judgment, in

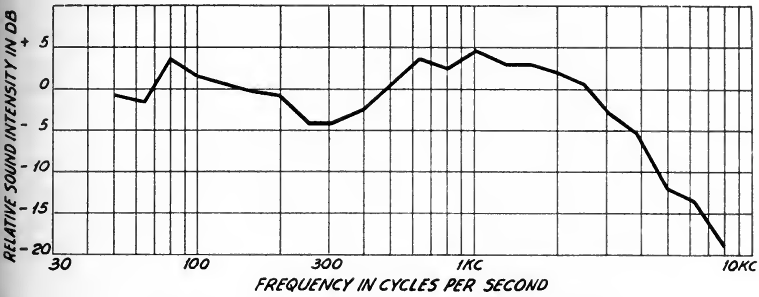

FIG. 11. Overall system acoustic characteristic.

view of economic conditions and considering what studios, theaters, and available recording and reproducing equipment could and would do, and what quality of sound film can reproduce without excessive maintenance.

MR. FRIEDL. Yes, it is true that these curves have been established with that practical consideration. In continuing this study of overall performance, the

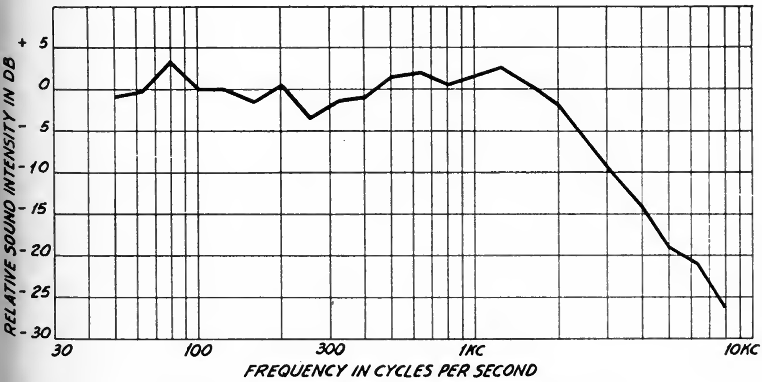

FIG. 12. Overall system acoustic characteristic.

end result—that is, bringing to the patron in the theater a better record or reproduction of the original—we urge more sincere coöperation of the recording, processing, and reproducing-equipment groups.

Just as the "Recommendations on Theater Sound Reproducing Equipment" (prepared by the Research Council of the Academy of Motion Picture Arts and Sciences), as read before the Society in Washington, outlined many desirable control factors, we would like to follow up and urge control factors in other links of the chain. At the present time the manufacturer of the theater equipment bears the responsibility of making acceptable to the patron the product delivered to the projection room in the film can. There is a certain latitude and limit to how much the projectionist or the sound reproducing equipment can compensate for recording and processing variations, particularly inasmuch as economies are regarded more consciously at the theater end of the chain than any place else in the industry. The composite chart that you saw at the beginning of the paper contains many more factors than we are able to discuss at this time.

MR GOLDSMITH: Referring to Fig. 1, what is meant by the "lens characteristic"? Do you mean the high-frequency loss which results from the relationship between the slit width and the length of the recorded wave on the film?

MR. DURST: Yes. This is a fixed loss. In addition, there are a number of other variables in most recording and reproducing systems. I have itemized a number of them in Fig. 2.

MR. GOLDSMITH: This is a paper of a helpful type because it shows how much work remains to be done in system improvement, and frankly gives details.

MR. DURST: It is an appeal in one respect to the industry to determine what type of characteristic is best, accept it as such, and lay it down in such a fashion that all concerned may work to it to their best advantage. It is very disturbing to find the very great differences that we do experience in the field. When a system is carefully tuned up for one picture, the quality of reproduction alters materially when the program is changed.

MR. ROBERTS: I am interested in the small column in Fig. 1 entitled "Laboratory." I would like a little more information on that one variation in high frequency. What does the 8-db. loss represent?

MR. DURST: The variations that may occur in attention of the high-frequency response characteristic range anywhere from 0 to 8 db.

MR. ROBERTS: From laboratory to laboratory?

MR. DURST: Yes, from laboratory to laboratory; or it is possible that it may vary to that extent in any one laboratory.

MR. ROBERTS: In any one reel?

MR. DURST: Not necessarily any one reel, but from one picture to another, or from one product to another.

MR. WOLF: I was shocked that there was such an overall variation, and that the system had so much response in the low end. I would like to know a little more about the theater where this response was measured. I assume you consider the response curve about as fine a one as you know of in your practical experience in the theater. Referring to the first curve, Fig. 3, the overall characteristic indicated rather uniform response except around the 150- to 400-cycle region, where it took a very decided dip for 4 or 5 db. and then went up again.

That is, I take it, an overall acoustic characteristic, measuring the output acoustically in the theater. Is that right?

MR. DURST: Yes.

MR. KELLOGG: It is theoretically impossible to make up by choice of frequency characteristic, for such factors as monaural pick-up, difference between microphone distance, and the impression of distance that the theater patron gets, and the fact that most sound is reproduced at unnaturally high levels. Nevertheless, there is unquestionably a frequency characteristic which on the average gives the best illusion, or, shall we say, makes the unnaturalness least conspicuous. This optimum characteristic no doubt depends on the factors just mentioned and others, but we do not know enough to figure it out. We must determine it by trial. It is simply a matter of taste.

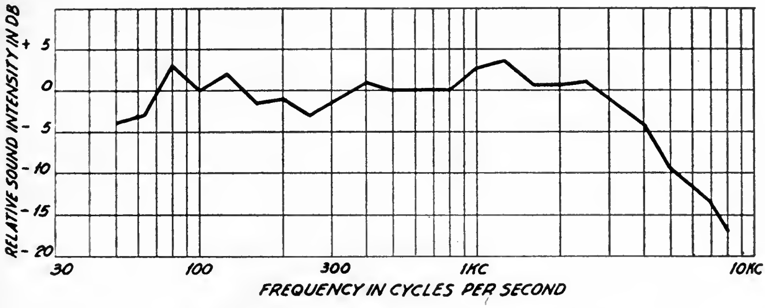

FIG. 13. Overall system acoustic characteristic.

MR. DURST: That is very true. In this instance a single microphone was used and the nodal points were explored to obtain readings of maximum intensity. It is, for purposes of comparison, approximately equivalent to what might otherwise have been obtained with a warble frequency and fixed microphones. The measurements were made in the auditorium approximately 40 feet from the speaker system.

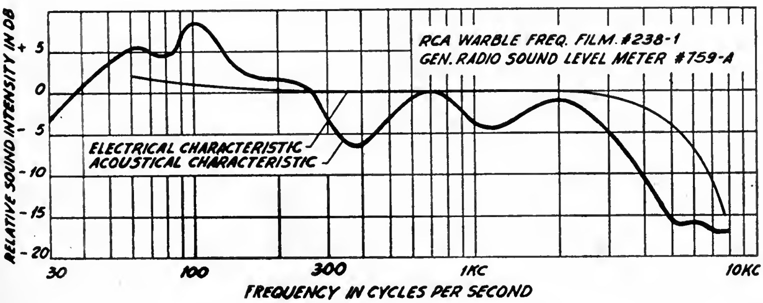

FIG. 14. Overall system acoustic characteristic (Paramount Theater, Los Angeles, Calif., ERPI Mirrophonic system; one *86* amplifier and two *87* amplifiers). Tests made by the Sound Department of Paramount Studio.

MR. WOLF: How did you integrate the sound without a warble tone or multiple microphones?

MR. DURST: By exploration of the wave pattern.

MR. WOLF: You picked one point that did not seem to have any low points?

MR. DURST: No, the microphone was moved until a maximum reading was obtained for each frequency reproduced from a standard constant-frequency film.

MR. WOLF: It was the average of several positions?

MR. DURST: No; it was the maximum reading obtained at any point in that vicinity. It was not a predetermined position, but the wave was explored for the maximum peak or signal.

MR. FRIEDL: As a matter of general interest, Figs. 11–16* show measurements in various theaters and also in a listening room, which were taken with a warble film and which would give comparable results. You will note a wide divergence of "end results," yet each of these represents a listening condition that is approved by a competent group of technical people.

MR. WOLF: I never saw a group that agreed.

MR. FRIEDL: A significant thing is the dip in the region of 200 to 400 cycles, because it is in this band that various levels of energy might make dialog as presently recorded sound very heavy. Such heaviness of dialog spoils naturalness and intelligibility.

MR. GOLDSMITH: A "booming" effect may result if the energy is not attenuated in that region.

MR. FRIEDL: These are all two-way systems. An interesting thing to note as you review dissertations and presentations on filter designs, is that they all refer to ideal designs. As a practical application, the designs are seldom used under the premises of the design, particularly with respect to impedance matching.

MR. DEPUE: How was the laboratory work checked up on these tests?

MR. DURST: Regular commercial prints were used for listening tests. Frequency measurements were taken with calibrated constant-frequency films and a warble film; also, oscillators were coupled to the input of the amplifier systems.

In the last illustration you will notice the absence of this dip of 250 cycles, that is, to the same extent as it appears in the other illustrations. This happens to be a studio listening room. The point I wish to bring out in this connection is that I believe it is important to the best interests of all concerned that the manufacturers of theater equipment know what type of characteristic the producers are using in listening to their products. If we ever hope to make it possible for theater customers to hear the same things that the producers hear in their review rooms, we must have the same type of characteristic. The example given shows a decided difference from measured theater characteristics. If that is a desired characteristic or a necessary one for recording purposes, then all theaters should have the same. However, we find it quite the contrary in reproducing a wide number of film products. Filling in this dip does not give a most pleasing result.

MR. HOVEY: Is that caused by acoustic conditions in the theater? I should think the first step would be to correct that.

MR. DURST: The necessity of a dip in the region of 250 cycles is general, because of variations in recording practice with respect to dialog equalization. It is usually created in the reproducing characteristic by impedance mismatching or in the design of the low-frequency horns. It may be corrected by acoustical networks within certain limits.

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* With respect to Figs. 14, 15, and 16, appreciation for his coöperation is expressed to Mr. L. Ryder, Director of Recording, Paramount Pictures, Inc., Hollywood, Calif.

MR. FRIEDL: It can also be done electrically with more flexibility, provided we agree on what we are trying to achieve. There are several ways of doing it. We are all striving for uniformity in the presentation of our product.

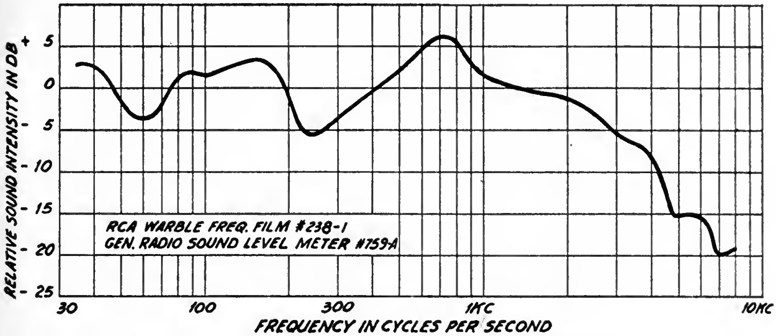

FIG. 15. Overall system acoustic characteristic (Paramount Studio Sound Theater). Tests made by the Sound Department of Paramount Studio.

If we agree on what we want in the end, the studios will work coöperatively, and we should achieve the uniformity we desire.

MR. HOVEY: The statement was made several times that this or that sound was satisfactory or good. I can not help wondering to what extent a state of

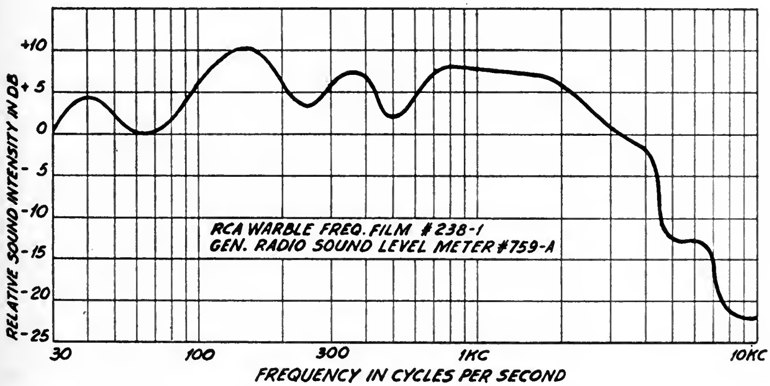

FIG. 16. Overall system acoustic characteristic (Paramount Studio Projection Room). Tests made by the Sound Department of Paramount Studios.

tone paralysis may enter into that. It has been my experience that when an installation is made, those who are in contact with it daily become, after a month or so, so sound paralyzed that even the most terrible sound seems all right to them. I wonder whether that is the experience of other engineers.

MR. FRANK: I might explain that by a story I have heard often about the Board of Directors of the old Victor Talking Machine Company. When the orthophonic phonograph was demonstrated to them, they said, "That is wonderful, but it does not sound like a phonograph." It certainly has been our experience in theater work that the longer we listen to sound quality, irrespective of what the quality is, the better we think it is, and it is only by direct comparison and technical analysis that we begin to tell whether we are hearing what is supposed to be "good" sound or not.

MR. HOVEY: Recently I witnessed an installation of what I considered unusually good sound, and the theater manager ordered it out and replaced it with an outfit about five years old because, he said, it sounded better. It would be interesting to know whether that is an unusual case or whether other engineers run into the same thing.

MR. GOLDSMITH: That is an unfortunately frequent case. In the early days of radio, there was once a controversy between the advocates of long horns and short horns, respectively, for loud speakers, the "long horns" stating that the loud booming response with practically no high frequency was admirable and that it was what they termed mellow and soothing; whereas the other group, the "short horns," insisted on suppression of low frequencies and emphasis on high frequencies until the result was a thin squeak. No agreement was ever reached between those two groups because each became confirmed in its conviction that its customary preference constituted ideal reproduction. There was no major progress until response curves were used as a guide to design.

MR. FRIEDL: Another analogy might be that although there are some really good radios on the market today and high-quality radio programs are broadcast, the reproduction in the average home is poor because the sound is unbalanced by inaccurate adjustment of the tone control.

We all desire to standardize theater equipment for high-quality reproduction. The companies interested in the production of films spend a lot of money to this end. It is their desire to control the quality without recommending the use of variable adjustments that would permit the projectionist to distort the balance of the frequency range with an adjustable tone control. Unless we can agree on a certain quality of performance and consistently control the variables that would disturb that quality, we are forced to admit that "good quality" is a matter of personal judgment. Thus: If a man who is running that theater wants to have it sound a certain way, a way that he feels satisfies his patrons, he will demand the same facilities as he uses in his home with his radio. After all, in the dubbing of a film there is a man who sits in a room where he listens and judges what he thinks is good reproduction. He might satisfy the directors; he might satisfy the producer and the studio personnel that he has done a good job. At the same time the deadline of the picture might be approaching or the budget running out, and that picture is going out to make money. The people in the theater end of the chain are supposed to correct all those ills. We hope the studio recording can be perfected to the point where we can eliminate that variable.

MR. WOLF: The only criticism I would have to the overall response curve is that it shows too many factors, represents so many things that you do not know what is at fault.

Where do you think the weakest link now exists? Is it in the theater acoustics or in the electrical system? Or is it still in the loud speaker system?

MR. DURST: I believe that by careful manipulation of the characteristics, a given theater can be made to sound fairly satisfactory. Granted there are acoustical conditions that can not be compensated for electrically, as a general average one can make equipment sound right. But, if what is put on the film is not designed to be reproduced over that characteristic, it never will sound right. If a given theater is adjusted so that it sounds right for one film, the next one that comes into that house may be altogether different, and the service engineer has to go back and readjust or retune the entire system to satisfy his customers.

MR. WOLF: I still believe in the theory of the uniform characteristic in every element of the circuit from the microphone all the way through. A great many are getting away from that, thinking perhaps they can have compensating influences in each element of the system, but I still think we will not get a uniform response until in the theater, we have uniformity in every piece of equipment.

MR. DURST: I do not believe that is altogether desirable from the recording standpoint. Producers have such diversity of story material, and in their effort to reproduce the true dramatic effect, it would be rather difficult for them to have any fixed characterics, but I do believe that they must all work to an established end result. In like manner, I think the manufacturer of reproducing equipment should work to that same end result. It should be up to him to decide whether he wants to taper off his horn or whether he wants to change his slit size. If he can obtain a better signal-to-noise ratio and better overall compensation by one means or the other, I think it should be left to his discretion.

MR. STROCK: I should like to say one word about all these variables that enter into the problem. In our own particular case, and I know it to be true in several of the other studios, what we do shows up only in what comes out of the horn in the theater, and we are continually checking the product that we listen to in our own theater from day to day against what it sounds like in the field. Of course, you have to define a "representative theater," but nevertheless it is a good theater that is generally accepted as giving good sound. After all, when you come down to saying whether sound is good or whether it is bad, our own definition of good sound is sound that comes out of a loud speaker that is natural and tempered by the perspective of what is going on in the picture; meaning that if you have a full head close-up of somebody saying some very touching and endearing words, you have to temper that by the size of the picture and the dramatics of the story. Nevertheless, good sound is natural sound.

MR. WOLF: What you are after is a facsimile of the original in most cases.

MR. STROCK: Not forgetting the picture.

SOME PRACTICAL ACCESSORIES FOR MOTION PICTURE RECORDING*

R. O. STROCK**

Summary.—*The addition of practical operational accessories to standard recording channels as purchased expedites operation and saves time. At the Eastern Service Studios a number of such accessories have been designed and are described briefly. It is the purpose of this paper to show what has been done at one studio in the hope that it may be of some interest and help to others who are engaged in recording work.*

Included in the equipment are the following items: A small collapsible, portable microphone boom for location work; a special microphone suspension to prevent mechanical noises from getting into the recording system; a small mixer console for stage work, to permit the mixer man to operate close to the scene of action; an accurate illumination meter, using a microammeter, for setting and checking the recording machine exposure; a compact re-recording mixer console equipped with equalizers, effect filters, amplifiers, and attenuators; a projected volume indicator and footage counter for use in re-recording rooms; a film playback adapter for use on a Western Electric film machine for location use; playback horns for stage and location use; and an air-brush adaptation for blooping re-recording tracks.

When recording channels are purchased they usually consist of several separate units following the general order and layout of the electrical schematic. The addition of certain practical operational accessories to these standard recording channels expedites operation and saves time. At the Eastern Service Studios a number of such accessories have been designed which are briefly described and illustrated herein. It is the purpose of this paper to show what has been done in this studio in the hope that it may be of some interest and help to others engaged in recording.

Portable Microphone Booms.—The first unit to be described is a small portable, collapsible microphone boom. For regular studio use we have the standard, medium, and large types of Mole-Richardson booms. There are many instances where a small microphone suspension is needed such as in pick-ups from a theater stage, small attic rooms, narrow hallways, *etc.* We have two types, one a very simple

* Presented at the 1938 Fall Meeting at Detroit, Mich.; received October 17, 1938.

** Eastern Service Studios, Long Island City, N. Y.

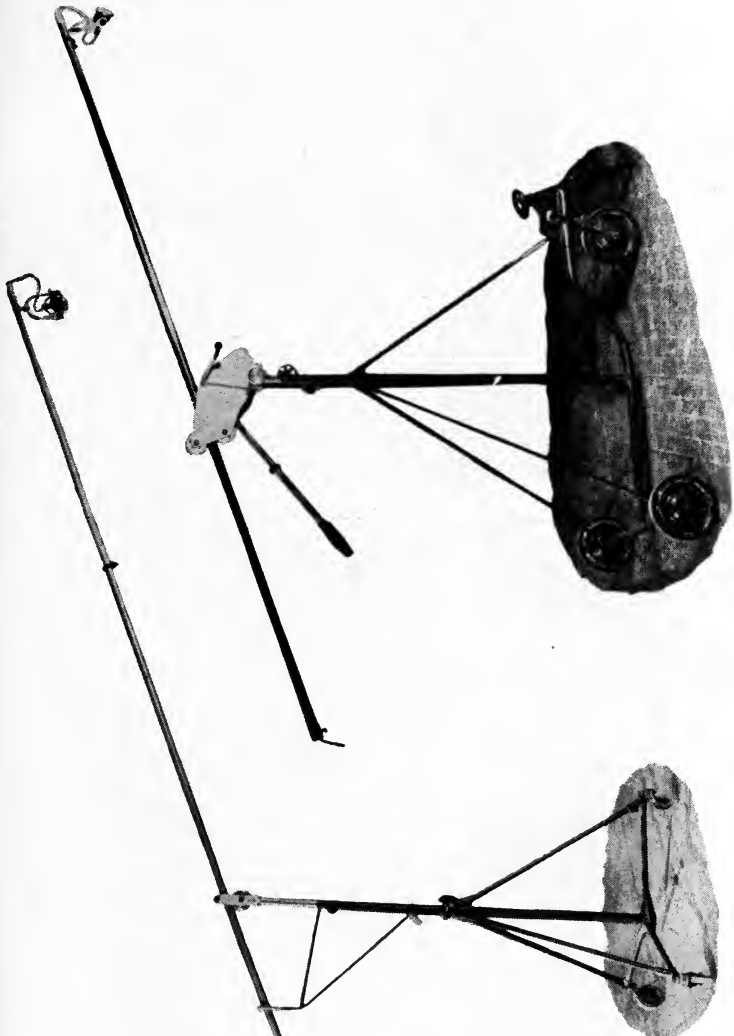

FIG. 1. Portable collapsible microphone boom.

FIG. 2. General purpose boom.

one and the other a bit more versatile but not complicated. The smaller one (Fig. 1) consists merely of two telescoping duralumin rods mounted on a yoke which is equipped to fit in a standard light stand. This is, of course, useful only for stationary shots. The general purpose small boom is shown in Fig. 2. It may be extended or retracted, lowered or raised noiselessly at will, and it is easily moved for trucking shots. It may be locked in any position by friction by the handle. It is easily dismantled for packing in the location trucks. Its total weight is about fifty pounds.

FIG. 3. (*Upper*) Standard microphone mounting.

FIG. 4. (*Lower*) Showing flexible lead between microphone boom cable and the microphone.

Microphone Suspensions.—Most microphones are subject to the disadvantage of converting mechanical shocks into electrical noises in the recording systems. The standard mountings (Fig. 3) for either the Western Electric *630* or *618* microphones do not provide for any shock absorbing medium between the microphone and the boom or support. Such an absorbing medium is necessary when moving the microphone rapidly during the recording. Microphone noise is largely due to mechanical noises within the boom being transmitted directly into the microphone. To help eliminate this direct transmission, a short flexible lead (Fig. 4) is provided between the boom cable and the microphone. This connector is usually made from telephone tinsel or other very flexible stranded wire and has proved very satisfactory. A retaining cord must be provided to avoid excess strain on the fragile tinsel leads.

The microphones are supported in several different types of mountings all of which are satisfactory from a noise standpoint. Shown in Fig. 4 is the mounting for the *630* microphone. Note that the microphone is held in a yoke which is supported by standard Lord rubber mountings for reducing mechanical shock to the microphone

FIG. 5. (*Upper*) Mounting for *618* microphone.
FIG. 6. (*Lower*) Mounting for *618* or *630* microphone.

proper. In Fig. 5 is the mounting for the *618* microphone. In this mounting the shock is absorbed by supporting the microphone in a ring held by elastic. In Fig. 6 is shown a mounting which may be adapted to either the *618* or the *630* microphone. All these mountings, when used in conjunction with the flexible connector, prevent mechanical noise from being transferred to the electrical recording system.

Mixer Consoles.—Most present-day motion picture voice recording is monitored and mixed from a small mixing console which can be placed close to the set or scene of action, as shown in Fig. 7. The advantages of the mixer man's being in close contact with the director and the cameraman and in such a position that he can at all times watch the action far outweighs the disadvantages, if any, of headphone monitoring. No loud speaker in a small monitor booth can equal theater characteristics. The mixer man must make a personal judgment between what he is hearing when recording and what he

FIG. 7. Small mixing console on set.

will hear in the finished sound in a theater. Therefore, he might just as well make his judgment between what he hears in the loud speaker compared to the theater horns as between a booth loud speaker and the theater horns.

Mixer consoles, as used at Eastern Service Studios, are as shown in Fig. 7. They are small and can be moved easily when the company moves to another set. A three-position mixer is used and has been found adequate for most ordinary picture work. The mixer is connected to an amplifier, and the combination is known as an ERPI *RA-150*, which is battery operated and uses electronic mixing.

The mixer is so connected that if it is necessary to move quickly to a nearby set for a pick-up shot, the mixer panel can be easily removed and carried to the location without moving the console. It is possible to work the mixer 300 feet away from its amplifier.

On the panel board (Fig. 7) are shown the mixer, the telephone for interstage communication, and the signal lights for the recording system. The amplifier is housed in one end of the console and the battery equipment in the other. In the rear is space for storing the microphone cable.

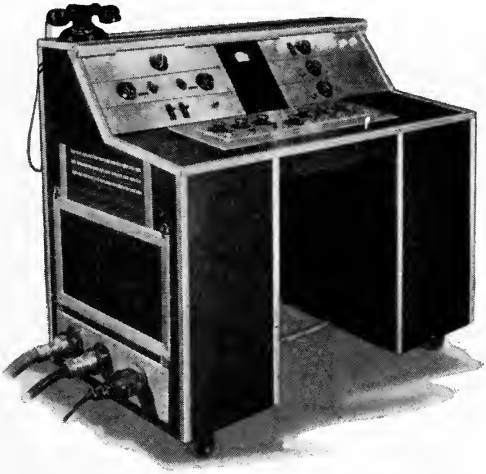

FIG. 8. General layout of re-recording mixer console.

Projected Volume Indicator and Footage Counter for Use in Re-Recording.—The next unit to be described is the re-recording mixer console. This is very similar to the stage pick-up unit but is used for the re-recording process and is a bit more complicated. Fig. 8 shows its general layout. The circuits are brought from the re-recording machines through the jack field on the end of the table and then through the mixer and into a main amplifier. The amplifier is a-c. operated and is mounted on a swinging hinge so it may be swung outward for changing tubes or for servicing. Equalizers, attenuators, telephone effect filters, high- and low-pass cut-off filters, and a universal high- and low-frequency equalizer are provided so they may be inserted in any desired mixer position for changing the circuit frequency characteristics. A level control is provided on the output of the amplifier for controlling general level into the recording rooms.

Re-recording mixer men must first be artists, and second engineers,

Fig. 9. Projected volume indicator and footage counter.

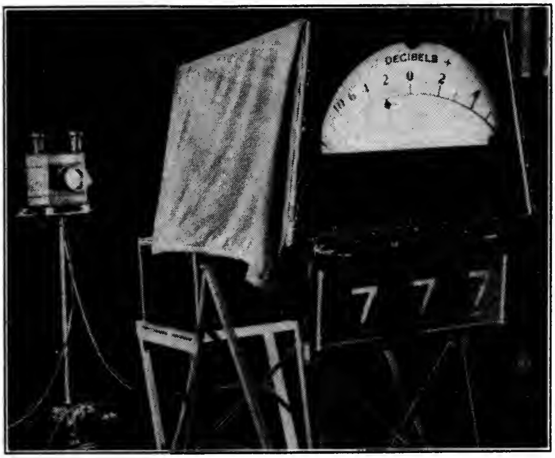

Fig. 10. Showing arrangement of volume indicator and footage counter.

for in the mixing of many sound-tracks into a composite effect, recognition must be made of cueing, levels, artistic effect required by the director, perspective, and geography of the scene at hand. In order to aid the mixer man in doing so many things at one time, and in addition, not divert his attention from the picture, a projected volume indicator and footage counter has been built. As can be seen in Fig. 9,

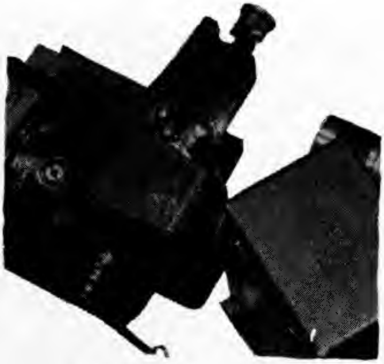

FIG. 11. Footage counter.

the volume indicator and footage counter images are projected to a considerable size directly below the picture, so it is possible for the mixer to see with ease the footage for spotting cues, the sound volume, and the picture, all at the same time. If the volume indicator is used on the re-recording table it is very difficult and tiring to try to change the line of sight between the picture and the volume indicator rapidly. This unit has been a great help in re-recording.

FIG 12. Illumination meter.

Fig. 10 shows how simply this has been accomplished. The volume indicator is placed on the rear of a standard Keystone postcard projector and its image projected upon the screen. Two 100-watt lamps are used to illuminate the meter and no difficulty from heating is experienced, the lamps remaining on for several days at a time during long re-recording sessions.

The footage counter also is shown in Fig. 10. A special Veeder counter, with the numbers upside down, was mounted on an interlocked motor which is electrically connected to the recording dis-

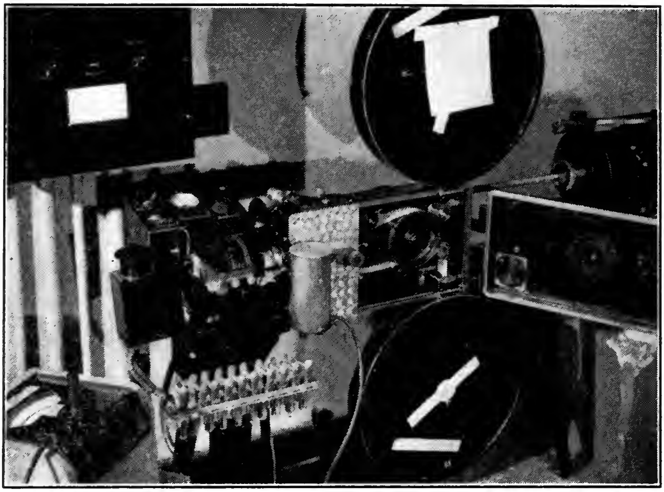

Fig. 13. Recording machine with illumination meter attached.

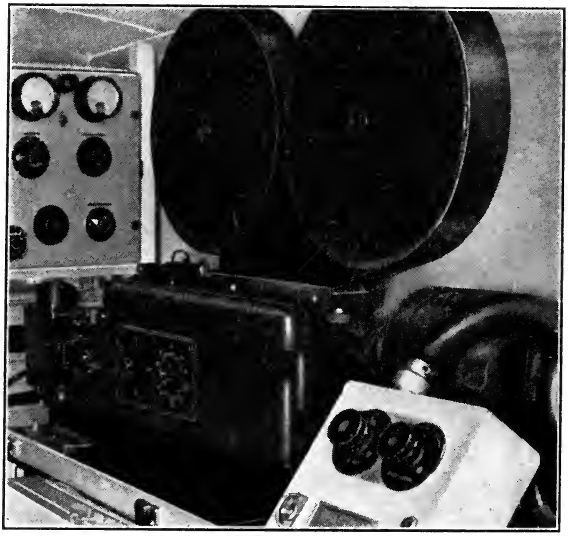

Fig. 14. Recording machine before being adapted for playback.

tributor system the same as the recording and projection motors. The counter (Fig. 11) is illuminated by a 100-watt screw-base lamp with a condenser lens, and its image is projected upon a screen directly

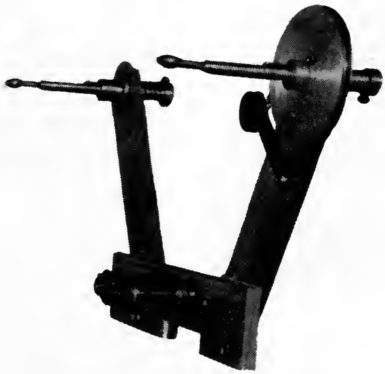

FIG. 15. Playback adapter.

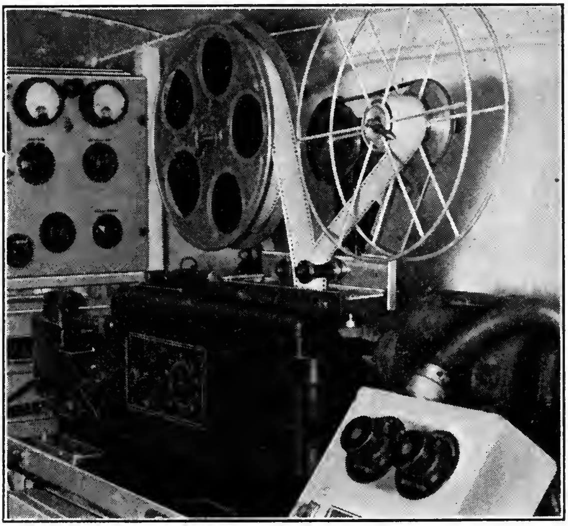

FIG. 16. Playback adapter unit mounted on the machine.

below the volume indicator image (Fig. 10). The counter is easily reset and the volume indicator meter can be removed easily for replacement if necessary.

Illumination Meter for Checking Recording Machine Exposure.—In order to control the quality of sound recording it is necessary to maintain the recording machine exposures very accurately. Ordinary ammeters in the lamp circuit can not be read accurately enough to control the illumination within the necessary limits. Our standards require that the negative exposure be held within 0.05 in visual diffuse density. In order to hold the exposure within this rather narrow limit an accurate illumination meter was designed, as shown in Fig. 12. It consists of a plate which can be clamped quickly on the recording machine (Fig. 13). On the plate is mounted a metallic mirror which intercepts the light-beam just in front of the film and reflects the light into a photoelectric cell mounted in the round container on the front of the plate. The photoelectric cell has low sensitivity and

FIG. 17. Blooper.

FIG. 18. Another design of blooper.

is operated in the very stable portion of its sensitivity curve. It is connected to a 0-2μa Rawson microammeter and a normal current of approximately 0.75 microampere flows through the photoelectric cell. An exposure test is made for the particular emulsion in use and the correct density is determined in the usual manner from the negative H&D curve, after which a curve is made plotting density against microammeter readings, and the correct reading obtained. The illumination can be checked very rapidly by the use of this instrument and it is the usual procedure to check the exposure after every five takes. The instrument has been in use for several years and has proved very satisfactory, showing that the exposure can be maintained within the 0.05 density limits for months at a time.

Film Playbacks for Location Trucks.—It is often necessary to use film playbacks on location. The standard *D86715* Western Electric recording machine for location trucks is not equipped for playbacks. One of our machines in a location truck has been modified so that it can be used for either recording or playback purposes. In Fig. 14 is shown the recording machine before adapting it to playback. In Fig. 15 is shown the adapter. It consists of two arms for holding the supply and take-up reels and a means of driving it. In Fig. 16 the unit is shown mounted on the machine. A photoelectric cell is placed inside the recording sprocket and its output fed through a low-capacity cable to the regular split-beam monitoring unit, whose output is fed through the recording amplifiers and then into a playback horn. The unit can be removed and the machine returned to the recording condition in only a few minutes by removing two thumb-screws and removing the drive belt. The film can be rewound without removing the reels from the machine.

FIG. 19. Blooper of Fig. 18 with plate in place over film.

Air-Brush for Blooping.—In re-recording it is very necessary that bloops caused by splices be entirely eliminated. We use two types of "bloopers." One is as shown in Fig. 17, described by E. I. Sponable some time ago. This unit does the job very well. We have designed another unit that does the job equally well and is shown in Fig. 18. It consists of a block and template with centering pins and an air-brush for spraying the blooping ink on the template and the splice. Rapid drying ink is used. In Fig. 19 is shown the plate in place over the film. The template provides assurance that the edges of the bloop are sharp and, because the back of the film is pressed against rubber, good contact can be obtained between the template and the film. The design of the bloop patch is the same as the one described by Sponable. This unit can be constructed very easily, and a standard air-brush and tank are used.

The accessories described above have been a great help to this studio in its operation. It is hoped that others engaged in recording work will describe their many operational accessories from time to time in the JOURNAL.

Credit for the design and suggestions on the units just described is given to our recording staff in general and in particular to Dan Doncaster, our mechanic, who built and suggested many of the items.

THE LIGHTING OF MOTION PICTURE THEATER AUDITORIUMS*

F. M. FALGE AND W. D. RIDDLE**

Summary.—*Here and there a theater is planned with lighting features utilizing the fundamental principles that have been expounded on many occasions. In too many cases, however, interior lighting has lagged far behind exterior lighting for advertising, and owner and public alike have suffered. In too many cases, also, the theater falls far short of complementing the attractive scenes so well projected upon the screen.*

This paper reiterates the aims and advantages of proper lighting, and outlines the problem of locating, and controlling the lighting properly so that it will be comfortable and pleasing and an aid, psychologically.

Because of the almost infinite variation in design for theater auditoriums, with influences all the way from cave-dwellers to the ultramodern, and from the bottom of the sea to the sky above, practically every conceivable lighting method or idea has been called into play. Unquestionably architectural influence and decorative character have played a far more important part than the provision of light for comfortable and safe seeing.

The purposes of auditorium lighting are several and varied. In this investigation we are chiefly concerned from the viewpoint of comfortable vision and how to provide for it while serving these other requirements as well. This paper presents experimental data applying to a limited range of auditorium conditions. Although by no means a comprehensive treatment, it does offer a little additional information in a field where quantitative studies have been badly needed.

In order to visualize the complete picture of the objectives of auditorium lighting as set forth on previous occasions[1,2,3,4] they are repeated here:

(*1*) *Comfortable Vision.*—Eyes should be aided in their adjustment to darkened interiors and made comfortable by adhering to brightness standards.

(*2*) *Convenience.*—People must see quickly and easily to locate seats, without annoyance to others and without individual usher service which is expensive.

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*Presented at the 1938 Fall Meeting at Detroit, Mich.; received October 19, 1938.

**General Electric Company, Cleveland, Ohio.

(3) *Safety.*—Light dispels the fears that patrons may feel in darkened theaters. Accidents and accident costs are also reduced.

(4) *Program Appreciation.*—Decorative lighting provides a "plus" value that secures a favorable psychological reaction, and is of aid in counteracting seasonal temperature complexes. It aids special programs or holiday celebrations and creates a mood that aids program appreciation. It makes people look better and feel better.

(5) *Cleanliness.*—Light reveals a clean theater.

As previously stated, it is desirable to give consideration to all these factors in lighting an auditorium, but this paper will deal primarily with the one factor of ocular comfort as affected by the quantity and direction of light and the location of sources, their brightness and that of the several parts of the visual field.

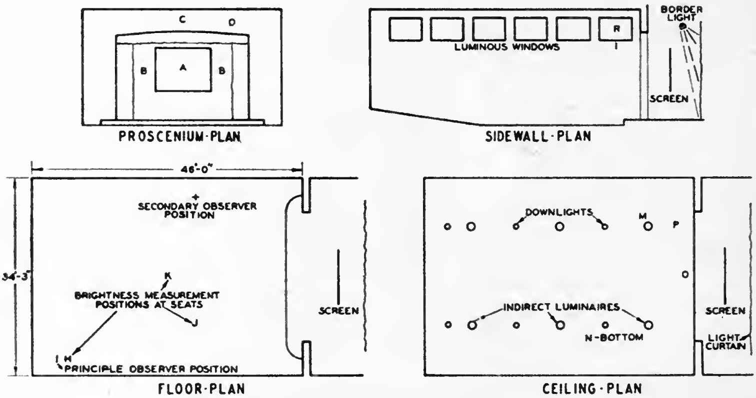

FIG. 1. Auditorium layout with illumination systems used in tests. Letters refer to locations measured for brightness.

In the past we were handicapped by the lack of a convenient and inexpensive brightness meter that would permit ready recording and analysis of brightness conditions throughout an auditorium as viewed from any given seat. Some years ago the SMPE Theater Lighting Committee[10] devoted much study to the characteristics of such an instrument. This need has been expressed in many Committee reports from time to time. Today, this need is met by the Luckiesh-Taylor brightness meter.[5] It is possible to focus the instrument on a very small spot, and accurately determine the brightness of that spot over a range exceeding that found in theaters. The brightness is read directly in candle-power per square-inch, or in the more readily comprehended foot-lambert.

The foot-lambert may be defined simply as the brightness of a perfect diffuser emitting one lumen per square-foot. Or, assuming perfect diffusion, the foot-lambert is the brightness resulting from the product of foot-candles illuminating a surface multiplied by the reflection or transmission factor of the surface. Hence it is sometimes referred to as foot-candle on white.

The tests conducted by the authors were made with six experienced observers in the auditorium of the Lighting Institute of Nela Park. The dimensions of this auditorium are 46 feet by 34 feet and the seating capacity is 250. Fig. 1 illustrates the auditorium layout and location of test positions. The small size of the theater will, of necessity, serve as a limit in the application of results to large theaters.

The lighting systems used in the tests and located in this auditorium have adequate thyratron and resistance control. They include:

(*1*) *Six suspended indirect type luminaires.*

(*2*) *Six luminous windows at each upper side wall with lighting directed toward the front part of the auditorium.*

(*3*) *Six pin-hole objective-lens downlights directed at an angle of 20 degrees toward the front of the auditorium.*

(*4*) *Stage borderlighting to light screen surroundings.*

(*5*) *Aisle lights.*

To fix the test conditions as much as possible, tests were first made with a slide picture having light and dark regions fairly evenly distributed. The picture was 71 inches wide by 51 inches high. The brightness of screen without picture averaged 14 foot-lamberts and the whites in the picture averaged 9 foot-lamberts. The principal test position was a side seat in the rear row which offered the most severe visual condition as far as ceiling and side-wall brightness was concerned.

It is readily apparent that a still picture would become monotonous and distractions would be more in evidence than with a moving picture. Some of the tests were accordingly re-run with a motion picture, with a height of 46 inches and a width of 65 inches. At the principal test positions, 43 feet from the screen, the angle subtended by the screen was 7 degrees. The average brightness of the blank screen with projector lighted and shutter operating was 4 foot-lamberts. With a picture the brightest whites were 3 foot-lamberts. The small size and low brightness of the screen are two of the limitations mentioned.

Experienced observers were selected and the objectives made known to them because this test was purely a visual one. It was interesting to note, however, how positive reactions were to visual discomfort, how close the reactions of various observers checked, and how close an agreement was had to earlier tests by others.

Test No. 1—Lighting from Picture Alone.—(Fig. 2) Observers concluded that a lighted screen alone was definitely uncomfortable due to glare, and very fatiguing, a conclusion supported by general experience.[1,4,6] Aisle lights did not aid appreciably in relieving this

FIG. 2. Test No. 1: Lighting from picture alone.

condition. It was not possible in this test to evaluate the discomfort factor of entering such a darkened auditorium from regions of higher brightness, but experience in theaters lighted in this manner indicates that it is definitely uncomfortable and annoying. This is substantiated also by previous investigations. In this case it is usually necessary to accompany patrons to seats with a flashlight, a procedure that is a rather poor seeing compromise and an expensive one. Aisle lights were of some help, due primarily to identification of aisles.

It was noted that variations in screen brightness due to unequal distribution of blacks and whites caused wide fluctuation of illumination on the ceiling and side walls that was distinctly annoying. This condition is accentuated when patrons wear light-colored summer clothing.

Test No. 2—Illumination of Screen Surroundings.—Previous investigations have concluded that screen surroundings should present some brightness. Jones[4] arrived at the conclusion that the contrast with the immediate surroundings should be less than 1 to 500 as compared with the brightest parts of the picture. O'Brien and Tuttle[7] concluded that the highest desirable brightness of the immediate surroundings is 0.8 foot-lambert and that the preferred brightness lay between 0.05 to 0.20. This provides a contrast range of $^1/_{100}$ to $^1/_{25}$ of the bright parts of the picture. Wolf[8] concluded that a border brightness of 0.047, providing a ratio of 1 to 100 with the brightest parts of the screen, was desirable. Schlanger[6] proposed a method of automatically varying this brightness with the picture.

In their tests the authors wished to determine the desirable brightness of the field surrounding the screen rather than just the frame for the picture. Observers agreed that as surrounding illumination of fairly uniform brightness increased glare was relieved. With the slide on the screen, a brightness of surroundings was soon reached in which it was felt that the background began to compete with the screen itself for attention. The unlighted border around the screen first became objectionable because of its extreme contrast with both screen and surroundings. When the screen was arranged so as to be immediately adjacent to the illuminated background this condition was relieved and a higher brightness of background was satisfactory. A brightness of background of $^1/_{25}$ to $^1/_{50}$ of that of the screen was found satisfactory. However, although relieving the screen glare, little illumination was added to the auditorium to provide the complete comfort condition desired.

Test No. 3—Upper Value of Desirable Illumination.—It was felt that this upper limit might be set as the point at which the movements of other observers became disturbing and that, before determining the quality or quantity of light desirable for comfort, it was necessary to determine this upper limit. This value was determined with a fairly comfortable system of lighting combining background illumination and indirect illumination from the suspended luminaires. With the slide, this value lay between 0.1 and 0.2 foot-candle. However, the animation of the motion pictures tended to render less conspicuous the movements of others, and values of 0.2 to 0.5 foot-candle were found to be satisfactory.

This condition was affected to a great extent by the color of clothes worn. At 0.5 foot-candle, medium or dark clothes were not readily noticed but light clothes were. The brightness of white clothes in this case was 0.35 foot-lambert. It can be concluded, therefore, that in the south, and during the summer when light-colored clothes are worn, levels of illumination should be somewhat lower.

Test No. 4—Lower Value of Desirable Illumination.—Determination of this lower value was more difficult and the factor of eye adaptation caused by entering the auditorium from regions of higher brightness had to be disregarded. The indirect lighting system was selected

FIG. 3. Test No. 7: Downlighting.

for this purpose. Starting with only the motion picture on the screen and gradually raising the level of illumination, it was found that relief from the glare of the screen came when the auditorium illumination ranged from 0.05 to 0.1 foot-candle. Measurements were made in foot-lamberts with the brightness meter and the corresponding illumination values were calculated.

Test No. 5—Indirect Lighting (Suspended Luminaires).—With the screen surroundings having a brightness of $^1/_{40}$ of the screen whites, several levels of indirect lighting were investigated.

With 0.5 foot-candle in the auditorium, the upper limit reached in test No. 3, the lighting was fairly comfortable but with the following shortcomings:

(*1*) The light falling on the screen measured 0.35 foot-lambert, which was enough to harm the picture contrasts seriously.

(*2*) The brightness on the upper part of the proscenium due to the close proximity of the two front luminaires became somewhat disturbing. This brightness was 1.8 foot-lamberts.

Objection No. 1 might be relieved somewhat by a shadow-box arrangement, and objection No. 2 by relocating the front luminaires.

A second test was made with this same indirect system providing 0.25 foot-candle in the auditorium. Objection No. 2 was now overcome but the light spilled on the screen was still objectionable, as it measured 0.18 foot-lambert.

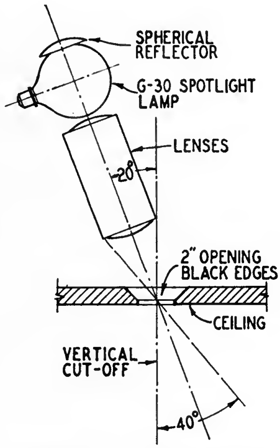

FIG. 4. The downlighting system used in Test No. 7, which affords one of the best methods now available of directing and controlling light for auditorium purposes.

Test No. 6—Luminous Elements (Windows) at Upper Side Walls.—Because the junction of ceiling and side walls is farthest from the line of vision when viewing the picture, it was thought that it would be found that highest brightnesses would be acceptable here. Tests with the lighted windows substantiated this fact. However, it was apparent that there was a decided distraction from a concentration of illumination at these positions which conflicted definitely with the screen. As a result, even though higher brightnesses did not appear glaring here, it was concluded that a low order of brightness, especially at the front of the auditorium, no higher than a brightness of 3 foot-lamberts should be used, which is in accord with the findings of Jones.[4] However, this brightness may be gradually increased toward the rear of the auditorium as the subtended angle at the eye of screen and light-source becomes greater. Many theaters have as their sole source of illumination shaded side-wall brackets. With a good combination having two 10-watt amber lamps the brightest point measured 21 foot-lamberts. Two 15-watt lamps gave a measurement of 65 foot-lamberts. The light oak background measured 8 foot-lamberts and with a white 31 foot-lamberts. These values are all above the one for comfort, indicating that this method of lighting is in general undesirable.

Test No. 7—Downlighting.—(Fig. 3) As previously pointed out, the downlighting system in this auditorium was of the objective-lens type, and it was so directed as to direct light forward of the vertical (Fig. 4). Brightness at the ceiling openings was low.

With downlighting alone, illumination could be raised to a point providing 0.08 foot-candle in the auditorium before the brightness on the heads of persons in the beams directly beneath the units became disturbing. At other locations values of 0.2 to 0.25 foot-candle were satisfactory. At no point did illumination fall upon the screen so as to be discernible, and ceiling or side-walls were not lighted so that there was no objectionable brightness here.

Test No. 8—Downlighting and Indirect Lighting.—By adding 0.04 foot-candle of indirect lighting the brightness of the direct downward light was relieved and the system was then quite comfortable.

An additional test was made by adding 0.25 foot-candle of downlighting to 0.25 foot-candle of indirect lighting to provide the maximum of 0.5 foot-candle, and this system was very comfortable. Picture quality was, however, impaired by spilled light on the screen from the indirect lighting.

Conclusions as a result of these tests and others cited were as follows for the given auditorium conditions:

(*1*) A picture viewed without any auditorium illumination is definitely uncomfortable.

(*2*) A minimum illumination of 0.05 to 0.1 foot-candle is required to soften picture contrast with background. Variation of picture size and brightness, and auditorium size would doubtless influence this figure. Jones[4] found that an illumination of 0.1 foot-candle at the front and 0.2 at the rear of the auditorium is desirable, and this is checked by the report before the International Commission of Illumination.[9]

(*3*) A maximum illumination of 0.5 foot-candle is permissible from the standpoint only of distraction caused by the movements of other persons.

(*4*) Some illumination—$^1/_{25}$ to $^1/_{50}$ of screen brightness—is desirable for the immediate screen surroundings. Higher relative brightnesses were satisfactory at greater angles from the screen. At the outer edges of the proscenium, values of 2 to 3 foot-lamberts were permissible, and approaching the rear of the auditorium considerably higher values are acceptable, depending upon their height above eye level.

(*5*) Indirect lighting has many advantages for auditorium lighting because the light is spread so as to be low in brightness and because an illuminated ceiling adds to comfort. But it is desirable to control the light at the front of the auditorium so that the brightness at points near the junction of ceiling and proscenium is below 2 to 3 foot-lamberts and the screen brightness contributed by spilled light is below 0.05 foot-lambert.

(*6*) Concentration of light at the front side walls is distracting. Such sources should be kept below 3 foot-lamberts. Side-wall brackets are in general too bright for comfortable vision.

(7) Downlighting by controlled beams of light needs to be supplemented by some indirect lighting. The combination of the two systems affords the best seeing conditions of any investigated, minimizing, as it does, bright conflicting sources and spilled light on screen.

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[8] WOLF, S. K.: "An Analysis of Theater and Screen Illumination Data," *J. Soc. Mot. Pic. Eng.*, **XXVI** (May, 1936), p. 532.

[9] Report of the (Japanese) Secretariat Committee, *Proc. Internat. Comm. Illum.*, Cambridge (England), 8th Session (Sept., 1931).

[10] Report of the Theater Lighting Committee, *J. Soc. Mot. Pict. Eng.*, **XIV** (Feb., 1931), p. 239.

DISCUSSION

MR. CRABTREE: The spots on the ceiling were somewhat annoying to me.

MR. FALGE: The picture does seem to give that impression. In the actual condition you would not see the spots or would not be conscious of them because they are well located. When there is a vertical cut-off and the eyes are not in the beam of the light the result would not be glaring. The illustrations do not give the proper impression.

MR. SCHLANGER: It is unfortunate that so careful a study was not made in a room having more suitable lighting arrangements. The direct-indirect type of lighting fixtures suspended from the ceiling are glare spots in the patrons' field of vision. The glass panel on the underside of the suspended fixtures in the direct lighting portion is the most disturbing element; however, the indirect light coming from the tops of these isolated and suspended fixtures is also objectionable.

Apparently the authors used these fixtures merely to help determine illumination levels, and they were not intended for recommended use. There are systems of indirect lighting that are more adaptable to this use; however, the use of secondary illumination of any kind during a screen presentation is debatable. The elimination of glare spots and contrasting levels of illumination during the screen presentation are exceedingly important. I have found that the general level of illumination can be increased to a surprising degree when the surfaces presented to the eyes are uniformly illuminated and devoid of all patterns caused by highlights, shadows, or contrasting decorations.

Secondary illumination of the auditorium surfaces during the screen presentation is most costly if carried out properly because the surfaces are usually dark enough to absorb screen light, thereby diminishing the efficiency of other forms of lighting. It seems that for greatest economy and simplicity, light surfaces reflecting the screen light would be efficient provided the reflections were controlled by the texture or angularity of the surfaces. Mr. Falge, what are the intensity and color of the walls of the auditorium where the tests were made?

MR. FALGE: Light ceiling and side walls, and a very light oak panelling on the lower side wall. The color: light oak finish, a sort of tan.

MR. SCHLANGER: I have had experience with theaters where the walls were pure white as well as where they were darker. Surprisingly enough, in some of the theaters where the walls were pure white the effect was not as objectionable as might be expected. If all the screen light reflected from surfaces is returned to the viewers' eyes an annoying flicker would result. To avoid this the texture or angularity of the surfaces could be such as to reflect a greater part of the light so that it falls upon the heads and sides of the viewers, leaving a small percentage of the light to reflect to the eyes. This would provide desirable diffuse lighting of the audience, and would also light up the wall and ceiling surfaces enough to avoid sharp contrast between the picture and the auditorium surface light.

A certain amount of secondary light can be used in addition to reflected screen light. Such secondary light-sources must be located on wall or ceiling surfaces that do not fall within the field of vision of the audience. The type of secondary lighting so employed would be optional, only efficiency and appearance being the important considerations. Direct lighting sources more efficient than the indirect can be successfully used. The secondary lighting serves also as emergency lighting in the event of a break in the screen light.

Motion picture theater auditoriums have been and are being designed according to Spanish, Aztec, or Modernistic inspirations. Such forms are unsuited to the purpose of the motion picture theater for two basic reasons. First, such decorations, which necessarily consist of forms creating shadows and highlights and differences in color and intensity in paint design, create the disturbing contrasts referred to before; second, such decoration quite often becomes an unsuitable setting for the subjects of the films.

It is possible to create an abstract form of decoration, using as inspiration such textures and angularities of surfaces as will properly react to screen light.

It should be pointed out that the screen size in relation to the auditorium size referred to in these tests was rather small, and therefore the factor of screen light was not fully accounted for.

MR. FRANK: Has any study been given to the color of light most desirable in a theater, or the use of fluorescent lights in auditoriums? Also, have any studies been made as to desirable aisle lighting?

MR. FALGE: With regard to Mr. Schlanger's questions, the under surface of the suspended luminaires was a source of annoyance and should have been omitted. The system was not the best one for indirect lighting, and much improvement could be made on it. As to the current consumption, there is considerable misunderstanding on the part of many theater operators as to what constitutes current consumption. I have visited theaters that had side-wall brackets with one bulb in each bracket and a total of about 100 watts for the auditorium lighting, and have been told, "I want my lighting improved, but I do not want to use any more current." Theater operators are inclined to think of their lighting bill as their projection bill. They forget that perhaps the greater portion of the bill goes into projection and that the few lamps mentioned above amount to very little.

With systems such as downlighting, and with better application of color and more efficient light-sources and equipment, it is feasible to light an auditorium economically to the low levels about which we are talking. It is the higher levels needed for intermission lighting that require more current, and yet the lights are used for such a short space of time that they are not excessively costly.

Mr. Schlanger's suggestion of reflecting the screen light from the side walls is worth considerable study. The light can be utilized as he suggests, and it would be interesting to see whether it could be done practically.

As to the suggestion that the theater auditorium should be entirely simple, with no special decorations at all, there is some question on that score. I listed other factors that are still of importance to the theater manager and owner. The patrons react to lighted interiors in other ways, even though our study was devoted primarily to seeing.

Referring to Mr. Frank's question, we could not go into the study of color this time. It is a difficult study to make, the conditions are difficult to stabilize, and reactions are very difficult to get. That is a problem for the future, and an important one. However, we have studied the color of light as it relates to the efficiency of systems. Fluorescent lighting has great possibilities for theater interiors because of the extremely high efficiency that is attainable. With the green, for instance, we get 60 lumens per watt, whereas with the regular green lamp only one lumen per watt. We can get efficiencies up to 100 times as much as with the usual colored light-sources.

Aisle lighting was included in our study. With little lighting in the auditorium, aisle lighting does help to identify the aisles, which seems to be its primary aim. However, with some of these other systems, well planned downlighting is used over the aisles, and in that case the aisle lighting is brought out very excellently through that means.

MR. CRABTREE: I think the keynote of this paper and discussion is to avoid distraction. If we could only get that idea over to the architects and publicize it to the same extent that the report of the Projection Practice Committee is being publicized, we would really be getting somewhere. In Rochester one of the principal theaters has just been redecorated, and apparently the management is highly pleased with it; but when you go downstairs and sit under the balcony there are glaring lights almost as intense as those from the side walls blazing into your eyes, so that enjoyment of the picture is impossible. It is quite apparent therefore that some architects are absolutely ignorant of the fundamentals involved.

As I have said before, to me the ideal condition is a completely darkened room. Experiments have shown, however, that the general level can be raised tremendously before the visibility of the picture is impaired, and under those conditions I do not think you need aisle lighting. In the rear-projection theaters, the general level is tremendously high, but the contrast of the picture is pleasing and adequate.

MR. FALGE: I think Mr. Crabtree's comments are absolutely right. That is the keynote of everything we have found. Eliminate distraction and you are much nearer a condition of comfort.

MR. WOLF: It is impracticable, however, to have complete darkness.

MR. FALGE: I think it is.

MR. CARLSON: I agree with Mr. Crabtree that the elimination of distracting influences is certainly necessary. Another way of expressing it would be that we are interested primarily in maintaining low differences in brightness. In other words, as in rear-projection theaters, a relatively high general level of illumination may be not only acceptable but actually pleasing, so long as there are no sources of excessive brightness in the field of view.

MR. SCHLANGER: I have tried out some fairly successful indirect systems in theaters, for use during the screen performances, that have not proved distracting. Unfortunately, these systems are used only during intermissions, because the theater operators have found them expensive for continuous operation. For best results, indirect lighting must be continuous and uninterrupted. Indirect lighting is inefficient because of the amount of light that must necessarily be trapped. For these reasons, it is too costly for daily operating periods of approximately eleven hours.

The special holiday or other decorative lighting effects to which Mr. Falge refers are desirable, and can be incorporated in a built-in manner in any lighting scheme, but such lighting is intended purely for intermissions and would be highly distracting during screen performances.

With regard to Mr. Crabtree's statement about the rear-projection theaters, I have found that regular front-projection theaters can be illuminated to levels as high as or higher than the levels found in the rear-projection theaters.

REVISED STANDARD ELECTRICAL CHARACTERISTICS FOR TWO-WAY REPRODUCING SYSTEMS IN THEATERS*

RESEARCH COUNCIL, ACADEMY OF MOTION PICTURE ARTS AND SCIENCES**

(As a result of additional tests and consideration of field operating conditions, these Revised Specifications are recommended to supersede the original Specifications of March 31, 1937, and the subsequent Specifications of June 8, 1937.)

Systems to Which These Specifications Apply: The two-way reproducing systems for which these characteristics are recommended, are:

Type I—ERPI Mirrophonic Systems *M-101*, *M-1*, *M-2*, and *M-3* using *594-A* loud-speaker units (metal diaphragm) and *TA-4181-A* low-frequency units, *M-4* using *555* loud-speaker units (metal diaphragm) and *TA-4181-A* low-frequency units, and *M-5* using *555* loud-speaker units (metal diaphragm) and *TA-4194* low-frequency units.

Type II—RCA system using *M.I.-1435* (metal diaphragm) and *M.I.-1432-A* low-frequency mechanisms.

Type III—Lansing equipped system using *284* or *285* (metal diaphragm) and *15X* low-frequency mechanisms.

Type IV—RCA system using *M.I.-1428-B* or *M.I.-1443* (non-metallic diaphragm) and *M.I.-1432-A* or *M.I.-1444* low-frequency mechanisms.

Measurement Point: These characteristics are valid for measurements made at the output of the power amplifier, including the low-pass filter, with a resistance equivalent to the speaker load, using the Academy Research Council Standard Multi-Frequency Test Reel (corrected),† and are subject to modifications to fit special acoustic conditions which exist in many theaters, due to the fact that the reverberation time or other acoustic characteristics are not optimum.

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* Reprinted from *Technical Bulletin*, Research Council, Academy of Motion Picture Arts & Sciences, October 10, 1938.

** Hollywood, Calif.

† The correction factors indicate the deviation from constant percentage modulation for each frequency.

The above Academy Research Council Test Reels have been compared to both the Altec *ED-20* (corrected),* and the RCA test film (Catalogue No. *26571*), and all these reels should give approximately the same characteristic on any one equipment.

Extensive field tests indicate that equipment set to these Standard Electrical Characteristics will give optimum reproduction of current studio recordings under all conditions.

It has also been found that the calibration of individual frequency reels in use in the field varies in some instances. In case results obtained from any of these reels are obviously in error, the calibration of the test reel used in making the run should be checked.

Acoustic Correction: Whenever such conditions exist that the particular characteristic recommended does not give satisfactory results (after the calibration of the reel used for the frequency run has been checked), it is recommended that the acoustic characteristics of the auditorium be corrected.

Mechanism Adjustment: With the available equipment as specified, operating with the Standard Electrical Characteristic, it is necessary in some instances that the sensitivity of the high- and low-frequency band be relatively adjusted to obtain a flat acoustic response on both sides of the cross-over. This adjustment usually takes the form of attenuating the high-frequency band, the amount of this attenuation depending upon the relative efficiency of both low- and high-frequency units and the specific properties of the auditorium involved.

Typical values are as follows:

Type I—ERPI Mirrophonic systems, *M-101*, *M-1*, *M-2*, *M-3*, and *M-5*, attenuate the high-frequency band 2 to 4 db.

Type I—ERPI Mirrophonic system, *M-4*, attenuates the high-frequency band 0 to 2 db.

Type II—RCA systems, *M.I.-1435* and *M.I.-1432-A*, attenuate the high-frequency band 0 to 2 db.

Type III—Lansing equipped systems attenuate the high-frequency band 0 to 2 db.

Type IV—RCA systems, *M.I.-1428-B*, *M.I.-1432-A*, *M.I.-1443*, and *M.I.-1444*, attenuate the low-frequency band 0 to 2 db.

Note: It should be remembered that the type and condition of screen used in the theater will in a measure affect the high-frequency response of the reproducing system.

Tolerance: A tolerance of ±1 db up to 3000 cycles, increasing progressively with frequency to ±2 db at 7000 cycles, is the maximum permitted for the following gain-frequency measurements.

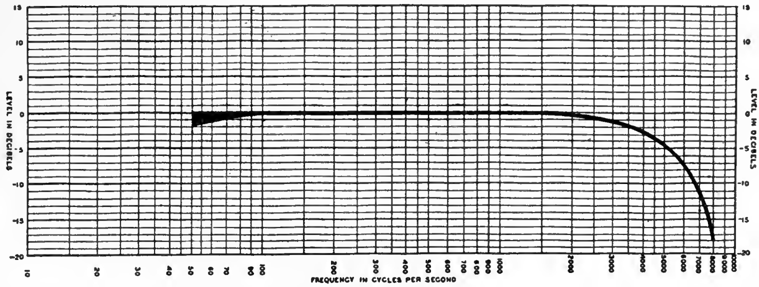

FIG. 1. Revised Standard Electrical Characteristic for two-way reproducing systems using metal diaphragms; Types I (*M-101, M-1, M-2* Systems), II, and III. For optimum results with current studio sound recordings Type I, II, and III Systems equipped with metal diaphragm speakers should be adjusted to this Revised Standard Electrical Characteristic.

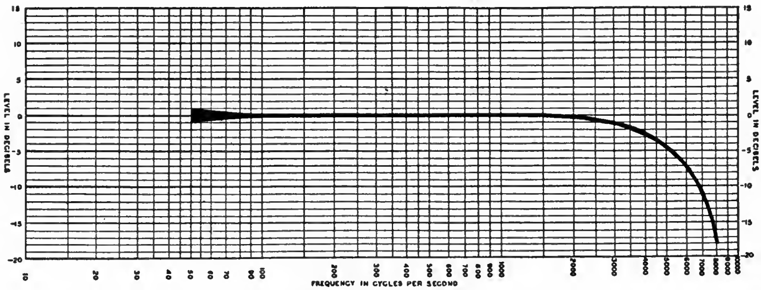

FIG. 2. Standard Electrical Characteristic for two-way reproducing systems using metal diaphragms; Type I (*M-3* Systems). This characteristic for Type I equipments (*M-3* Systems) has not been changed, and remains as specified in the original publication of March 31, 1937, and the subsequent publication of June 8, 1937.

Electrical Runs, Measured at the Output of the Power Amplifier with a Resistance Equivalent to the Speaker Load Using the Academy Research Council Standard Multi-Frequency Test Reel (Corrected), Altec Test Film (ED-20, Corrected), or RCA Test Film (Catalogue No. 26571)

The tolerances of ±1 db. up to 3000 cycles, increasing progressively with frequency to a maximum of ±2 db. at 7000 cycles, should be rigidly maintained in adjusting equipment to these specifications.

Electrical Runs, Measured at the Output of the Power Amplifier with a Resistance Equivalent to the Speaker Load Using the Academy Research Council Standard Multi-Frequency Test Reel (Corrected), Altec Test Film (ED-20, Corrected), or RCA Test Film (Catalogue No. 26571)

The tolerances of ±1 db. up to 3000 cycles, increasing progressively with frequency to a maximum of ±2 db. at 7000 cycles, should be rigidly maintained in adjusting equipment to these specifications.

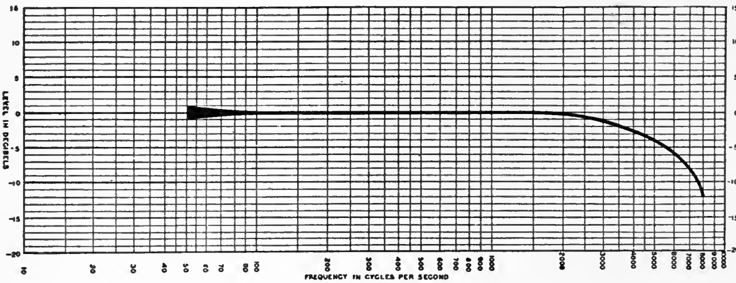

FIG. 3. Revised Standard Electrical Characteristic for two-way reproducing systems using metal diaphragms; Type I (*M-4, M-5* Systems). For optimum results with current studio sound recordings, Type I systems equipped with metal diaphragm speakers should be adjusted to this revised Standard Electrical Characteristic.

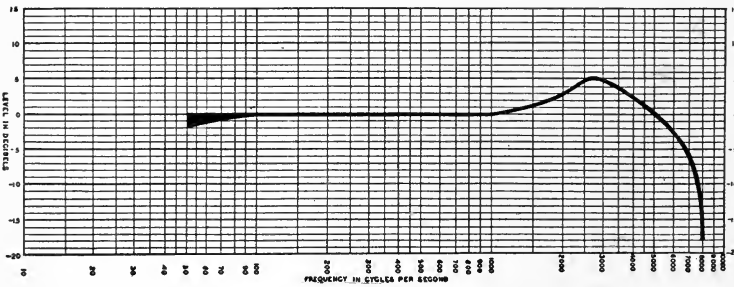

FIG. 4. Revised Standard Electrical Characteristic for two-way reproducing systems using RCA non-metallic diaphragms; Type IV. For optimum results with current studio sound recordings, those two-way reproducing systems equipped with non-metallic diaphragm speakers (Type IV) should be adjusted to this revised Standard Electrical Characteristic.

Electrical Runs, Measured at the Output of the Power Amplifier with a Resistance Equivalent to the Speaker Load Using the Academy Research Council Standard Multi-Frequency Test Reel (Corrected), Altec Test Film (ED-20, Corrected), or RCA Test Film (Catalogue No. 26571)

The tolerances of ±1 db. up to 3000 cycles, increasing progressively with frequency to a maximum of ±2 db. at 7000 cycles, should be rigidly maintained in adjusting equipment to these specifications.

Electrical Runs, Measured at the Output of the Power Amplifier with a Resistance Equivalent to the Speaker Load Using the Academy Research Council Standard Multi-Frequency Test Reel (Corrected), Altec Test Film (ED-20, Corrected), or RCA Test Film (Catalogue No. 26571)

The tolerances of ±1 db. up to 3000 cycles, increasing progressively with frequency to a maximum of ±2 db at 7000 cycles, should be rigidly maintained in adjusting equipment to these specifications.

ORGANIZATION OF THE WORK OF THE PAPERS COMMITTEE*

Since a new committee Chairman will be appointed for the year 1939, the present Chairman has considered it desirable to place on record, for the guidance of future chairmen, a somewhat detailed account of the procedures involved in preparing the papers programs for our Semi-Annual Conventions, as follows.

Committee Personnel.—Experience has shown that an increasing number of the papers in our JOURNAL are being written by technicians in the studios and laboratories on the West Coast. In February, 1937, at the suggestion of H. G. Tasker, Past-President of the Society, a sub-committee of the Papers Committee was formed on the West Coast with W. A. Mueller as Chairman and L. A. Aicholtz as Secretary. Each of the major studios and laboratories was represented. This plan centralized the work of paper solicitation on the West Coast and has proved a very practicable arrangement. It is strongly urged, therefore, that future chairmen adopt a similar plan, so that there will always be an active and representative sub-committee on the West Coast.

Other members of the general Papers Committee should be chosen from the leading industrial firms in the East and Middle West in order that a direct relationship will be established with the principal laboratories and branches of the industry. Members should also be selected in Europe in those countries where cinematographic research programs are known to be in progress. Since the work of the Committee must be carried on largely by correspondence, the personnel should not be too large.

ORGANIZATION OF COMMITTEE WORK

Details of the work may be classified as follows in the order of time before, during, and after a meeting:

(*1*) *Copy for Journal Notice of the Meeting.*—The copy for a request for papers should be published in each issue of the JOURNAL for four months before the meeting. This copy should be prepared about one month after the close of one meeting. A typical notice is the follow-

* Received December 28, 1938.

ing one used for the 1938 Fall Meeting (Detroit, Mich., Oct. 31–Nov. 2, 1938). This notice was printed on the inside cover of the JOURNAL for June, July, August, and September, 1938.

PAPERS FOR THE FALL CONVENTION

Manuscripts of papers received by September 1st will be given immediate consideration by the Papers Committee and the Board of Editors, and the best will be selected and given preferred positions on the program of the Convention, with ample time for presentation and discussion, or about 30 minutes to one hour.

Titles and abstracts of all papers must be received by September 15th to be considered for listing on the Preliminary Program.

Two complete copies of each manuscript must be sent to the Chairman of the Papers Committee by October 1st, in order that the paper be listed on the Final Program for presentation. Manuscripts arriving after October 1st may, at the discretion of the Papers Committee, be scheduled on the Program to be read by title or substituted for other papers in the event of cancellations.

(*2*) *Preliminary Letters.*—(*a*) About three months before the meeting, all members of the Committee should be circularized by letter, giving dates of meeting, closing dates for titles, abstracts, and manuscripts. Previous Committee correspondence should be studied and a summary given in each letter of any papers which have been held over from previous meetings.

(*b*) A prospect file should be kept for each meeting and every prospect should be sent a letter of inquiry on the status of a paper for the next meeting.

(*c*) The condition of the industry should be analyzed and letters sent to possible authors of papers on subjects of current interest.

(*d*) A letter should be sent to each of the Vice-Presidents of the Society inquiring as to the possibility of reports from the Committees under their supervision.

(*3*) *Preparation of Authors' Form.*—This form may be mimeographed. Copies should be sent to each member of the Committee about two weeks after the first letter with a letter of reminder. A typical form is attached to this report. As favorable replies are received from the letters sent to prospective authors, an Authors' Form should be sent out accompanied by a reprint of the *Regulations of the SMPE Related to the Preparation of Papers for Presentation and Publication* (*J. Soc. Mot. Pict. Eng.*, **31**, 215, Aug., 1938). Each committee member and author should be informed of the necessity that abstracts be sent in by the date specified and that two copies of each manuscript must be delivered by the date indicated.

(4) *Abstracts of the Papers to Journal Editor.*—It is usually necessary to revise some of the abstracts as received from the authors, and all abstracts should preferably be retyped to give a desirable uniformity of copy for the printer. Some abstracts are too long; some are written poorly as to sentence construction; and occasionally one is received that is advertising copy rather than an informative, concise statement of the author's paper. It is important, therefore, that every abstract be read carefully before release for printing in the JOURNAL. Abstract copy should be sent to the editor in time to appear in the JOURNAL issued prior to the meeting.

Galley proof of abstracts should also be read to pick up printing errors, especially with regard to names of authors and their company affiliations. Extra sets of galleys of the abstracts should be supplied the Chairman of the Publicity Committee for the use of the trade publications. These should not be released, however, until publication has been made in the JOURNAL. Arrangements for these details can be made with the Editorial Office.

(5) *Preparation of Preliminary Program.*—The preparation of the program requires a careful study of the abstract of each paper before a suitable arrangement can be made of the papers under various special headings. These "sessions" or "symposiums" have proved an effective and popular scheme for concentrating the interest and stimulating discussion at our semi-annual meetings. It is recommended that this plan be continued.

The arrangement of the papers should also be planned with regard to the work of the Publicity Committee. For example, papers of news value should preferably be scheduled on the first and second days of the meeting and distributed to bring at least one such paper in each morning and afternoon session.

When meetings are held in the East, it is recommended that the technical paper sessions be restricted to the daytime and held in the evening only if the subject matter is very outstanding and is accompanied by a demonstration. Examples of such evening sessions are: The paper on "Color Photography" by C. E. K. Mees at the Rochester meeting, October 12, 1936; the "Television Demonstration" by the Radio Corporation of America at the New York meeting, October 14, 1937; and the paper on "The Transmission of Motion Pictures over a Coaxial Cable" by H. E. Ives at the Washington meeting, April 25, 1938.

When the meetings are held on the West Coast, however, evening sessions should be planned because many of the technical workers in the studios find it difficult to get away from production during the day but can attend an evening session. Studio visits or open mornings should be arranged to permit members from the East to see actual production conditions.

It is recommended that an approximate time allotment be given each paper on the preliminary program so the author will know the time that has been allowed for his presentation and the discussion of it.

The preliminary program copy should be sent in to the editor sufficiently in advance of the meeting to permit correction of proof and mailing of the program *at least three weeks before the meeting.*

(*6*) *Mail Preliminary Program to Each Author.*—A copy of the preliminary program accompanied by a letter should be mailed to every author. This letter should urge the author to condense his paper and rehearse its presentation to keep within the time limits specified. It should repeat the request for two copies of the manuscript by a specified date. A sample letter is appended to this report. A colored paper stock helps to insure that the recipient reads the letter.

(*7*) *Check All Manuscripts.*—Every manuscript should be examined as received to determine whether (*1*) two copies have been sent in; (*2*) all figures are included; and (*3*) whether drawings and graphs have been prepared according to regulations, *etc.* If some of these requirements have not been met, the author should be informed at once.

Authors who have failed to send their manuscripts in by the final date specified for receipt of manuscripts should be informed by letter that the Papers Committee desire the manuscript at the earliest convenience of the author. Papers arriving late may, at the discretion of the Committee, be scheduled on the final program to be read by title or substituted for other papers in the event of cancellations.

It should also be pointed out to authors that although two complete copies of their manuscript are desired, it is agreeable to supply preliminary copies requiring further slight alterations in text or completion of illustrations before final release. Such changes should be made within two weeks after the meeting.

(*8*) *Preparation of Final Program.*—Copy for the final program should be prepared about one week before the meeting. The time for delivery of each paper should be printed along the left margin. This plan has several advantages, namely, (*1*) the author is informed of his starting time and total time for delivery and discussion; (*2*) those members and guests attending the meeting know approximately which paper is being read at any given time; and (*3*) the chairman of the meeting has the time schedule as a guide. Whenever possible the arrangement of the papers on the final program should not be changed from that of the preliminary program. Cancellations or the offer of a paper on a very timely subject may make a rearrangement necessary.

In general, papers whose authors will not be present should usually be placed on the last afternoon or at the end of the session on other days. Such papers should be marked with asterisks with the explanation printed that papers so marked will be restricted to ten minutes for presentation, or may be requested to be read by title if the time is greatly limited. A request should be made of the author that he assign someone to give a digest of his paper and inform the Papers Committee several days before the meeting.

Apparatus papers and manufacturers' announcements of new products should generally be restricted to ten minutes for presentation.

The proof of the final program should be checked by the Chairman on Saturday morning before the Convention opens on Monday. A request should be made for sufficient copies to be delivered Saturday afternoon or evening so that they may be distributed to the Board of Governors the next day and to the Publicity Committee.

(*9*) *Final Check-Up at Meeting.*—It is important that the Chairman of the Papers Committee get in touch with every author and any other individuals who have been assigned to read papers in the absence of the authors, to determine whether all their arrangements are complete and that they are ready to present their paper at and for the time specified on the final program. Good showmanship requires that every author be ready when called upon in order that each paper will be read as scheduled on the program.

The question of undelivered manuscripts, missing illustrations, corrections on manuscripts, and other details should be discussed with the author or his designee at the meeting as this is the best opportunity for the Chairman of the Committee to get such information.

It is also suggested that the question of papers for the next meeting of the Society be kept in mind and that suggestions and offers for papers be recorded.

(*10*) *Examination of Manuscripts Preparatory to Submission to the Board of Editors.*—A final check should be made of every manuscript, preferably by reading the manuscript before it is turned over to the Chairman of the Board of Editors for consideration for acceptance for publication. Notation should be made on the manuscript of any special requests made by the author relative to publication.

General Suggestions.—The work of the Papers Committee is not an easy task because most individuals in this industry, whether in research, manufacture, production, or exhibition, are so busy with their daily problems that they seldom wish to take the time to write up the results of their work. The most interesting papers, however, are often those dealing with current developments and, if the Papers Committee is alert to its responsibilities, such papers can only be secured by approaching those individuals who are working in the fields in question. It is necessary, therefore, that the members of this Committee establish a cordial working relationship with the leaders in various centers of activity in the industry. When these leaders have suitable material for papers for our Society, they are more likely to offer it to us for consideration. These leaders should be circularized at intervals as to the possibility of papers by themselves or their staffs.

It is realized that it is not possible to lay down any set of rules for the most satisfactory organization of the work of any Committee but it is hoped that the suggestions given herein may prove of some value to those individuals who accept the responsibility of chairmanship of the Papers Committee in the future.

G. E. MATTHEWS
Chairman, Papers Committee

AUTHOR'S FORM

SMPE FALL CONVENTION

Oct. 31–Nov. 2, 1938—Detroit, Michigan.

Please fill in and return *at once* to ...., Chairman, Papers Committee, SMPE, Kodak Park, Rochester, N. Y.

1. Title of Paper..

....

(Give exact wording)

2. Author (s) Name (s)..

(Give initials)

3. Company Affiliation and Address.................................

4. *Abstract.* A complete abstract (about 200 words) is required by Sept. 15th for publication in the October number of the Journal.

5. *Manuscript.* It is requested that the complete manuscript be sent in to the chairman of the Papers Committee not later than Sept. 15th if preferred listing on the program is desired. *Two copies of each manuscript must be received by October 1st* or the paper may be listed to be read by title on the final program.

6. Do you expect to present the paper in person? Yes...... No......
If not, who will present the paper?..

(Time will be restricted if author (s) not present)

7. Time required for presentation....................Minutes

(Usually 15–20 Min.)

8. Do you expect to show lantern slides? Yes...... No......

(Facilities will be provided)

9. Do you plan to show films with your papers? Yes...... No......
Are they sound...... or silent......? Length?...... (Ft.) 35 mm.?...... 16 mm.?......

10. *Special Requirements.* State in detail any special requirements as to demonstrations, electrical power supply, projection, etc. Facilities will be provided for the projection of lantern slides, 16-mm. and 35-mm. motion picture films.

....

....

Rulings on Publicity on Papers and Acceptance of Papers for Publication.

(1) Acceptance of papers by the Papers Committee does not imply agreement to publish. The Board of Editors reserve the right to decline to publish even though the paper may have been presented at the convention, unless the manuscript is received and accepted one month before the convention.

(2) Publicity incident to the presentation of papers at conventions is the responsibility solely of the Papers and Publicity Committees of the Society and should not be undertaken by the authors or their representatives.

(3) For further details on rules for papers, see the reprint *Regulations of the SMPE Related to the Preparation of Papers for Presentation and Publication.*

SPECIAL BULLETIN OF THE PAPERS COMMITTEE OF THE SOCIETY OF MOTION PICTURE ENGINEERS

Place.....................
Date.....................

Name and Address of Author
Dear Mr....................

A preliminary program for the (*Place*) meeting is enclosed for your information. Please note the date and time specified for your paper. It is requested that you condense your paper for presentation at the meeting and *time it carefully* to fit in with the specified time requirements. *This can be done only by actual rehearsal.* Papers for the Apparatus Symposium will be restricted to 10 minutes for presentation.

Papers must be given on the dates specified, unless a change is approved by motion of the convention delegates at the proposal of the chairman.

Papers designated with an asterisk (*) will, in the absence of the author (s) generally be restricted to 10 minutes for presentation or may be requested to be read by title, if the time is greatly limited.

The full manuscript should be submitted for publication but is subject to final approval by the Board of Editors. Please check over your manuscript carefully and see that it conforms with the regulations governing papers.

Two copies of your manuscript must be in my hands by (*Date*) in order that he paper be listed on the final program.

Yours cordially,
(*Signature*)
Chairman, Papers Committee

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, N. Y. Micro copies of articles, in magazines that are available may be obtained from the Bibliofilm Service, Department of Agriculture, Washington, D. C.

Educational Screen

17 (Nov., 1938), No. 9

Motion Pictures—Not for Theaters—III (pp. 291–294). — A. D. Krows

Electronics

11 (Nov., 1938), No. 11

Television Synchronization (pp. 18–20) — E. W. Engstrom and R. S. Holmes

An Automatic Remote Amplifier (p. 21). — G. H. Brewer

Selecting Loud Speakers for Special Operating Conditions (pp. 22–24). — L. B. Hallman, Jr.

Light and Sound (p. 25).

A Laboratory Television Receiver—V (pp. 26–29). — D. G. Fink

Advanced Disc Recording (pp. 34–36, 82). — C. J. Le Bel

International Photographer

10 (Nov., 1938), No. 10

New Stereoscopic Method (pp. 10–11). — L. H. Shirpser

Projection Symposium (pp. 24–27). — W. S. Thompson

International Projectionist

13 (Nov., 1938), No. 11

Advance Preparations Minimize Sound System Emergencies (pp. 7–10). — A. Nadell

Mechanics of Motion Picture Projection (pp. 10–11, 21–26). — J. Frank, Jr.

Theater Structure, Screen Light and Revised Projection Room Plans (pp. 12–15). — Report of the SMPE Projection Practice Committee

Kinematograph Weekly

261 (Nov. 3, 1938), No. 1646

Sound-Tracks on Ozaphane Film Stock (p. 29).

Motion Picture Herald, Better Theatres

133 (Nov. 12, 1938), No. 7

Lighting the Theater Interior with the New Fluorescent Lamps (pp. 17–19, 25–26). — F. M. Falge

1939 SPRING CONVENTION

SOCIETY OF MOTION PICTURE ENGINEERS

HOLLYWOOD ROOSEVELT HOTEL
HOLLYWOOD, CALIFORNIA
APRIL 17th–21st, INCLUSIVE

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J. G. FRAYNE, *Chairman*

P. MOLE	C. R. DAILY	H. W. REMERSCHIED
J. DURST	S. HARRIS	C. N. BATSEL

O. F. NEV

Headquarters

Headquarters of the Convention will be the Hollywood Roosevelt Hotel, where excellent accommodations are assured. A reception suite will be provided for the Ladies' Committee, and an excellent program of entertainment will be arranged for the ladies who attend the Convention.

Special hotel rates, guaranteed to SMPE delegates, European plan, will be as follows:

One person, room and bath	$ 3.50
Two persons, double bed and bath	5.00
Two persons, twin beds and bath	6.00
Parlor suite and bath, 1 person	8.00
Parlor suite and bath, 2 persons	12.00

Indoor and outdoor garage facilities adjacent to the Hotel will be available to those who motor to the Convention.

Members and guests of the Society will be expected to register immediately upon arriving at the Hotel. Convention badges and identification cards will be supplied which will be required for admittance to the various sessions, the studios, and several Hollywood motion picture theaters.

Railroad Fares

The following table lists the railroad fares and Pullman charges:

City	Railroad Fare (round trip)	Pullman (one way)
Washington	$132.20	$22.35
Chicago	90.30	16.55
Boston	147.50	23.65
Detroit	106.75	19.20
New York	139.75	22.85
Rochester	124.05	20.50
Cleveland	110.00	19.20
Philadelphia	135.50	22.35
Pittsburgh	117.40	19.70

The railroad fares given above are for round trips, sixty-day limits. Arrangements may be made with the railroads to take different routes going and coming, if so desired, but once the choice is made it must be adhered to, as changes in the itinerary may be effected only with considerable difficulty and formality. Delegates should consult their local passenger agents as to schedules, rates, and stop-over privileges.

Technical Sessions

The Hollywood meeting always offers our membership an opportunity to become better acquainted with the studio technicians and production problems, and arrangements will be made to visit several of the studios. The Local Papers Committee under the chairmanship of Mr. L. A. Aicholtz is collaborating closely with the General Papers Committee in arranging the details of the program. Complete details of the program will be published in a later issue of the JOURNAL.

Semi-Annual Banquet and Dance

The Semi-Annual Banquet of the Society will be held at the Hotel on Thursday, April 20th. Addresses will be delivered by prominent members of the industry, followed by dancing and entertainment. Tables reserved for 8, 10, or 12 persons; tickets obtainable at the registration desk.

New Equipment Exhibit

An exhibit of newly developed motion picture equipment will be held in the *Bombay and Singapore* Rooms of the Hotel, on the mezzanine. Those who wish to enter their equipment in this exhibit should communicate as early as possible with the general office of the Society at the Hotel Pennsylvania, New York, N. Y.

Motion Pictures

At the time of registering, passes will be issued to the delegates to the Convention, admitting them to the following motion picture theaters in Hollywood, by courtesy of the companies named: Grauman's *Chinese* and *Egyptian* Theaters (Fox West Coast Theaters Corp.), Warner's *Hollywood* Theater (Warner Brothers Theaters, Inc.), Pantages *Hollywood* Theater (Rodney Pantages, Inc.). These passes will be valid for the duration of the Convention.

Inspection Tours and Diversions

Arrangements are under way to visit one or more of the prominent Hollywood studios, and passes will be available to registered members to several Hollywood motion picture theaters. Arrangements may be made for golfing and for special trips to points of interest in and about Hollywood.

Ladies' Program

An especially attractive program for the ladies attending the Convention is being arranged by Mrs. N. Levinson, *hostess*, and the Ladies' Committee. A suite will be provided in the Hotel, where the ladies will register and meet for the various events upon their program. Further details will be published in a succeeding issue of the JOURNAL.

Points of Interest

En route: Boulder Dam, Las Vegas, Nevada; and the various National Parks.

Hollywood and vicinity: Beautiful Catalina Island; Zeiss Planetarium; Mt. Wilson Observatory; Lookout Point, on Lookout Mountain; Huntington Library and Art Gallery (by appointment only); Palm Springs, Calif.; Beaches at Ocean Park and Venice, Calif.; famous old Spanish missions; Los Angeles Museum (housing the SMPE motion picture exhibit); Mexican village and street, Los Angeles.

In addition, numerous interesting side trips may be made to various points throughout the West, both by railroad and bus. Among the bus trips available are those to Santa Barbara, Death Valley, Agua Caliente, Laguna, Pasadena, and Palm Springs, and special tours may be made throughout the Hollywood area, visiting the motion picture and radio studios.

On February 18, 1939, the Golden Gate International Exposition will open at San Francisco, an overnight trip from Hollywood. The Exposition will last throughout the summer so that opportunity will be afforded the eastern members to take in this attraction on their convention trip.

SOCIETY ANNOUNCEMENTS

ATLANTIC COAST SECTION

As a result of recent elections, announced at the meeting of the Section on January 11th, the following members constitute the Board of Managers for 1939:

*D. E. HYNDMAN, *Chairman*

G. FRIEDL, JR., *Past-Chairman* **H. GRIFFIN, *Manager*
*P. J. LARSEN, *Sec.-Treas.* *R. O. STROCK, *Manager*

*Term expires December 31, 1939
**Term expires December 31, 1940

The meeting of January 11th was held at the Hotel Pennsylvania, New York, N. Y., and was devoted to a celebration of the centenary of the announcement to the French Academy of Sciences in January, 1839, by Arago, of the contributions of Daguerre to the art of photography. Two papers were presented as follows:

"The Early History of Photography," by Edward Epstean.
"Daguerre's Contribution to Photography," by Beaumont Newhall.

The joint presentation told the story of how the world was awakened in 1839 to the idea of photography and how, as the result of the divulgation of Daguerre's method, scientists were stimulated to perfect their independent processes, notably John Fox Talbot in England, whose work was concerned with a positive-negative process admitting of duplication by printing, whereas Daguerre's was a "one-shot" method.

The details of the birth of photography and the early technics were also described, and Mr. Newhall's lecture was illustrated by several lantern-slide copies of original Daguerreotypes. The meeting was well attended and considerable interest was shown in the presentations.

HOLLYWOOD CONVENTION

As outlined in the preceding section of this issue, and also as announced on the inside front cover, the next convention of the Society will be held on April 17th–21st, inclusive, at Hollywood, Calif., with headquarters at the Hollywood Roosevelt Hotel.

SOCIETY OF MOTION PICTURE ENGINEERS

REPORT OF THE TREASURER FOR 1938

Balance, Dec. 31, 1937			$21,353.84
Receipts during 1938			
Membership dues	$12,217.94		
Sustaining Membership	3,400.00		
Publication (Journal sales, reprints, subscriptions, advertising, *etc.*)	5,008.84		
Other income (membership certificates, Journal binders, test-films, interest, *etc.*)	9,860.34		
Total		$30,487.12	
Disbursements during 1938			
Publication (Journal, reprints, binders, *etc.*)	$10,810.45		
Office expenses, rent, and salaries	10,670.13		
Officers' expenses	1,014.62		
Local Sections	655.30		
Other expenses (dues and fees, test-films, misc.)	4,466.60		
Total		$27,617.10	
			2,870.02
Balance, December 31, 1938			$24,223.86

L. W. Davee, *Treasurer*

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
1920	10	$1.00
1921	12	1.00
1922	15	1.00
1924	19	1.25
	20	1.25
1925	21	$1.25
	22	1.25
	23	1.25
	24	1.25
1926	25	1.25
	26	1.25
	27	1.25
	28	1.25
1927	29	$1.25
	32	1.25
1928	33	2.50
	34	2.50
	35	2.50
	36	2.50
1929	37	3.00
	38	3.00

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

SOCIETY SUPPLIES

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

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

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

SMPE Standards.—The revised edition of the *SMPE Standards and Recommended Practice* was published in the March, 1938, issue of the JOURNAL, copies of which may be obtained for one dollar each.

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

Lapel Buttons.—The insignia of the Society, gold filled, with safety screw back. One dollar each.

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

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

JOURNAL

OF THE SOCIETY OF

MOTION PICTURE ENGINEERS

Volume XXXII **March, 1939**

CONTENTS

JOURNAL
OF THE SOCIETY OF
MOTION PICTURE ENGINEERS

Subscription to non-members, $8.00 per annum; to members, $5.00 per annum, included in their annual membership dues; single copies, $1.00. A discount on subscription or single copies of 15 per cent is allowed to accredited agencies. Order from the Society of Motion Picture Engineers, Inc., 20th and Northampton Sts., Easton, Pa., or Hotel Pennsylvania, New York, N. Y.

Published monthly at Easton, Pa., by the Society of Motion Picture Engineers.

Publication Office, 20th & Northampton Sts., Easton, Pa.

General and Editorial Office, Hotel Pennsylvania, New York, N. Y.

West-Coast Office, Suite 226, Equitable Bldg., Hollywood, Calif.

Entered as second class matter January 15, 1930, at the Post Office at Easton, Pa., under the Act of March 3, 1879.

LATEST DEVELOPMENTS IN VARIABLE-AREA PROCESSING*

A. C. BLANEY AND G. M. BEST†**

Summary.—*The purpose of this paper is to present a series of curves showing the photographic control of variable-area sound-tracks in commercial production at Warner Bros. Studio, and to show the wide tolerances in film processing permissible with Class A push-pull recording, a factor that is of especial interest in daily production.*

The results of a study of the technic involved in fine-grain photographic duplicating of variable-area sound-track, for foreign release are also discussed.

The photographic control of variable-area sound-tracks in commercial laboratories has been satisfactorily established by the use of modulated high-frequency test recordings. The nature of these tests has been previously described by Baker and Robinson:[1]

The quality of variable-width sound records depends to a great extent upon image definition. The requirements for a perfect sound-track are complete transparency in the clear portion, complete opacity in the dark portions, an extremely sharp boundary between the clear and dark portions, and exact duplication of the wave traced upon the track by the galvanometer.

Distortion is introduced by any change in average transmission in recording high-frequency waves. At high densities the average transmission is reduced, and at very low densities is increased by the presence of the high-frequency waves. The average transmission is compared to the transmission through the film for a 50-per cent exposed track without signal.

It is possible to find a density at which there is little, if any, change in average transmission, and this density corresponds to most nearly perfect image definition and least distortion . . . .

A modulated high-frequency recording affords an extremely accurate means of determining correct negative and print densities for given conditions of laboratory processing. An oscillator, designed for several carrier frequencies, is provided with a 400-cycle modulator for recording. The modulated carrier is recorded for several values or lamp current, and processed to several negative densities. Prints are then proceeded to various values of density, and the 400-

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*Presented at the 1938 Fall Meeting at Detroit, Mich.; received October 10, 1938.

**RCA Manufacturing Co., Hollywood, Calif.

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

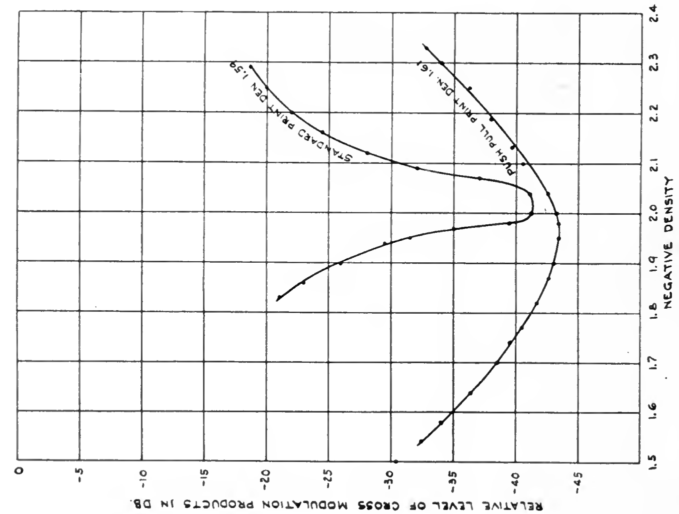

FIG. 1. Cancellation curves for standard bilateral and Class *A* push-pull tracks, plotted against negative density.

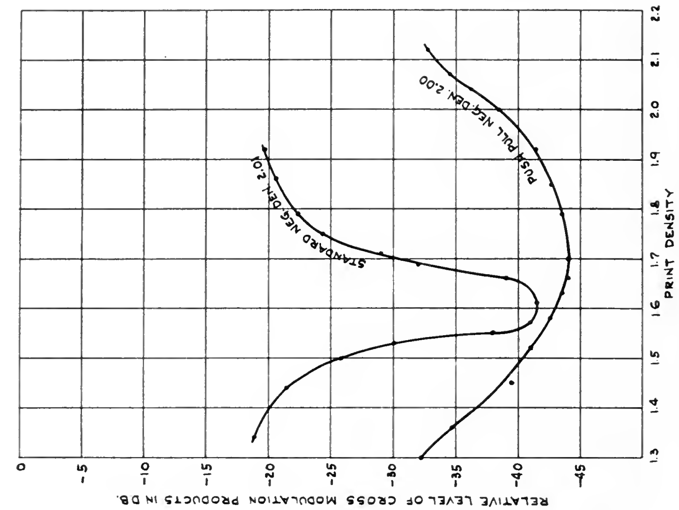

FIG. 2. Same as Fig. 1, but plotted against print density.

cycle output measured on suitable reproducing equipment. The combination of negative and print densities that gives least 400-cycle output indicates the condition for best image definition and least distortion . . . .

This method of test was used to determine the data presented in this paper.

In the daily production of sound-tracks, certain variations in track density are always present. These variations are due to a number of causes, such as emulsion speed, exposure, development, retrogression, temperature, *etc.* While these variations may be held to a minimum, they become apparent when the final film is assembled for re-recording. Such variations require accurate measurement of track density, the use of a card-index system for indexing the densities of the several hundred scenes of each production, and the timing of the cut negative when prints for re-recording purposes are made. This procedure involves clerical expense, extra handling of the negative, and a considerable loss of time in preparing the re-recording prints.

Such variations are practically eliminated by the use of Class *A* push-pull for the original daily production. The advantage of the Class *A* track is primarily due to cancellation of even-harmonic distortions which may arise from daily variations in the process. Thus the daily track, recorded push-pull, provides a higher average and more uniform quality than the standard track. Accurate timing of the negative is unnecessary when making the print for re-recording, as variations in negative density within reasonable limits produce so little change in the relative level of cross-modulation products that they can be disregarded.

Fig. 1 shows the comparative cancellation curves for standard bilateral and Class *A* push-pull tracks plotted against negative density. These data are established by frequency tests consisting of (*1*) 1000 cycles for reference level, (*2*) modulated 9000 cycles for distortion test. It has been found by practical experience that a cancellation of 30 db. is satisfactory for all types of material; therefore density tolerances may be established at this value of cancellation. Thus from Fig. 1 the negative density tolerance for the standard track at a print density of 1.59 is from 1.93 to 2.10, while for the push-pull track the density latitude is almost unlimited. It can be readily seen from this that variations in negative density present in the daily production become relatively unimportant when using the push-pull system, and that only very erratic conditions would necessitate special timing of the negative.

Fig. 2 shows the same comparison, plotted against print density. Here the optimum negative density as indicated in Fig. 1 is made into a loop and printed to a number of densities within the range of the printer. Again the latitude in print density for the standard track is somewhat limited, being within the range of 1.53 to 1.70, whereas the push-pull is almost unlimited. While the latitude of the standard track is sufficiently broad to cover variations in the re-recorded negative and release printing, the use of push-pull tremendously simplifies the daily production routine.

Due to theater limitations, it is necessary to make all re-recorded tracks standard for release. However, since the re-recording is accomplished in a comparatively short period of time, is done in large sections, and is subject to better control than the daily production, the variations are much less. The density tolerances on the standard track are sufficiently wide to accommodate all normal variations that exist during the re-recording process.

Photographic Dupes.—Most producing companies retain the original sound-track and picture negatives in the United States, preferring to send photographic dupes to the foreign market rather than risk having the original negative cut by censors or damaged in transit. For economic reasons, most photographic dupes for foreign release are made with the picture and sound-track on the same film. Since considerable emphasis has been placed on the necessity of having a gamma of 2.00 or over for variable-area tracks, there has been much skepticism as to the possibility of making high-quality composite dupes by following the picture process, which requires the use of relatively low gammas. It must be pointed out that high gamma is necessary only when it must be used as a means to increase sharpness; if the emulsion and development produce the necessary contrast and sharpness, the actual gamma is unimportant.

With fine-grain duplicating positive and negative emulsions of great resolving power now available, experiments were first carried out in the RCA engineering laboratory at Camden to determine what degree of sound quality could be reproduced in a composite photographic dupe. Frequency measurements indicated the losses to be very small, and duplicate prints of speech and music compared very favorably with prints from the original negative. Production work at the Warner Hollywood laboratory proved conclusively the satisfactory operation of the process. All data for this paper were taken from production work at the Warner Bros. laboratory.

Since the picture specifications control the development characteristic of each step of the duplicating process, there is left only the quality and intensity of the printing light to be controlled in printing the track.

The frequency negative for the duplicating tests is made on the same recorder and at the same time as the re-recorded negative, so that it will exactly represent the conditions of the release negative. This negative is also used for control of the domestic release prints.

Fig. 3 shows the cancellation curve for the Eastman fine-grain duplicating positive stock type *1365* developed to a gamma of 1.26 in *D-76* developer, printed from the release negative test having a density of 2.05. This print is exposed with white light because there is very little sharpness to be gained by using filtered light on this emulsion. It is seen that the greatest cancellation occurs at a positive density of 1.45, which, if the print was to be used for theater reproduction, would be the correct print density. However, it is not desirable to use this print density for making the duplicate negative. Due to picture specifications, the dupe negative is developed to a low gamma and will thus have a comparatively large amount of image spread. Therefore, to cancel some of this, it is desirable to use a master positive having image spread in the opposite direction. A density of 1.9 on the type *1365* fine-grain positive has considerable image spread and is about the highest density contrast that can be obtained on the track at this gamma, so a print density of this value is used for the master positive.

Fig. 4 is the cancellation curve of the dupe negative printed from the 1.9-density master. The stock used is the Eastman fine-grain duplicating negative type *1203* developed in *D-76* developer to a gamma of 0.58. This stock is panchromatic in its sensitivity, and considerable gain in sharpness can be obtained by the use of a filter. A Corning No. *556* filter 5 mm. thick restricts the actinic light to wavelengths shorter than 5000 Å and procures most of the possible advantage. Also, the total amount of light required for printing this stock with the filter is no more than is required for the type *1365* stock.

The curve shows that the maximum cancellation occurs at the same density as the maximum density contrast; therefore a density of 1.33 is indicated for making the final prints. However, it has been found from experience with a number of pictures put through the duping process, that it is advisable to work within a density range on the dark side of the indicated maximum cancellation point, so that

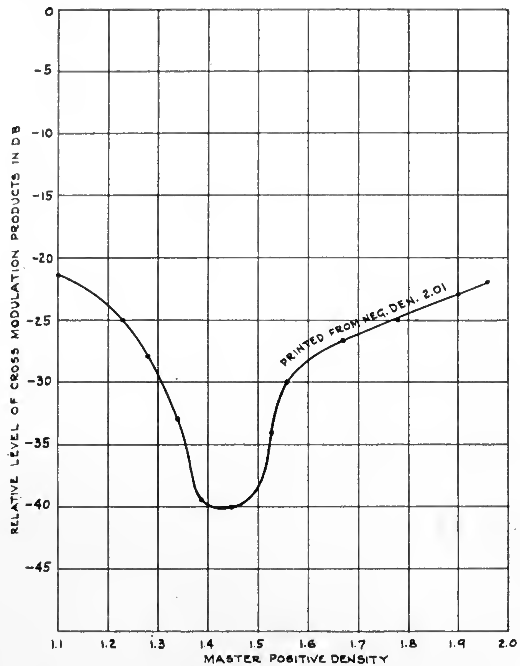

FIG. 3. Cancellation curve of EK fine-grain duplicating positive stock type *1365* (gamma 1.26, D-76 developer), release negative test density 2.05.

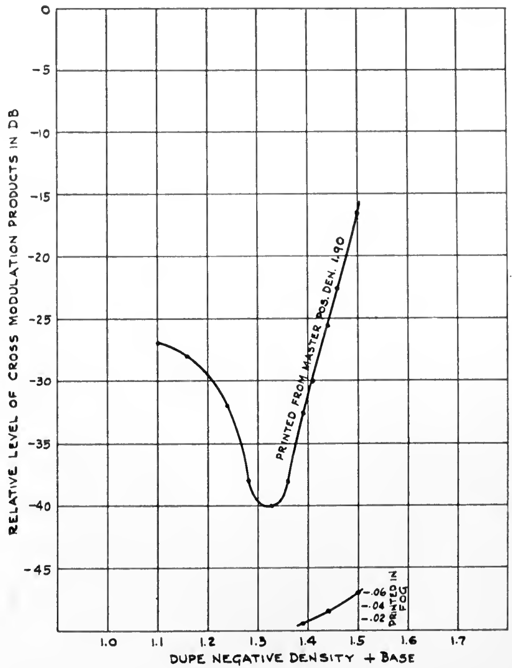

FIG. 4. Cancellation curve of dupe negative printed from the 1.9-density master: fine-grain duplicating negative type *1203*, D-76 developer, gamma 0.58.

in commercial practice this range is from 1.33 to 1.40. Negatives that are below the 1.33 optimum density quickly become excessively sibilant, and those that are kept within the range from 1.33 to 1.40 suffer no impairment of frequency characteristic and no sibilants are introduced in excess of those already existent in the recording.

Fig. 5 shows the cancellation curve for the positive type *1301* prints made from the dupe negative. These prints are made accord-

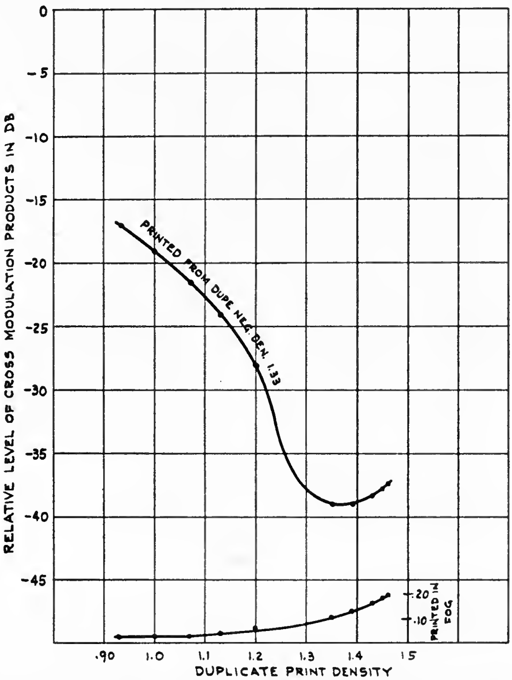

FIG. 5. Cancellation curve for positive type prints made from the dupe negative.

ing to the standard release practice restricting the exposing light to a wavelength shorter than 4000 Å by a Corning *584* filter and developed to a gamma of 2.28. The maximum cancellation value as indicated by the curve at a track density of 1.35 is used for the final prints from the duplicate negative. The curve also indicates a possible ±0.1 density variation without serious effect.

Frequency response tests indicate an overall level loss of 1 db. due to the printed-in fog on the dupe prints, and an attenuation at 7000 cycles of 1 db., as compared with an original print.

The sound quality that can be obtained in a print is largely dependent upon the performance of the printer. Slippage must either be eliminated or reduced to a minimum and held constant. And, most important of all, the films must be maintained in absolute contact. The benefit of these factors can be appreciated only by experiencing the results produced by such a printer.

It is advisable to carry the frequency test through the duping process along with the production material. This test becomes useful in two ways: first, it is a check on the duping process, and second, the test dupe negative is sent to the foreign laboratory so that the proper printing conditions may be established for that particular production.

A number of pictures have been satisfactorily duped by this process at the Warner Hollywood laboratory. It is their practice to make one master positive from which two dupe negatives are made. All these films are exported to foreign markets. However, in order to check the process a complete composite release print is made from each dupe negative. As evidence of the quality obtained, these prints compare so favorable with those made direct from the original negative that they are used in the domestic release.

REFERENCE

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

DISCUSSION

MR. ROBERTS: Why in all these curves did the authors obtain optima on both negative and positive processes? It is my understanding of cross-modulation theory that a certain fill occurs in the negative process, and then a certain amount of fill of the opposite kind in the positive process, which causes a dip in the curve forming an optimum position which we try to print.

In this process the authors apparently get an optimum on *1365* positive film. One would expect that, because the fill of the negative is being cancelled. Now, they pick a point above the optimum, where the cancellation is greater than is needed. Therefore, one would expect that the negative on *1203* film would give an optimum; but the authors apparently pick the optimum point on the *1203* negative curve and make their prints from that.

It would seem to me that one would be finished once he had picked an optimum for the negative, and not expect an optimum on the final *1301* print, but just get a sort of rising curve.

MR. WOLFE: No matter what the image-spread may be on the negative with which we start, there is an optimum print from that negative. It may not always be the same. We do normally try to select the density of the original negative at a point that will bring the cancellation at a desired density on the print, but if we use a different negative density there would still be an optimum print density, but not at the same point.

MR. ROBERTS: In using a negative and print we have a combination. In general, we get optima on, say, print processes, but why is it you get optima in both negative and positive? I regard the negative and positive as a unit, and we get a family of curves for every negative and positive. But if we plotted the cross-modulation products of the original negative, as it is taken from the developing machine, we would not get a minimum. Why, then, should we get a minimum in a duplicate negative process?

MR. WOLFE: If you take a negative and vary the exposure you will get a minimum. We sometimes make use of that fact when we wish to play the negative. For example, if we know in advance that a particular piece of film is being made for play-back purposes only, it will not be printed, and it is exposed differently from the way in which it would be exposed if we expected to print it; so the variable is exposure on the negative. Again I think the point is quite definite, that there is a minimum in every case, and where that minimum occurs depends entirely upon the preceding process.

MR. ROBERTS: I had the idea that in one process we got only one sort of effect; that is, in the negative we have only the fill of the valley; and in the print we fill the valley corresponding to the peak of the negative, so as to equalize and make the sound-wave symmetrical.

MR. WOLFE: What we are talking about here is image-spread, and it must be clear that in every photographic process there is an exposure and a development condition that results in a minimum amount of image-spread. It so happens that for the normal practical process we expose and develop the negative in a manner that does not give the negative minimum image-spread.

That is done in order that the image-spread may be used to cancel the image-spread of the print that results when the print is at a density value desirable from the standpoint of the level of sound reproduced.

IMPROVING THE FIDELITY OF DISK RECORDS FOR DIRECT PLAYBACK*

H. J. HASBROUCK**

Summary.—*Recent advances in design, and in materals of which the recording disks are composed, have resulted in improved fidelity. Both the volume range obtainable, and the frequency range, have been extended, satisfying present-day requirements of motion picture and broadcast applications.*

For reproduction, there is provided a new light-weight lateral pick-up having high sensitivity and equipped with a permanent diamond point. This reproducer, in combination with its associated circuit, is suitable for use on all lateral cut disk records.

Pre- and post-equalization are employed in making high-fidelity records, insuring a low noise level. This reduction of background noise together with the wide frequency range and low distortion create an illusion of realism or "presence" during reproduction.

Usually a large number of playings is not required from direct playback disks. However, because of the low mechanical impedance of the new RCA pick-up and the improved composition of the disks, it is possible to reproduce many times without appreciable increase in noise or distortion.

Constant demand for better direct playback recordings has resulted in the development of equipment and disks of improved quality. These advances have opened new fields and today the applications for direct playback recording are numerous.

The art has advanced well past an experimental state and is now used on a production scale for sound motion pictures, radio broadcasting, schools, industrial advertising, musical education, auditions, government activities, and aviation.

RCA has developed direct playback equipment having improved performance characteristics. A typical studio installation is shown in Fig. 1. Here may be seen the feed-screw mechanism with recording head and the new light-weight lateral reproducer.

Lateral or "push-pull" modulation was adopted because of its low distortion characteristics. A frequency range of 50 to 10,000 cps. is

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*Presented at the 1938 Fall Meeting at Detroit, Mich.; received October 24, 1938.

**RCA Manufacturing Co., Camden, N. J.

covered with reasonable uniformity. A volume range of approximately 55 db. is obtainable using the frequency range specified. The records have sufficient life for most purposes and when protected from dust, finger prints, and oxidation may be played seventy-five

FIG. 1. Recording and reproducing system for broadcast studio use.

or more times using the light-weight flexible pick-up shown. Usually a large number of playings is not required and no special care in handling the disks is ordinarily demanded.

The MI 4887 recording head consists of a mechanical band-pass network terminated by a special mechanical resistance material. The

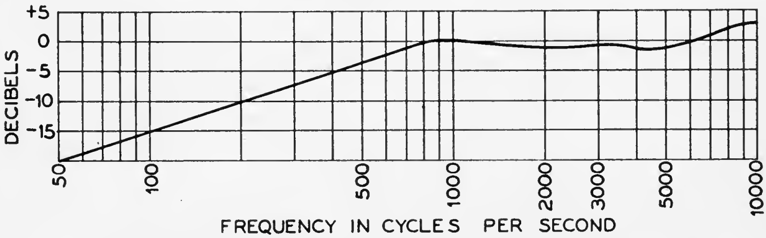

FIG. 2. Frequency response recorder head (*MI-4887*) optical measurement, lateral stylus velocity.

impedance of the moving system is such that the motion of the cutting stylus is practically unaffected by the impedance of the record composition. This permits a free-space microscopic measurement of the performance of the head, which is duplicated almost exactly when cutting a record. The frequency response characteristics of two types of recorder heads are shown in Fig. 2. It will be seen that frequencies below 800 cps. are controlled so as to hold the amplitudes about constant, the stylus velocity diminishing as the frequency is reduced.

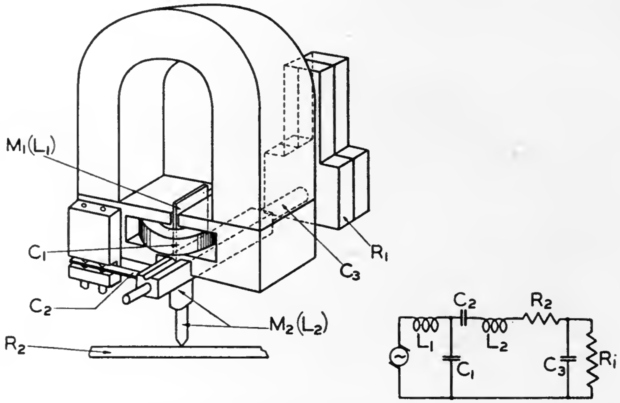

FIG. 3. Construction of recording cutter and equivalent electrical circuit.

This practice is followed generally in disk recording to avoid cutting through to adjacent grooves at low frequencies. The loss is made by suitable compensation in the reproducing circuit.

The construction of the recording cutter and the equivalent electrical circuit are shown in Fig. 3. Since for constant current in the recorder winding, the armature receives a constant force, the electrical circuit is shown working from a constant-voltage source. The output of the mechanical system is represented by the lateral stylus velocity and is equivalent to current through the second inductance of the electrical network. This circuit has a rising characteristic with increasing frequency, compensating for diminishing current through the recorder winding due to inductance.

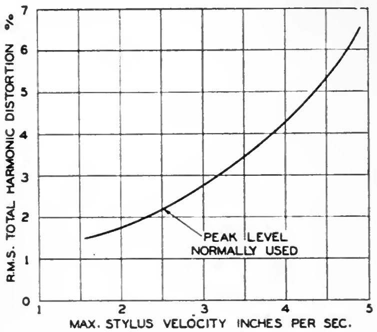

FIG. 4. Total distortion (rms.) to be expected at 400 cps.

The merits of lateral recording have been discussed at length. Of chief importance is the cancellation of even harmonic distortion.[1]

Under normal operating conditions, the overall distortion of the combined recording and playback operations is less than 5 percent. The rms. total distortion to be expected at 400 cps. at varying degrees of modulation is indicated in Fig. 4. These observations were made at a record speed of 33.3 rpm. and a diameter of 12 inches.

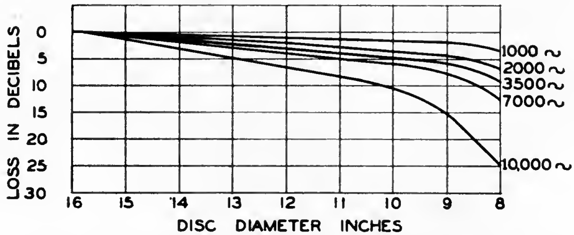

FIG. 5. Average losses at various record diameters at 33.3 rpm.

All disk systems suffer from high-frequency transfer losses and increased distortion when the record diameter or linear surface speed becomes too small. The average losses encountered at various record diameters at 33.3 rpm. are shown in Fig. 5. These are for soft composition blanks used in direct playback work. The losses are less serious on standard records pressed from harder material.

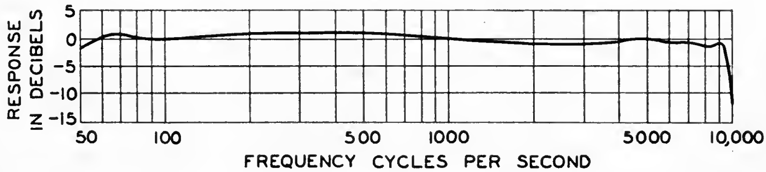

FIG. 6. Reproducer characteristic with standard 12-inch pressing at 33.3 rpm.

These losses are caused by a combination of the finite size of the reproducing point, the wavelength of the recorded sound, the weight of the pick-up, and the compliance of the record stock. It is possible to compensate to some extent for the losses but it has not been found practicable to attempt full compensation above 6000 to 7000 cps. because of the serious attenuation in the upper register. Therefore, in making high-fidelity records where quality is of paramount importance, the best results are obtained by dividing the time into two or more disks and confining the recording to reasonably high linear speeds.

Some reduction in transfer loss can be effected by departing from standard groove dimensions, for example, by reducing the radius from 0.0023 inch to 0.001 inch. A further reduction could be made by increasing average record speed. In view of the extensive duplication of equipment neither solution appears to be economical.

The *MI-4856* reproducer is intended primarily for use on non-abrasive high-fidelity records but may be used on all lateral records having standard groove dimensions, including composition coated disks used for immediate playback. It is equipped with a permanent diamond point, the radius of which corresponds to the 0.0023-inch standard. This radius is held to limits not exceeding plus or minus 0.0001 inch to insure an even distribution of pressure over the bottom of a standard groove.

The frequency response characteristic of the reproducer from a standard test pressing twelve inches in diameter and running at 33.3

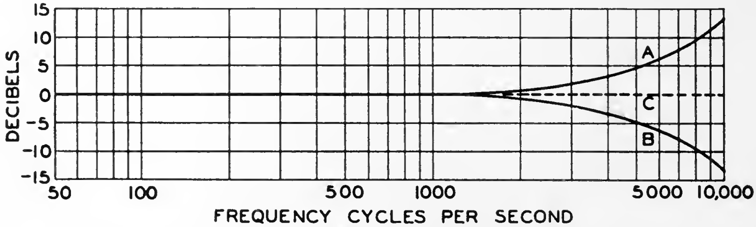

FIG. 7. Recording and reproducing amplifier charcteristics.

rpm. is shown in Fig. 6. The internal construction of the pick-up is shown schematically in Fig. 8. The armature is of the clamped reed type. The two upper air-gaps are inactive, being filled by non-magnetic spacers. Since the armature impedance is too high to be directly coupled to the record a linkage having a 6 to 1 leverage ratio or a 36 to 1 impedance ratio, is employed. The diamond point is secured in the lower end of an extremely light pivot arm spring supported vertically but rigid laterally. Thus, the pivot arm is permitted to rise, as during "pinching," without lifting the entire pick-up. In the direction of useful motion being transmitted to the armature, the linkage has a minimum of compliance and the upper cut-off is high or about 9000 cps. This peak is reduced by means of a block of loaded rubber arranged as a selective damper tuned approximately to the peak frequency.

The response of the pick-up working into a resistance load would droop at high frequencies because of the inductance of its winding unless the winding were kept small. This is not consistent with high output. Therefore a shunt capacity is connected across the pick-up which, by reacting broadly with the inductance, increases the response through a portion of the upper range. The reproducer has a slightly rising characteristic at the upper end, enough to offset high-frequency needle or transfer losses encountered at a mean record diameter of twelve inches at 33.3 rpm.

In making high-fidelity records, including disks for immediate playback, use is made of what is known as pre- and post-equalization or complementary compensation. Because of the energy distribution in most speech and music, it is possible to accentuate the higher frequencies when making a record and attenuate them in reproduction, thereby reducing the surface or ground-noise due to the record stock.

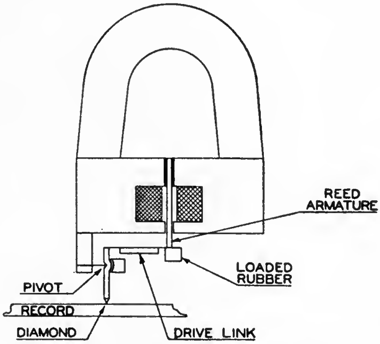

FIG. 8. Construction of pick-up.

Fig. 7 shows the recording and reproducing amplifier characteristics and the ideal overall to which must be added the characteristics of the reproducer. This method of reducing surface noise can be used successfully in most cases without adding appreciable distortion.

Tests indicate negligible wear of the diamond stylus on non-abrasive records. On shellac composition records there is sufficient wear after 5000 ten-inch faces to justify replacement of the point. This is considerably longer life than so-called permanent points of iridium or sapphire, when used on abrasive records with the same pressure of two ounces.

An improvement in pick-up tracking has been made by offsetting the head with respect to the arm. This angle, which is about ten degrees, results in two positions of tangency with the groove, one near the center of the record and the second near the outer edge. The error in tracking angle between these positions is less than 5 degrees.

REFERENCE

[1] PIERCE, J. A., AND HUNT, F. V.: "Distortion in Sound Reproduction from Phonograph Records," *J. Soc. Mot. Pict. Eng.*, **XXXI** (Aug., 1938), p. 157.

DISCUSSION

MR. WOLF: Is this a conventional form of acetate?

MR. HASBROUCK: Yes. The response was equalized to 9500 or 10,000 cps. There was no limitation below that either in recording or reproduction.

MR. WOLF: Are any of the studios now making use of it for playback?

MR. HASBROUCK: Yes, many of them, both motion picture and broadcast studios.

MR. CARVER: When you say the "conventional type acetate" I suppose you mean nitrate. All I have ever seen was nitrate.

MR. HASBROUCK: That word "acetate" is misused. It is a nitrate base. There are other ingredients.

MR. CRABTREE: What are the merits of this lateral system as against the hill-and-dale?

MR. HASBROUCK: That has been discussed at great length in many publications. The chief advantage is the cancellation of even-harmonic distortion in the lateral system. It is similar to a "push-pull" amplifier.

MR. JOHNSON: The hill-and-dale controversy is like an automobile running over a rough road, compared to an engine on a wavy track. The best contact between the needle and the groove will, of course, be in the lateral cut track. When the stylus digs deeper the drag is greater, and there is likely to be chattering.

MR. CRABTREE: Many years ago we had demonstrations at these meetings of hill-and-dale records which, to me, were quite pleasing. It is unfortunate that the author did not bring along his recorder and actually record in the room and reproduce, say, a speech by our President. I wish we could arrange at the next meeting for someone to put on such a demonstration. It means so much more when we hear the original and then the reproduction, than to hear merely the reproduction.

MR. WOLF: Is this system used in Hollywood to the exclusion of other playback methods? Is the Miller system being used at all for immediate playback:

MR. WOLFE: To the best of my knowledge, the Miller system is not being used in the studios, but this method is certainly not the only one in use for playback purposes.

Again, so far as I know, variable-density negative is not being played back in the studios, but R.K.O. does play back variable-area negative in certain cases. Two methods of playing back are used: either acetate disk, some of it lateral and some hill-and-dale, or by reproduction from film.

MR. WOLF: I think before long electromagnetic recording will probably be in the studios. The Bell Laboratory has been working for a number of years on that method of recording. I think you will see at the New York World's Fair, if not before, a quality of magnetic recording comparable with the best playbacks most of us have ever heard. That medium will also be very useful for certain kinds of playback and editing.

THE CENTENARY OF PHOTOGRAPHY AND THE MOTION PICTURE*

EDWARD EPSTEAN**

January 7, 1939, marked the centenary of the day when Arago communicated to the French Academy of Sciences news of the invention by Daguerre of what was to be known as the daguerreotype.

At the suggestion of the Société Française de Photographie that ceremonies and meetings be held by scientific and engineering bodies throughout the world to commemorate this Centenary, the Atlantic Coast Section of the SMPE devoted its January, 1939, meeting to two presentations: the one that follows, by Edward Epstean, describing the historical background of Daguerre's time, as related to photography, or "light writing"; and the second by Beaumont Newhall, describing more in detail the work of Daguerre and his process.

The erroneous popular idea that engineers are mechanics, with no interest in the history or philosophy of their profession is, I am sure, not held by the members of this Society. I do not hesitate, therefore, on this Centenary of the "Discovery of Photography," to address you on this subject, tracing the history and progress of the art leading to your specialized science of motion picture engineering.

Motion pictures, as we know them today, were originally called "animated photographs" and later "moving pictures."

Robert Hunt, the English professor of physical science, wrote in 1854: "The progress of discovery is ordinarily slow, and it often happens that a great fact is allowed to lie dormant for years, or for ages, which, when eventually revived, is found to render a fine interpretation of some of Nature's harmonious phenomena and to minister to the wants or the pleasures of existence. Of this position, Photography is peculiarly illustrative."

The universal application of photography, which ranges from the hobby of the amateur on through the wide fields of science and industry, might suffice to arouse in any one the desire for a short study of its antecedents and its early development. This year is extremely

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*Presented at a meeting of the Atlantic Coast Section, January 11, 1939.

** New York, N. Y.

appropriate, because January 7, 1939, marks the Centenary of the day when the French scientist, Arago, member of the Chamber of Deputies and of the Academy of Sciences, communicated the first news of this new discovery to the members of the Academy. After a few months of necessary political procedure, the French Government, through Arago, published the details of the process—not of photography, but of the daguerreotype.

To give a full history of what today is called photography with its background, development, and innumerable applications would require many volumes. The word photography, from its derivation, implies primarily a study of light, and early in Genesis the word is mentioned in its very first verses. Ever since, philosophy and science have attempted without success to define and explain Light. Dr. Woodbridge, of Columbia University, writes in his chapter on the subject that: "it is a paradox" and it probably will remain so, in saecula saeculorum. We know little of its action and you will easily understand my meaning when I call your attention to the use of the phrase: "seeing the sun, the moon, the stars." What we see, of course, is only the radiation of their light and not its source. Distance, time and space, its brilliancy, and its movement, our imperfect optical apparatus—all make it impossible to see that essence which we include in the term "the light." I have read that stars which have been extinct for 400 years still impress our vision with their light.

Resuming our study of photography we find the camera obscura. Some historians have tried to trace its origin to the Arabs. Astrologers were attached to the courts of their rulers, whose lives, fortunes, and wars were influenced by the astrological studies of the planets, based on the day and hour of the ruler's birth. In order to study them apart from the myriads of other stars surrounding them, the seers built observation huts where no light could enter save through a hole in the roof of the "dark room."

Leonardo da Vinci in his notes on optics states: " . . . if the front of a building . . . which is illuminated by the sun has a dwelling over against it, and in that part of the front which does not face the sun you make a small round hole, all the objects which are lighted by the sun will transmit their images through this hole, and will be visible inside the dwelling on the opposite wall which should be made white. And they will be there exactly but inverted; and if in different parts of the same wall you make similar holes you will produce the same effect in each." And thus we have "light" writing through a so-called "pinhole lens" on a white wall or on white paper fastened opposite the hole.

Cameras, front boards, bellows, and plate holders have since been constantly improved. From the beginnings of photography the camera obscura was equipped with a single lens, but soon thereafter came the periscopic lens, the meniscus prism, and double objectives.

Astrologers were displaced, largely through the greed for precious metals, by the alchemists, forerunners of the chemist—in our specialized field the photochemist.

Northern Italy, which provided colored ribbons and fabrics for Europe during the eighteenth century, was naturally interested in the action of dyes and colors, and to Beccarius is ascribed the priority of discovery of the light sensitivity of chloride of silver. An earlier work, in Latin, by Agricola (1490–1555) deals with silver ores. This work was translated into English by President and Mrs. Hoover. Here is one of the examples of a comatose condition, because a closer study of this work might have hastened an understanding of the action of light on the silver salts. It is quite certain that the alchemists of the sixteenth century knew of the aqueous production of silver chloride.

Again we see a dormant period in the progress of the discovery of photography, which extends to the end of the eighteenth century. One of the men to whom great credit is due in this celebration, discovered—again not photography but as he named it—heliography. Joseph Nicéphore Niepce (1765–1833), educated for the priesthood, therefore equipped with a knowledge of the humanities and a training in elementary science, was drawn into the vortex of the wars of the French Revolution. He was discharged from the army at his request, being debilitated by a fever which at the time raged both in the army and among the civilian population.

Niepce's part in the invention of photography is best stated in his own words. He described his process as "automatically fixing by the action of light the image formed in the camera obscura and the reproduction by printing with the aid of known processes of engraving." Niepce experimenting with lithography (1813–1815), then new in the reproductive process, attempted to obtain designs on stone and metal by the action of light instead of by manual drawing, and thus produced etched intaglio plates. He used diaphragms in his lens and added bellows to his camera. His first camera images were obtained in 1816, at the end of which year, being unable to fix his paper negatives, he abandoned the use of silver chloride and began experiments with asphaltum. While successful in the copying of engravings by contact, he turned back in 1826, substituting glass for metal and paper, to intaglio etching of images obtained in the camera. But he did not succeed in reproducing the middle tones, and in that year—1826—Daguerre heard of Niepce through the Paris optician Chevalier, and in 1829 we find Niepce sending to Daguerre "a view from nature engraved on a silvered pewter plate." He met Daguerre personally in August, 1827, on a trip through Paris. At that time Daguerre's progress had resulted in nothing but fantastic experiments, without any significance in obtaining images by the action of light, while Niepce had achieved actual results before the end of 1822. Toward the end of 1827, while visiting his dying brother in England, Niepce presented to the Royal Society a short memoir entitled "Héliographie, dessins et gravures." Since, however, he did not disclose the details of his manipulations the communication was returned, unread, by the Society. Returning to Paris in January, 1828 he was urged by his friends during his stay, which was prolonged until the end of February, to join Daguerre in perfecting and exploiting his invention. It was in 1829 that Niepce first used iodine to blacken the silvered background of his images. In December of that year articles of partnership were drawn at Chalon-sur-Saône between Niepce and Daguerre, on a visit Daguerre paid to Niepce for this purpose. Niepce died on July 5, 1833, in his sixty-ninth year.

Louis Mandé Daguerre (1767–1851), the other pioneer honored at this Centenary, had none of the culture and scientific training which Niepce enjoyed in his youth. He was preëminently an artist, blessed with imagination, seeking fame and publicity, and fortunate in having powerful friends. We have no record of his having had any preparation for chemistry or optics of photography. But he showed a positive genius for adapting the ideas of others. His share in the invention of photography was not disclosed until six years after the death of his partner, to whom little credit was given in the publication of the daguerreotype process. Having been sent to Paris in his youth to study art, he eventually, in collaboration with the distinguished painter, Bouton, created the Diorama, a marked improvement on the panorama. Incidentally, the panorama was introduced in Paris by the American, Robert Fulton, the inventor of the steamboat, during a visit from 1800–1804. Daguerre's novel lighting effects added to the mobility of the scene and to the attractiveness of the colors in the views displayed. Daguerre was made a Chevalier of the Legion of Honour in 1824 and it is said that the profits of the Diorama in the same year amounted to two hundred thousand francs. It is this financial success which permitted him in his leisure time to study and to make the experiments for finding the means of fixing the image obtained in the camera obscura. The Diorama burned on March 3, 1839, inflicting a serious financial loss on Daguerre. The fact is indisputable that Daguerre was the inventor of the daguerreotype, and one of the inventors of photography. He must be given credit, as the first to recognize the light sensitivity of iodide of silver as well as the property of vapors of mercury to reveal the latent image. Whether he discovered these things by chance or whether he built on the pioneer knowledge of Niepce and others before him can not rob him of this honor.* He died on July 10, 1851, in his eighty-fourth year.

The earliest information given to the public about the daguerreotype was the report made by Arago to the Academy of Sciences on January 7, 1839, as chairman of the committee, consisting of Humboldt, Biot, and himself, appointed to visit Daguerre. His speech before the Chamber of Deputies on July 3, 1839, was followed by a similar address by Gay-Lussac in the Chamber of Peers on July 30th, in support of the bill acquiring the purchase of the daguerreotype and diorama by the French government. A few days later the Minister of the Interior instructed Arago to promulgate the processes to the world, and this Arago did in his address to the Academy of Sciences on August 19, 1839. This splendid gesture of the French government in freely giving this portentous discovery to the world can not be emphasized sufficiently.

Arago's famous address to the Academy contained no technical details. These were later printed in the official handbook of daguerreotypy: Historique et Description des Procédés du Daguerréotype et du Diorama, written by Daguerre, which passed through several editions and appeared in most foreign languages before the end of the year. No previous discovery in history had awakened such universal interest.

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* Briefly, the Daguerre process is as follows: A metal plate is thoroughly cleaned and polished and is then coated with silver, which is, in turn, highly polished. Metallic iodine is then sublimed on the silver coating, producing the light-sensitive silver iodide. After exposure the image is developed by fumes of mercury and is fixed with sodium thiosulfate, or hypo.

Into this chorus of universal praise, however, there came a discordant strain from England. Daguerre, in England alone, had patented his invention. Talbot, the English scientist, claimed priority for the invention of his process of "photogenic drawing," which he communicated to the Royal Society on January 31, 1839.

Let us look into the history of the beg nnings and development of photography in England.

Thomas Wedgwood, during the years from 1792 to 1800, carried on experiments which he published in the *Journal of the Royal Institution*, London, under the title "An Account of the Method of Copying Paintings upon Glass, and of Making Profiles, by the Agency of Light upon Nitrate of Silver, Invented by T. Wedgwood, Esq., with Observations by H. (Sir Humphry) Davy." Wedgwood was the first to conceive the idea of delineating the form of objects by the action of light, but he died without having found the means of fixing (making permanent) these photographic images.

Sir John (John Frederick William) Herschel (1792–1871), a great scientist, who knew and applied the axiom that science without philosophy was like the body without mind, directed his researches to the physical laws governing chemical reactions. It is he who pointed out that hyposulfite of soda is the best fixing agent.

After careful research, I do not hesitate to state that it was Sir John Herschel who coined the word "photography." Dr. Erich Stenger's claim that it was the German astronomer Mädler who first used the term (February 25, 1839) was dispelled in my mind at the time of a memorable visit which I paid to Miss Hardcastle, Sir John's granddaughter, who resides in Observatory House at Slough, near London—the home of Sir John. I found there considerable correspondence between the two astronomers, and I have no doubt that a close search would disclose the use of the word in Sir John's correspondence with Dr. Mädler before the publication in the newspaper column cited by Professor Stenger.

William Henry Fox Talbot (1800–1877), philologist and archeologist, states: "In the spring of 1834 I began to put in practice a method of employing . . . the property . . . possessed by nitrate of silver . . . its discoloration when exposed to the violet rays of light." He published his "experiments" under the name "Photogenic Drawing" in 1839, explaining the preparation of photogenic paper, the washing, drying, and coating of it and his success in increasing its sensitivity—exposure of five minutes. It was early in 1840 that the

Calotype process (*kallos* meaning beautiful in Greek) reached the continent but daguerreotypes were preferred, at least until Blanquart-Evrard perfected Talbot's process. The great advantage of the Talbotype was, of course, its ability to multiply the record obtained in the negative by any number of positive prints.

We must not pass over this period without mentioning the Scot, Mungo Ponton, who laid the foundation for the present relief and other reproduction processes by announcing the light-sensitive property of bichromate of potash.

During all this time improvements in the design and construction of cameras and lenses were introduced, new researches in photochemistry and innumerable methods of making photographic copies.

A short American note may be given place here. In no other country in the world was daguerreotypy more enthusiastically received or so widely practiced as in America. A very complete account of the early American procedure in daguerreotypy, by Dr. J. W. Draper, of New York was published in the London and Edinburgh Philosophical Magazine for September, 1840.

Daguerreotypes and Calotypes, however, were shortly to be displaced by the wet collodion process. Domont and Ménard recognized in 1847 the solubility of certain kinds of gun cotton in ether and alcohol, giving us collodion, the name of which is derived from the Greek word denoting "like glue—sticky." The credit for its first use in photography, January, 1850, is ascribed by Dr. Eder to Gustave le Gray in Paris. A closer study of the subject, however, confers the merit of introducing the first practical collodion process on the Englishman, Frederick Scott Archer. It displaced all previous methods in the decade preceding 1860, and for twenty years the wet collodion process occupied the first place among photographic negative methods. In the seventies along came the bromo-silver dry collodion emulsion with excess of silver nitrate, followed, late in that decade, by gelatine bromide-silver emulsions, alkaline development—the gelatine dry plate era. Here we meet George Eastman, introducing the stripping film and roll holder, with later the Kodak camera and daylight-loading roll-film—modern photography.

Chronology now leads us to interject here brief mention of stereoscopic photography. The principle of binocular vision was known in remote times but just a hundred years ago, the English physicist, Charles Wheatstone, of Gloucester, England (1802–1875), invented (1838) the mirror stereoscope, through which one viewed two slightly dissimilar images of the same object, as seen by the two eyes, and obtained a single image having the natural solidity or relief of the object. In Wheatstone's instrument, of course, only geometrical designs could be used. Figures and scenes were unattainable until photography supplied the means by making two simultaneous exposures of the same subject with two lenses placed equally apart from a median line.

Sir David Brewster (1781–1868) replaced Wheatstone's mirrors with round prisms and in 1844 produced a practical apparatus, which we know as the refracting or lenticular stereoscope. And it is here that we find the first liaison with animated photography.

The chrysalis from which the metabulous, beautiful, brightly colored butterfly—our cinema—emerged, seems to have been the stroboscope—*strobos* is derived from a Greek word meaning "a whirling." But a thousand years before 1833, the year when, within a few months of each other, the Belgian Plateau and the Austrian Stampfer developed their inventions, a Roman poet, Lucretius Careus, wrote a verse practically dealing with "moving pictures." Translated from the Latin it is something as follows:

"Verily, it is no miracle when images move their arms and other members of their bodies around, in rhythmic time. Indeed, as one passes another appears in different pose, the former seems to have changed its gestures. The change of course must take place rapidly."

However, Lucretius expresses only the fact of the persistence of vision, not the mechanics or the demonstration.

Wilfred Funk in his book "So You Think It's New," attempts to go still farther back and writes: "Movies? They had them in far-off Greece. Pictures were painted on pillars in progressive fashion, the idea being to ride by them on horseback and thus get the effect of motion. Then some smart inventor devised a better method. He painted a series of pictures in spiral sequence on a single revolving pillar. This was spun by a rope and thus the audience enjoyed the first cinema."

Plateau and Stampfer painted moving figures, for instance, that of a dancer, on the periphery of a disk and on that of a cardboard they cut slits, the number of which depended on the series of subjects and the speed of the motion. These, turned quickly by hand, revolved on their axes in front of a mirror, producing the illusion of movement in the figures.

Faraday took up the subject of dividing the apparent animate movement of objects from the inanimate and *vice versa*. He read a paper before the Royal Society in 1831 on "A Peculiar Class of Optical Deceptions Showing Wheel Phenomena."

Plateau called his apparatus *phenakistiscope, phantasmascope,* and *phantascope.* In Austria they were called *zoetropes* and other names. In 1833–1834 the Englishman Horner described the "marvel drum." The Scotch physicist Maxwell constructed such a drum with optical adjustment by inserting concave lenses into the viewing slits of the drum. The American patent of A. B. Brown, August 10, 1839, is the first to mention the rapidly changing exposure, interrupted with the aid of a rotating shutter and at the same time simultaneously interrupting the picture plate. This arrangement corresponded to the Maltese Cross of modern motion picture apparatus and presents in its essential characteristics the modern motion picture machine.

I have no doubt you are better informed than I am on the development of the motion picture industry in the photographic field, its cameras and accessories, its reproduction of color, and its synchronization with sound. At any rate, the technical journals specializing in motion picture engineering and production give a much better presentation of the subject than I could possible do. However, my cursory study of the subject and the information gained from the Historical Committee of your Society have given me certain information which I have combined in the following paragraphs.

Edward Muybridge, born in England in 1830, emigrating to America, became a professional photographer and was appointed director of Photographic Survey of the California Coast. In 1872 he attracted the attention of Governor Leland Stanford of California, who was a lover of horses and kept a racing stable. A wager on the question of whether a horse when running at full speed touched the ground with one or more feet, led Governor Stanford to the desire of registering this motion. At about the same time a Frenchman, Jules Marey, pursuing an investigation along the same lines, had devised a system for the analysis of movement, which he called Chronography. Governor Stanford, who heard of this, had the happy idea to settle the wager by the aid of photography, an idea quite novel when we consider photographic technic at that time. Marey had never thought of such a possibility but Muybridge practically devoted his whole life to the perfecting of motion photography. In the analysis of movement Marey and Muybridge kept each other informed of the progress of their work and the experiments of these two men make an interesting study.

Researches by Terry Ramsaye, reported in "A Million and One Nights—the History of the Motion Picture," indicated that little or no progress was made in the solution of the problem by Muybridge and that Governor Stanford finally called in an engineer, John D. Isaacs, who worked out the fundamentals of the scheme, tried out the scheme successfully, and then turned it over to Muybridge. During the succeeding years, Muybridge applied these ideas with considerable skill, but did not show any originality in improving upon them. The date when Isaacs obtained satisfactory pictures by this method was about 1882, although Muybridge has often been erroneously credited with working out the scheme several years prior to that date. He died in 1904.

Ducos du Hauron patented in 1864: "An apparatus having for its purpose the photographic reproduction, in any quantity, of a scene with all the changes to which it is subjected during a specified time." The apparatus was never constructed. The details of the patent were never published and his methods are unknown today. He was far ahead of his time. His arrangement of rotating lenses was realized thirty years later by the American Jenkins.

C. Francis Jenkins (1867–1934) played a noteworthy role in connection with motion picture photography in America. Jenkins was the founder of the Society of Motion Picture Engineers. He constructed in 1893 a motion picture camera called the "*Phantoskop*" which was described in the "The Photographic Times," Vol. **25,** p. 2, July 6, 1894. A peep-hole type of viewing machine was also invented by Jenkins and a patent, U. S. No. 536,539 was issued to him on March 26, 1895.

Research by your Historical Committee has shown that these early devices of Jenkins had no commercial practicability, and that it is Thomas Armat, rather than Jenkins, who is entitled to major credit for the design of the first successful motion picture projector. In subsequent years, Jenkins devised and developed valuable inventions related to the science of motion picture engineering, among which the high-speed camera was one of the most successful.

The contributions of William Friese-Greene, an English photographer, and those of our own Thomas Alva Edison (1847–1931) fall within our own times and within the much more comprehensive compass of your own experience.

Auguste and Louis Lumière of Lyons, France, not only coined the word "cinématographe" and gave their first exhibition at Paris in 1895, but were also the first to place on the market remarkably simple and efficient apparatus for taking and projecting serial pictures in which the perforated film strip was for the first time held and moved by a gripper. It is, of course, well known that this firm had been making dry plates for years. The history of the Brothers Lumière and their accomplishments deserve a special biography, for their services to photography in all its branches are extremely important.

In conclusion, I can but ask you to compare your present palatial and itinerant motion picture camera on automobile trucks with the apparatus with which the early American photographers had to contend. Professor Robert Taft, in his splendid book on *Photography and the American Scene* recently published by Macmillan, speaks of "independent photographers who were gradually pushing west (or east from the west coast) as the line of the frontier gradually changed." He speaks of C. E. Watkins of San Francisco, who was born in New York and went to California as a young man around the 1850's. In 1861 "Watkins made his first trip into the Yosemite Valley, which was disinguished by the fact that he took with him a camera constructed by himself, capable of taking a plate 18 × 22 inches in size. The use of these large plates by a wet plate photographer, working under the most favorable circumstances, was attended with considerable difficulty. It was a feat of no mean skill to flow the collodion on these plates, obtain a uniform film, and then sensitize, expose, and develop them when they were still moist. . . A twelve-mule train was necessary to transport Watkins and his supplies to the valley, and five of these mules carried his equipment as he made his photographic tour of the region. As each photograph was made the darkroom tent had to be unpacked and set up, the plates prepared in the small tent, and developed immediately after exposure. The equipment was then repacked and the mule train moved on to obtain the next view."

The daguerreotype of 1839, the Centenary of which we are commemorating this year, has developed into the ubiquitous photography of today, invading every field of art, science, and industry, of which the motion picture is such a brilliant example—it has been a long road to Hollywood!

THE SURFACE OF THE NEAREST STAR*

R. R. McMATH**

Summary.—*Taking motion pictures of celestial phenomona that show change is not as simple as it would first appear. Work on spectroheliokinematography was started in 1928, and in 1931 the instrumentation was donated to the University of Michigan by the founders of the McMath-Hulbert Observatory.*

The combined tower telescope and spectroheliokinematograph of this observatory, now one of the most powerful pieces of solar apparatus in the world, is described and some of the solar data obtained with it are discussed.

The atoms in the surfaces of all the billions of stars accessible with our telescopes may fittingly be compared to minute sending stations, broadcasting each on its appointed multitude of narrow wave-length bands, preserving their allotted "channels" with almost infinite exactitude and endeavoring thus to send us certain important messages relating to the temperature and the constitution of the stars in which they are located. With out telescopes, and to a far greater extent with those optical receiving stations we call spectrographs, we are today reading a few of the messages these distant stars are endeavoring to broadcast to us.

Certain equally important messages relating to the actual spatial behavior and physical movements in stellar surfaces seem, however, permanently beyond our reach. For no telescope, existing, projected, or imaginable, can show a star to us as anything but a diskless point of light; an actual stellar diameter of a million miles or more will vanish almost into a mathematical point at stellar distances of trillions or quadrillions of miles.

Thus it becomes very fortunate for our knowledge of the distant stars that we have a star so close at hand that we can see its disk and study the actual motions on its surface. The star referred to is, of course, our own sun, a mere bagatelle of ninety-three millions of miles distant, and, fortunately for the truth of the deductions we may make from it as to the surface behavior of stars in general, a respect-

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** The McMath-Hulbert Observatory, University of Michigan.

able, run-of-the-mill, middle-aged star, neither very hot nor very cool as stars go, and neither a giant nor quite a dwarf among its millions of brother suns. The entirely average position of our sun as to size, luminosity, mass, and other characteristics thus facilitates and makes more probable any deductions we may wish to draw from it in application to more distant suns. To repeat, any study of the stars of our universe must start with and be based upon a study of our nearest star—the sun.

About twelve years ago the writer, with two most helpful colleagues—Judge Henry S. Hulbert and the late Francis C. McMath, my father—decided that a fallow and hitherto neglected field lay invitingly open for research through the application of the motion picture to such astronomical phenomena as exhibit rapid motion or change. A small, but most completely equipped telescope was designed and built for the highly exacting technic of the motion picture as applied to astronomical photography, and this installation was located at Lake Angelus, about five miles to the north of Pontiac, Mich. The instrumental equipment was gradually augmented and improved through several years of gradual evolution and development, too long and too technical to detail here, and in 1931 the plant, under the name of the McMath-Hulbert Observatory, was deeded by its founders to the University of Michigan.

Our initial aims were frankly educational. We envisaged the manifold assistance that carefully planned astronomical films would give to the work of astronomical instruction in schools and colleges. How much more effective it would be, we reasoned, to project for a class a three-minute film, showing, for example, the rotation of the planet Jupiter on its axis and the revolutions of its moons about the planet, than merely to lecture to a class that such things were happening. Many thousand feet of such educational films were taken by the McMath-Hulbert Observatory of planets and their satellites, the phenomena of sunrise and sunset on the slowly rotating moon, and similar subjects, and a considerable number of educational reels of such types have been shown to scientific societies and distributed to schools and colleges.

It is with a feeling of some regret that we have had to drop most of our efforts to provide purely instructional adjuvants for astronomical teaching—we hope only temporarily—for we are still firmly convinced as to the great value of such astronomical films for the instructor as well as for the student.

The reason for this temporary abandonment is comparatively simple; it has come about merely because a further extension of this motion picture technic to that nearest star we call the sun has opened up such new and astonishingly inviting fields of scientific research that we have been compelled, willy-nilly, to devote every waking moment to a new and fascinating field of most useful scientific work on the sun—the actual depiction of the storms around sun-spots, and the intricacy of the motions of the mighty gaseous prominences

FIG. 1. The McMath-Hulbert Observatory of The University of Michigan, from a photograph by Sidney D. Waldon.

that rise for many thousands of miles above the solar surface, and move and change and disintegrate with speeds that range from a few miles per second up to explosive velocities of several hundred miles per second. The many puzzles which are exhibited by these new pictures, some of which remain as yet unsolved, force us to the conclusion that our initial purely educational aim must give ground for the present to a program of pure scientific research.

There are several respects in which the new motion pictures of solar phenomena are unique, and we may be pardoned for assembling certain of their outstanding characteristics at this point.

(*1*) These pictures are in a very real sense "modern," inasmuch as the first solar films taken with the new McMath-Hulbert tower telescope were made on July 2, 1936, one day after the completion of the tower.

(*2*) They are definitely unique, because no other installation at present exists which has the instrumentation for similar motion picture records of solar phenomena.

(*3*) They were the most nearly *continuous* records of solar phenomena ever made, and in this factor, as will be noted below, lies perhaps the largest portion of their value as scientific documents for research purposes. Photographs of the solar surface in white light, and spectroheliograms of solar prominences in the light of calcium or hydrogen have been taken for several decades, but most of these were effectively "stills," to use the terminology of the motion picture studio. Such stills, taken at time-intervals of an hour or less, have given valuable data as to the changes occurring in solar features; the continuous character of these new records shows, however, the changes *as they are taking place*, and not only make possible a more detailed study of the mechanisms underlying the phenomena, but also have brought to light a mass of new details, hitherto unsuspected, and unrecorded in the still pictures of the past.

There are in the world to-day seven tower telescopes for studies of the sun; that at Lake Angelus is not only the most recent, but embodies many refinements of design. This instrument may be succinctly described as a telescope which remains fixed in a vertical position, with an arrangement of motor-driven mirrors at the top of the tower, termed a coelostat, to follow the sun as it moves across the sky and to throw its image vertically downward; the Lake Angelus instrument is approximately fifty feet in height. The various mirrors in this optical train are of pyrex, which is peculiarly fitted for solar instruments because of its very low coefficient of thermal expansion. These mirrors are covered with a thin coating of aluminum, deposited by evaporation in a vacuum; due to this use of mirrors rather than lenses, we have an achromatic telescope that is exceedingly rapid photographically. For this reason, the exposures with the Lake Angelus apparatus may be made very short; exposures on solar prominences in current work range from ten to thirty seconds, where most other installations must count their exposure times in minutes rather in seconds; such short exposures make for a record that is practically continuous.

At the bottom of the tower the solar image formed by the mirror train falls upon the slit of a spectroheliograph. This rather technical instrument may be briefly described for the layman as a spectrograph which passes the light from the solar image through a narrow slit and then through a lens to a grating or prism which is located in a heavy rotatable steel cage in a well thirty-five feet deep beneath the tower. The grating disperses and spreads out the light in the form of a spectrum and reflects this spectrum through the same lens back to the upper end. Here a second slit is installed that is the "heart" of the apparatus. With this second slit we pick out some one particular wavelength of some element in the solar spectrum and *throw all the rest of the solar light away.* Solar prominences, for example, are particularly rich in the elements calcium and hydrogen. Thus we may pick out one definite wavelength of calcium and secure a photograph of a narrow strip of the sun where the solar image falls upon the narrow slit, *in calcium light only*, where an ordinary photograph in "white" light would show nothing, because of the overpowering brilliance of the light coming from other chemical elements in the sun. But a photograph of a narrow strip of the sun in calcium light would be useless and almost meaningless; what we need is a calcium or a hydrogen light picture of a considerable area, either of the solar disk itself or of an area of the solar limb where some large prominence is seen in profile. To secure such a picture of an area, the first slit is moved back and forth over the chosen area of the solar image and the second, or "picking-out" slit is given a precisely equal but exactly opposite motion so as always to receive the calcium wavelength of the spectrum reflected from the grating, and that wavelength only.

The result of this scanning process, performed twice a second, is a calcium or a hydrogen picture of an area. Some other elements may be selected as well, in case we wish to secure an iron picture or a helium picture, and all these pictures in the light of some chosen element would ordinarily be entirely invisible, but are made possible only by this process of sorting out a definite wavelength and discarding all the rest of the light from the sun.

The above brief and schematic description, manifestly, can give but a slight idea of the actual complexity of the apparatus, some conception of which may be derived from the fact that there are about forty small electric motors scattered over the tower mechanisms from the coelostat at the top to the grating cage down in the well, and each of these is controlled by its individual push-button. In these respects the present installation is doubtless the most convenient in existence, as the observer at the spectroheliograph head can perform any adjustment or manipulation without leaving his station, merely by pressing an electric push-button.

The apparent complexity of certain features of the mechanism of this tower telescope is, in some senses, merely a necessary consequence of the exacting technic that has been found indispensable for the taking of satisfactory motion pictures of this and other celestial phenomena. A "run" or "scene" may comprise anything from a few hundred to over a thousand separate pictures on the film; the word "frame" is customarily used for these individual pictures; six or eight hours of continuous work will ordinarily go into a run comprising a thousand separate frames.

Manifestly, all the frames of a scene must be as perfectly registered as possible, to avoid flickering and unsteadiness on the screen. Early in the work on the moon and planets that preceded this solar work, it was found that no existing form of telescope drive gave sufficient accuracy. Accordingly, merely as a by-product of the larger program, and after four other methods had been tried and found wanting, a new and improved form of telescope drive was devised, based upon an infinitely flexible and instantly variable control of the input electrical frequency to the telescope drive motor, secured through resistance-ballasted thermionic tubes. This form of telescope drive is known as the McMath-Hulbert electric drive; it brings it to pass that the telescope becomes an automatically *following* instead of a manually *guided* apparatus; it has since been adopted for the drive of the McDonald reflector in Texas, for three telescopes at Lick Observatory, and is under consideration for other projected large telescope mountings. The instruments at Lake Angelus were also the first to employ a similar accurately controlled drive in the declination component, in addition to the ordinary motion given in the right ascension coördinate.

In the astronomical motion picture technic, it must also be possible to arrange for any probable desired duration of the actual exposure, as well as for the duration of the "dark time" between exposures. A gearing train in an underground control room adjacent to the tower makes possible the selection of these times and controls the shutter of the special motion picture camera. A description, or even a bare tabulation, of all the necessary mechanical details is, however, manifestly impossible in a general article. Only one additional desideratum may be noted. The hundreds of separate frames in a scene would have scant scientific value as records of motion and change if accurate timing arrangements were not provided. Accordingly each individual frame automatically makes a record of its time electrically on a continuously running chronograph in the underground control room.

With an exposure of twenty-seven seconds on a solar prominence and a dark time of three seconds, two frames will be taken per minute; they will be projected on the screen at the customary rate of sixteen per second, or 960 frames per minute. Thus it will be evident that the projected picture will have a "compression factor" of 1:480. Such a compression of the record is not only inevitable, but a very distinct advantage, rather than a detriment.

Suppose, as is not at all unusual, that a bright knot is seen to form 100,000 miles above the solar surface and then to descend at the rate of 40 miles per second, about average as solar prominence velocities run, but still 80 times the speed of a high-power rifle bullet. Its total time of descent to the sun will be forty-two minutes. Instead of having to wait that long in our seats to see the history of this descending knot, the above compression factor of 1:480 reduces it to about 5 seconds, and a scene which is made up of several such knots in motion will occupy the very convenient interval of 20 or 25 seconds and appears practically continuous in its record of motions and changes.

By design, considerable space has here been given to an outline of the technic of the motion picture as adapted to an astronomical end, and the apparatus necessary for the purpose, in order to emphasize, not only the more difficult features of the research on its mechanical side but also the unique character of the resulting record.

During the seasons of 1936 and 1937 over ten thousand feet of standard 35-mm. film were exposed in the new tower telescope on the solar prominences or on features of the solar disk itself. Even though every possible mechanical convenience or electrical adjustment has been provided, and even though this tower telescope has been pronounced to be the most rapid, flexible, and convenient in existence, the total amount of labor and attention involved in taking over one thousand separate photographs in the run on a clear day which may extend from 8 A.M. or earlier till 6 P.M. is very considerable. It is a pleasure to make acknowledgment at this point to my two colleagues and to those who have assisted in the somewhat complicated

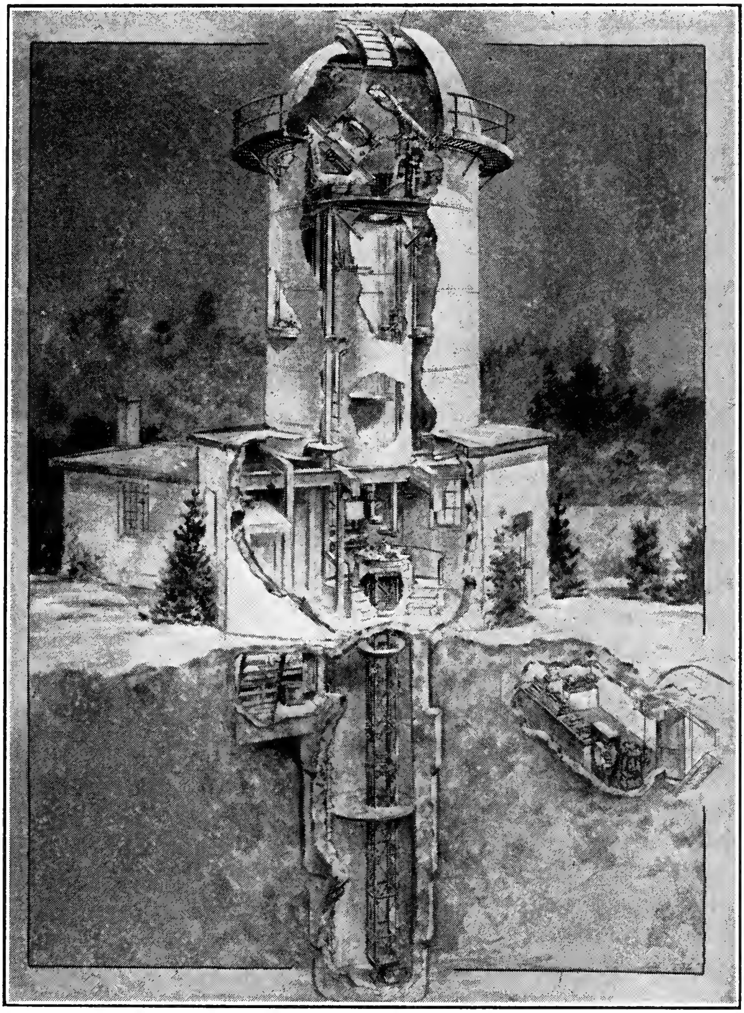

FIG. 2. The 50′ tower telescope of the McMath-Hulbert Observatory from a drawing by Russell W. Porter.

technic of solar prominence photography and measurement—to our research associate, Dr. Edison Pettit, of the Mount Wilson Observatory, and to Harold E. Sawyer, assistant astronomer, and John Brodie, assistant, in the McMath-Hulbert Observatory; others have given assistance for shorter periods. We owe also a special debt of thanks to Dr. Heber D. Curtis, director of the observatories of the University of Michigan, who has, from its very inceptance, given every encouragement to this program of solar research and every assistance within his power.

These films, when projected under proper conditions, show scenes of unexampled grandeur, and radically change our preconceived notions of the surface of a star. Though we knew from the "still" photographs of the past that the sun's surface was marked by constant activity as manifested by those solar storms called sun-spots, by the flocculi and by the prominences, these films for the first time bring to us the actual motions in a continuous record, which we may repeat as often as we need for our scientific studies. These motion pictures very effectively change our conception of a star's surface from something at least relatively static to a picture that is intensely kinetic; we begin to realize that the surface of a star is an unending maelstrom of motions due to titanic forces whose precise nature can not as yet be regarded as completely explained.

Even though we are astronomers, we are very human, and we too derive much the same pleasure as does the layman who sees these films and is enthusiastic in his praise of them, viewed merely as inspiring spectacles. And yet, strange as it may seem, we who are taking and studying these new records of solar activity take rather amiss the enthusiastic praises we hear from laymen or from scientists in other fields who apparently regard them as merely interesting "movies." We feel quite strongly that the magnificence of these displays is, in many respects, only a very secondary consideration in our evaluation of these pictures as scientific records, from which facts of very definite value are being derived as to the actual nature of the surface of a star.

"Conflagrations," explosions, skyrocket sheaves of light like the grand finale of the 4th of July celebrations of our boyhood, are all admittedly inspiring when we realize the tremendous speeds that are actually involved, the temperature of more than 10,000°F, that our pictures embraces an area 150,000 miles high and 200,000 miles wide, and that our earth would be but a small disk on the same scale and quite unimportant in comparison to the mighty flames and streamers of incadescent gas that form these solar storms. Yet to us the motions and laws of motion that we are deriving and the nature of the mysterious forces that seem eternally operative on the surface of a star are much the more important considerations as we view these new films.

This new method of attack on the problems exhibited by the surface of a star is still too youthful to admit of explanations of each and every phenomenon observed. Fresh puzzles too frequently show themselves in each run on a new and active prominence, and if the history of our past work is any criterion, the coming season of 1938 will bring to light as many new features as have those of the two preceding years. The complexity of some of the more active prominence displays frequently baffles description, and we often find that the only way to be sure of all that is taking place is a repeated showing of the film; frequently we will notice some minor peculiarity or puzzle in the tenth or twelfth showing that had previously escaped us and had, of course, never been suspected in the still pictures of the past.

While, as already noted, we are still working on many of the puzzles presented, and are withholding a more precise formation of hypotheses till more data have been collected, some of the results of the work on the sun with the new tower telescope and our improved motion picture technic may be assembled as follows, either in more general statements or in descriptions of isolated phenomena.

(*1*) It has become necessary to add three subdivisions to Dr. Pettit's accepted classification scheme for solar prominences, to include three new types of prominence whose existence was not hitherto suspected. These are:

(*a*) *Surges*.—These are very short-lived prominences like spearheads of flame, that stab upward 1000 to 10,000 miles or so from the solar chromosphere and as rapidly subside again, with a total life period of only a few minutes. As seen in profile in runs on prominences, the limb of the sun will occasionally exhibit an almost continuous activity of this type. In pictures of the solar disk proper, the sudden short-lived splotches of brilliant light that appear and disappear in areas about sun-spots are believed to be these same surges, seen from above.

(*b*) *Ejections*.—This name has been given to the balls of luminous chromospheric matter thrown out of sun-spot areas like Roman-candle displays. They are relatively faint and seem to leave the sun without returning. In one or two cases these balls seem rather more like hollow spheres or perhaps in the form of smoke rings; it is difficult to decide with the material now available.

(*c*) *Coronal Type Streamers*.—These are very puzzling. In such

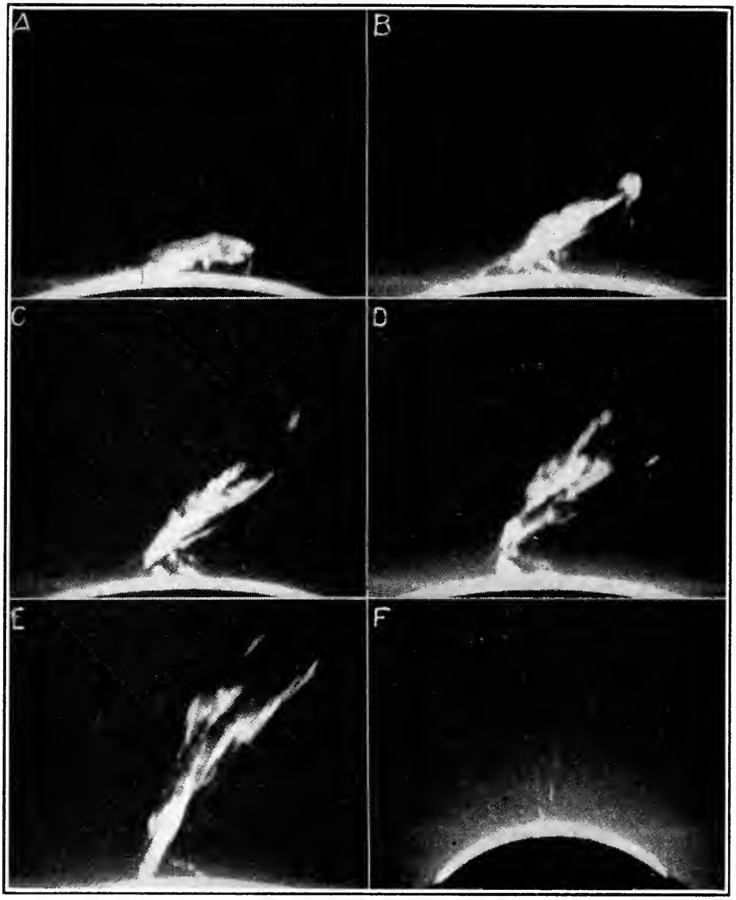

FIG. 3. Great eruptive prominence of September 17, 1937, photographed at The McMath-Hulbert Observatory.

A. $14^h50.^m69$	B. $14^h55.^m84$	C. $15^h06.^m13$ GCT
D. $15^h09.^m11$	E. $15^h14.^m31$	F. $16^h06.^m\ 7$ GCT

Exposures A to E with 20-ft. focus mirror, F with lens of 74 inches focal length. In "F" the prominence goes out of the picture 1,000,000 km. above the sun.

streamers matter appears to form, or more properly to become luminous, at an altitude of 120,000 miles or more above the surface of the sun and then to descend in successive streamers to the solar surface. These coronal streamers are generally rather faint and have never been detected before.

(*2*) Several very interesting examples of *violently eruptive* prominences have been recorded. For one of these, taken in September, 1937, though the entire period covered by the scene was only 80 minutes, the upper portions could not be kept within the motion picture frame in spite of three successive changes to shorter focal lengths; the total height was about 620,000 miles, which held the world's record until the recent record of 900,000 miles for a prominence photographed at Mount Wilson. The velocity of this Lake Angelus prominence reached 432 miles per second; as this is considerably greater than the "velocity of escape" under gravitational attraction at this distance from the sun, this is believed to be the first recorded instance where we have observed matter shot out into space beyond the sun's attraction, though such possibilities have long been recognized in theory.

(*3*) *Arch Types.*—Several great arches of unusual interest have been recorded. In one of these it was nearly 100,000 miles between the "feet of the rainbow." Though there was no noticeable accretion of material at the top of this arch, luminous knots of gas are observed continuously descending to the sun in *both directions* from the summit on the arch. Why?

(*4*) *Predominance of Matter in Descent.*—Even if we include the prominences of eruptive type mentioned under *2* above, perhaps 90 per cent of our prominence scenes record matter in descent only. On a number of great "banyan-tree" prominences, with multiple stalks or trunks connecting the enlarged upper portions to the chromosphere, bright nodules of matter will be observed spiralling downward along the "trunks." We have mentioned above under *1c* the growth luminescence in, or actual formation of faint clouds high above the sun, from which the coronal type streamers descend, phenomena which seem to necessitate the postulation of some form of solar chromospheric atmosphere intermixed with the corona.

Much the same class of phenomena are exhibited in lower bright streamers of the beautiful "set-pieces" of a fountain type; the motion of descent is here often clear and rapid; any corresponding ascent of matter on a possible rising arm of the complete trajectory is either very much fainter or entirely absent. Astronomers who see these films for the first time frequently attempt to explain this curious phenomenon by ascribing the invisibility of the ascending side of the streamer to the Doppler effect, arguing that some velocity in the line of sight moves the wavelength under observation "off the slit" for the ascending branch and implying that these films give a partial rather than a true picture of these motions. We are utterly unable to accept this explanation in the vast majority of cases, for we have noted only two cases of sudden brightening of small patches near the chromosphere that may possibly be due to the Doppler effect, that is, to a velocity in the line of sight sufficient to bring a different wavelength and hence a previously unobserved detail into the slit of the instrument. But an elementary consideration of the geometry of these prominence arches would predicate roughly equal velocities in the line of sight for matter at corresponding portions of the hypothetical ascending or the descending branches of the arch. Moreover, although workers in the past have maintained that narrow slits are an inescapable necessity in spectroheliographic work, we have, as a result of numerous experiments with wider slits, taken beautifully clear and sharp spectroheliograms in the *H* alpha line of hydrogen with *both* slits 0.5 mm. (about one fiftieth of an inch) in width. This width would necessitate a difference in radial velocity of about ± 110 km. per second (68 miles per second) to move a portion of our picture off the slit and thus render some parts invisible. While higher velocities are occasionally observed in eruptive prominences, such velocities have only rarely been found in these arch trajectories.

The phenomenon remains a puzzle. It is apparent that what goes down very probably came up, but why should the upward journey be predominantly invisible? Is it that the gases on their upward path are in some different temperature or ionization state, changing back to another and photographically recordable state soon after passing the crest of their trajectory? Data are being collected that may eventually give an answer to this pressing and difficult question.

(*5*) Previous work had detected *no motions* within the *dark* hydrogen flocculi. We have been fortunate enough to "catch" and to photograph for a total elapsed time of $5^1/_2$ days an enormous hydrogen flocculus whose total length must have been of the order of 700,000 miles, extending over a considerable portion of the solar disk. Its internal motions and its final disintegration were clearly recorded. So far as is known, this is the first case where the life-history of one of these dark hydrogen flocculi has been followed from its first appearance to the end.

(*6*) Abundant confirmation has been secured in the study of motions in prominence streamers in support of the curious *laws of prominence motion* discovered earlier by Dr. Pettit. The velocity of a prominence or prominence formation is uniform, increasing suddenly at intervals. When there is a change in velocity the new velocity is generally a simple multiple of the previous velocity. That is, a knot that has been moving along a streamer, at a uniform speed of, say, 21 miles per second will suddenly (sometimes in less than a minute) be accelerated to a uniform speed of 42 miles per second, without any apparent transition through intermediate velocities. This puzzling phenomenon has been studied and extended to include nearly all prominence types at Lake Angelus. Like some others found in the Lake Angelus work mentioned above, it shows that we have many still unknown factors with which to deal before we can secure an explanation of all the laws that govern the motion of gaseous matter near the surface of a star.

Such, then, are some of the results, as well as some of the problems, that are growing out of the application of this new technic to the study of a star's surface behavior; the work is being continued as fast as time and money will permit. The very richness of the material being secured has its embarrasing features; it will easily be seen that the detailed measurement of the motions even in one tenth of the frames of a prominence picture that includes over a thousand separate pictures involves a great deal of time and not a little calculation. The number of the prominences, as well as the number and the activity of the flocculi and other disk features, shows an intimate connection with the curve of the number of sun-spots that reaches a maximum roughly every eleven and a third years. We have recently been passing through a period of maximum sun-spot activity, but we do not yet know what detail changes in prominence activity will be observed on our films at a sun-spot minimum. We are inclined to predict that while we shall then have fewer prominences on which to work, they still will be of equal value in formulating theories of the surface layers of a star. Certainly only a beginning of our program of research will have been made until we have worked completely through at least one sun-spot cycle.

At the close of his presentation, Mr. McMath showed motion pictures of the sun taken with the spectroheliokinematograph described in the paper. The motion pictures showed the prominences and other phenomena of the sun taken under hydrogen and calcium light. The types of prominences and streamers are described in the paper. Sun spots and other eruptions and ejections were shown.

DISCUSSION

MR. MCMATH: Please bear in mind that you were looking at atoms, and do not try to interpret what you have seen in terms of molecular physics. The temperatures are at least 10,000 °F, and as far as we know there are few molecules or atoms in association at that temperature. Of course, we are photographing a very simple atom.

Mr. Crabtree: How long do the eruptions last?

Mr. McMath: The duration is measured in either days or minutes, the shortest being about 20 minutes.

Mr. Kellogg: Mr. McMath has given us a real thrill. How nearly the same would the picture be if it were taken with hydrogen instead of calcium? Are the gases localized? Is what we saw a phenomenon in hydrogen gas alone, or calcium alone?

Mr. McMath: No, it appears that the prominence is a homogeneous mixture of gases. They actually are about 98 per cent hydrogen gas, and the rest is principally calcium and helium. As we approach the chromosphere we commence to get traces of heavier elements, for instance, sodium. We have simultaneous pictures, many thousands of feet of them, taken in calcium and hydrogen, at precisely the same time, and the two pictures look practically alike, and the two gases behave alike and measure alike.

Mr. Kellogg: Is what appears to be motion really regions of intense progressive ionization of gas by free traveling electrons or by electromagnetic waves, rather than the motion of the material itself?

Mr. McMath: It is a very long story. These prominences are seen at eclipses, and we have some eclipse photography under the whole integrated light which would eliminate some spectroscopic implications. Since we have done this work in neutral hydrogen atoms, as well as the ionized calcium, we believe that we are looking at the streaming of individual atoms.

Mr. Matthews: How thick is the chromosphere? Does it vary in thickness from time to time?

Mr. McMath: It will average from between 5000 and 6000 kilometers at eclipses. When a picture is taken with white light with an ordinary camera, we get a picture of the photosphere. That is where the spots show up black. Just above the photosphere is a layer of gases, the chromosphere. This is the reversing area, from which we get the dark hydrogen line of the solar spectrum, known as an absorption line. In the prominences, of course, we take the picture in the emission line of the hydrogen.

Mr. Wolf: What do you anticipate can be done with the new 200-inch telescope?

Mr. McMath: It will probably never be used on the sun. I am on the Advisory Committee for the 200-inch telescope, and I wish it would be used for the sun, but it will not be. There are some objections to solar work with an equatorial telescope, not easily explained in a few minutes.

Mr. Johnson: In the course of the day is there a sensible change in the apparent motion of the sun?

Mr. McMath: That is due to refraction. At sunrise and sunset we get maximum refraction. At sunrise the sun appears in the telescope to travel more slowly than it does when on the meridian at noon.

Mr. Matthews: Have you any explanation of why the prominences are drawn back in?

Mr. McMath: No. All the earlier work was based on material rising from the sun. An English group tried to explain the prominences by radiation pressure. Now we find, in, say, one hundred hours of photography, about 90 per cent of the pictures show material going down into the sun. All evidence obtained at eclipses denies specifically the existence of chromospheric material in the corona or in the solar atmosphere, we will say. However, we are forced into the postulation of some kind of solar atmosphere. The material is certainly there. It would not appear out of nothing.

MR. STROCK: Are these prominences the disturbances that are correlated with radio fading?

MR. MCMATH: Not always. That problem is being investigated by J. H. Dellinger of the Radio Division of the National Bureau of Standards, and others. There have been certain chromospheric eruptions that have been coincident with general short-wave radio fadeouts on the sunlit hemisphere. We do not know precisely what type of activity is associated with these fadeouts. Sometimes very intense activity has no noticeable effect upon radio reception. The enormous eruption of September 17, 1939, had no effect upon radio reception at all, and yet it was very intense.

MR. STROCK: Do we know whether these prominences are tied in with the so-called eleven-year sun-spot cycle?

MR. MCMATH: They occur with solar activity. The more sun spots, the more solar activity; and the more solar activity, the more prominences.

THE ELECTRICAL PRODUCTION OF MUSICAL TONES*

S. T. FISHER**

Summary.—*Music is a study that is primarily an art; its scientific aspects have been recognized since ancient days. An outline is given of the physical basis of harmony upon which in turn are based the musical scales. A short outline of the historical development of the modern scale is included, the discords produced in the tempered scale due to natural harmonics and summation and difference tones being noted. In the electronic instruments the musical tones can be generated as such in the first instance, or may be produced as a synthesis of pure tones; instruments embodying these principles are described briefly. A method of the synthesis of musical qualities is described, and at the presentation of the paper, such tones were demonstrated using the Hammond (electric) organ, the wave-forms being shown on an oscillograph.*

In conclusion it is suggested that the possibility of removing the limitations of the traditional keyboard instruments gives an opportunity of abandoning the tempered scale in favor of the just scale.

This paper deals with a topic that lies partly in the realm of art and partly in the realm of science; it is not clear where one ends and the other begins. If the question is debated as to wherein lies the superiority of Beethoven over Puccini, science can take no part. The problem is either too vague or too complicated to be dealt with on a precise basis. Physics can not tell us why we find Beethoven particularly pleasing but it can explain why an error made in transposing his music from one key to another would make it disagreeable.

Let us first look at the elementary facts of the physical basis of music. Music is an art; our response to it is psychological and emotional. Nevertheless if, as engineers, we set out to produce, to transmit, and to reproduce music, we are forced to translate the intangible into terms of the tangible. Just as a knowledge of anatomy is basic in the training of a sculptor or painter, so in music it is necessary to understand the arithmetic that forms the groundwork of the art.

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There are three attributes that we recognize as essential in music: rhythm, melody, harmony. *Rhythm*, the maintenance and accenting of the time intervals at which sounds are produced, is the simplest and most obvious part of music, and is the chief characteristic of primitive music. *Melody* is the linking together of notes of different pitches and durations in a sequence that is pleasing, harmonious, and readily capable of being memorized. It is the attribute of music next in complexity to rhythm, and many modern types of music, *e. g.*, the Persian, consist only of single notes played in sequence and in rhythm—the kind of music a man whistling and tapping his foot produces. The third attribute, *harmony*, is inextricably bound up with melody in a very complicated fashion, and is the art and science of sounding two or more notes simultaneously so that a pleasing effect is obtained, of greater richness, variety, and interest than a single note can produce.

It is plain that music requires a fixed series of notes whose pitches, *i. e.*, frequencies, are such that they give pleasing effects when sounded in various sequences, and that can be grouped in a number of ways and sounded simultaneously without offending the ear. What then are the physical realities back of such terms as "pleasing," "offending"? A melody sounds well when its component notes are those that sound well in harmony. This leads to the simple rule that has been universally recognized for at least 30 centuries as the fundamental basis of music: *Two notes sounded simultaneously are harmonious if the ratio of their frequencies can be expressed as the ratio of small integral numbers.*

From this rule, we should expect that notes with the following frequency ratios would be harmonious, the degree of concord lessening as we go down the list:

$$\frac{1}{1}, \frac{2}{1}, \frac{3}{1}, \frac{4}{1}, \frac{5}{1}, \text{ etc.}, \frac{3}{2}, \frac{4}{3}, \frac{5}{3}, \frac{5}{4}, \text{ etc.}$$

The reason why the combination of two tones is harmonious when the tone frequencies have a simple numerical ratio has been the subject for conjecture since Pythagoras, who flourished about 700 B.C. Pythagoras considered such harmony inherent in nature and theology; Confucius also solved the problem by a relapse to metaphysics. In the 18th century the mathematician Euler brought psychology to bear, and attributed the concord to our delight in method and orderliness, and proposed an elaborate system long since discarded for rating the concord or discord of various combinations. Rameau and D'Alembert about the same time decided that since an octave and a 12th (octave plus fifth) were produced in nature as the 2nd and 3rd harmonics of a tone, it was in the nature of things that these should be concordant intervals. In 1862 Helmholtz proposed the theory that, with modifications, is generally held today. It really explains, not why concords are pleasant, but why discords are unpleasant. The situation appears to be this: The normal human being gets pleasure from doing difficult things. The crossword puzzle addict cares nothing for simple puzzles; the more baffling they are the more pleasing it is to find a solution. The sportsman who could shoot his partridges on the ground or his ducks in the water deliberately performs the much more difficult feat of shooting them flying.

It appears that listening to single-note melodies is too simple, and so we prefer to listen to complicated tone groups rather than single tones. At the same time if a number of notes are sounded simultaneously to form a single chord, there must be no frequencies introduced that are objectionable. If two notes do not have a simple numerical ratio between their frequencies, then either the fundamentals or some harmonics of these will beat together to form harsh low-frequency beat notes, and the only notes between which tolerable concord exists are those combinations that do not produce such beat notes.

The simplest harmony exists between octaves, that is, between two tones where one is 2, 4, 8, *etc.*, times the other in frequency. This was the only harmony used by the Greeks. It is readily obtained in singing, since men's and boys' voices are about one octave apart; in instrumental music the Greeks obtained it by inserting a bridge in their lyres one-third the distance along the strings. To us this kind of harmony sounds childish, flat, uninteresting. Later, music in Europe, in the first or second century B.C., used the interval of the 5th, which is *CG* on our keyboard, a frequency ratio of 3:2. The 5th is the most important interval in modern music, and stringed instruments and pipes as far back as the 5th century B.C. were tuned to the intervals *C*, *F*, *G*, C^1. Early in the Christian era, a 5-note scale became very common, both in Europe and Asia, and modern Scotch and Chinese music is frequently found in this scale, the notes on our keyboard being *C*, *D*, *F*, *G*, *A*. It will be found that many traditional melodies are played using only these notes, and that any tune restricted to these notes has a characteristic quality that we ordinarily associate with Scotch music. This scale appears to be very deeply rooted in our civilization, almost as deeply as our more common seven-note scale.

The question that naturally arises is: How did our musical scale develop and is there anything unique about it? If there were human beings on the planet Mars, for example, would they have developed the same scale we use or would it be something quite different? The answer is that they would probably have developed our modern musical scale, since it has a certain uniqueness that no other sequence of notes could have and is an attempt to fit a musical notation to the inevitableness of arithmetic.

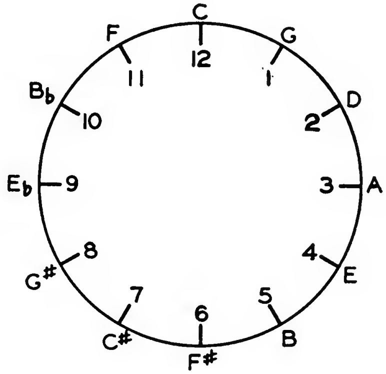

FIG. 1. The twelve semitones of the 7-note scale. Each note has the ratio 2:3 with the note after it and the ratio 3:2 with the note before it (based on relation $(^3/_2)^{12} \div 2^7$).

This scale arose simultaneously in many parts of Europe and Asia over a period of some centuries and the sort of process taking place must have been identical in each locality. There seems to be hardly any doubt that the development was as follows: A pipe or string would be tuned to some note, say *C* on our keyboard. At the dawn of musical appreciation the octave was added, since it was early found that octave notes together give very pleasing concordance. Later, the 5th was added, that is, *G*, and we then had a three-note scale: *C*, *G*, C^1. With the beginning of harmony it would soon be realized that whereas a single-note melody could be made using any desired interval between the notes, as soon as two melodies are combined the notes in the scale have to be adjusted so that the two parts sound well together.

With a scale of *C*, *G*, C^1, the next logical development would be to add a string or pipe that would sound as well with *G* as does *C*. This is again a 5th above *G* and is *D* on our scale. We now have four notes from which several harmonies can be obtained: *CG*, *GD*, CC^1. A later development of harmony also accepted GC^1 although this probably was not accepted at first. Another fifth above *D* gives *A*, and by following this process right up the scale, we find that the notes shown in Fig. 1 are obtained. Going up by a 5th twelve times brings us out again to our starting note *C*, seven octaves up. It is evident that when the early experimenters found they had again reached *C* they would consider that they had used all the natural notes and would be content with this scale of twelve tones. In other words, the modern musical scale is an inevitable result of the elementary equation in arithmetic:

$$\left(\frac{3}{2}\right)^{12} \doteqdot 2^7 \text{ (12 fifths = 7 octaves)}$$

$$129.75 \doteqdot 128$$

The equality is not exact but is quite close. The residual interval is a quarter of a semitone, and is called the "comma of Pythagoras," Pythagoras having first pointed out the mathematical basis of the musical scale. A much more exact relation is that

$$\left(\frac{3}{2}\right)^{53} = 2^{31}$$

This would mean a 53-note octave, which is obviously too cumbersome for convenience. With the 12-note scale, if the inexactness of the basic relation is distributed over the twelve notes, we have a scale that obviously gives reasonably good concord and at the same time is fairly convenient, since only five additional notes have been put in to fill the gaps of our basic structure of seven notes. It is interesting to note that a 53-note scale was proposed by Mercator, the map-maker, about 1550, and about the year 1700 several organs were constructed whose keyboard contained 53 keys to the octave. A subsequent simplification was to reduce this to nineteen notes and the 19-note keyboard appears to have been adopted on quite a large scale during the Middle Ages. It is not, however, as exact as the 12-note scale. It will be noticed that the 5-note scale mentioned previously is obtained as any sequence of five fifths. While from the foregoing it is seen that a scale of twelve notes has been constructed, actually, according to a tradition going back possibly to 2000 B.C., a 7-note scale is used, the five additional notes being employed only as accidentals—that is, for occasional effects—or in order to permit music to be shifted in position on the keyboard—that is, to be raised or lowered in pitch. Our 7-note scale is the scale that comes as second nature to everyone, whether he has any musical training or not; this is the familiar *do, re, mi, fa, sol, la, ti, do*. All music is written in this scale, which in the key of *C* is represented by the white notes on the piano keyboard. It is seen that this 7-note scale goes up by unequal increments and, if we adopt the usual musical language, the intervals between the notes in ascending order are tone, tone, semitone, tone, tone, tone, semitone. When the black keys are added as well, then all the intervals become semitones.

A large number of scales have been constructed on the 7-note basis with five additional semitones in which the frequency intervals between the notes have been arranged according to a number of rules so as to give the nearest approach to exact harmony. Most of these need not detain us; three, however, are of outstanding interest: those called the "mean-tone scale," "just scale," and the "equally tempered scale." From the time of Pythagoras it has been recognized that the mathematical basis of the musical scale is inexact and, Pythagoras having pointed out specifically that seven octaves are not quite equal to twelve fifths, a number of schemes have been devised in the intervening centuries to distribute this error in various ways over the scale. The mean-tone scale, proposed by the Greeks and used throughout the Middle Ages, was the first successful attempt to do this. In this scale the twelve ascending 5ths making up the seven octaves were each flattened slightly so that the final note was correct in either sequence. This scale was tolerable but suffered from the serious defect that the intervals that were noticeably inharmonious were those most generally used. In the mean-tone scale a tone was a frequency ratio of 9:8, and a semitone, a ratio of 256:243—that is, the semitone was not half the tone. It will be seen what complication this leads to when it is desired to shift a piece of music upward or downward in the frequency spectrum, the operation the musician calls changing the key. When this is done in the mean-tone scale the harmony is badly disturbed, since the interval of a fifth, for example, can be expanded or compressed, depending on its position on the keyboard. Nevertheless, this scale was in use for many centuries and was used by the earlier of the great modern masters of music. On keyboard instruments where the tuning was fairly exact and where the harmony was complicated, it was very common for the musician to retune his instrument for the key in which the music was set. In orchestral instruments where the tuning is much less exact and the source of origin of the tones more diffuse, this was not done. The stringed instruments, the violin, the viola, the 'cello, and the double bass, do not employ frets on the strings, and as a result the exact into-nation is continually under control of the performer, so that a violinist, for example, could play in the mean-tone scale and, when he changed key, readjust the intervals so that they would still be harmonious in the new key. Factors like these rendered the mean-tone scale satisfactory, even to the great musicians.

About the year 1700, however, the modern scale began to be adopted. It had been known for many centuries and was probably in use in China in 1000 B.C. A complete description of it appears in Chinese manuscripts of 1500 A.D., including the mathematical relations involved. This scale was proposed and became adopted because it has one great merit: it permits the player to shift from one key to another without any change in the intervals by which the scale progresses. There are twelve intervals in the musical scale and the equally tempered arrangement is this: that the frequency ratio of each note to the preceding one is the twelfth root of 2. It will be seen then that no matter what position on the keyboard a piece of music is set, the effect and the harmony are precisely the same, the only difference being an overall change in pitch. The equally tempered scale has one fortunate property, in that the interval of a fifth is almost exact. It is likely that one of the contributing causes toward the adoption of this scale was the fact that, when the development of the piano had progressed through the stages of spinet, harpsichord, clavichord, and all the others, to the modern form, the difficulty of retuning the instrument for each key, which is necessary on the mean-tone scale and without which the harmonies were sufficiently inaccurate to be intolerable, made it imperative to devise an arrangement in which this retuning was not necessary.

The Greeks, although they had used the 7-note scale, had no such device as a change of key, since they did not employ harmony as we know it. They used, however, a change of mode, something that has almost disappeared from modern music. There were seven modes in Greek music and they were actually not simple changes in pitch of the whole of a piece of music but a change from one sequence of tones and semitones to another; in other words, there were seven different scales. Of these modes, two have remained: our major mode, which is the usual scale *C, D, E, F, G, A, B*, and, our minor mode which may, for example, be *A, B, C, D, E, F, G*. The Greeks attributed definite characteristics to each of their modes and this has been carried into our own music, so much so that the expression "in a minor key" is an accepted English phrase.

Another thing that has been carried into modern musical thought from the modes of the Greeks and more recently the keys of the mean-tone scale, is the fiction that many musicians believe that different keys on the equally tempered scale have characteristic qualities. This simply is not so. A change of key in the equally tempered scale results in nothing except a change of pitch. There is no change in the character of the music. This can be demonstrated beyond any question when it is pointed out that the key of $F^{\#}$ major (6 sharps) uses the identical notes of the key of G^{b} major (6 flats). Incidental effects do, however, exist. A violinist, unaccompanied, tends to play in true harmonic intervals; a change of key changes the number of strings that are played "open," *i. e.*, at their maximum length. Some instruments have different qualities for different positions of playing, as the piano, and in some instruments some notes may be poor, as $C^{\#}$ on the flute, and some notes may be unusually good, as high *D* on the same instrument.

The Chinese musical scale of which mention has been made before, consists of our 12-note equally tempered scale, but the music has this fundamental difference: that all twelve notes are employed in any given piece of music—that is, this music, as a musician would say, belongs in the chromatic scale. This scale was arrived at by the Chinese as an outcrop of their study of numerology and is precisely correct. They took a bamboo flute tube of a given length and made up the scale by shortening the tube in twelve steps, the decrement in length of each step being a fixed proportion of the length of the preceding step.

The equally tempered scale was not much used in England until about the year 1850 and was not generally used for some years afterward. At the Exhibition of 1851, for example, it is said that not a single organ exhibited was in the equally tempered scale but that all were in the mean-tone scale. This seems to be rather a severe commentary on the English ear for harmony, since the equally tempered scale had been adopted generally in Europe one hundred and fifty years before, solely on the grounds that the mean-tone scale was intolerable except in the key of *C*.

The other scale of fundamental interest in music is the just, or harmonic, scale. This is a theoretically correct scale but suffers from the disability that it can be played only in one key. It consists of a series of notes whose frequencies are represented by the numbers 1, $^9/_8$, $^5/_4$, $^4/_3$, $^3/_2$, $^5/_3$, $^{15}/_8$, and 2. It will be seen that all these notes bear simple numerical relations to the key note and therefore this scale is very rich in exact harmonies. Unfortunately there occur in it three different sizes of intervals, one having a ratio of 9/8, one having a ratio of 10/9, and one having a ratio of 15/16, so that at present no keyboard instrument is tuned to this scale. There seems very little doubt, however, that when a violinist is playing unaccompanied by a keyboard instrument, he plays in this scale, and measurements made by Helmholtz and others indicate that this is so. In Table I is shown a comparison of the harmonic or just scale and the tempered scale intervals. This table shows two things: first, the

TABLE I

Comparison of Harmonic and Tempered Scale Intervals

Note	Tempered Scale Frequency	Harmonic Scale Frequency	Harmonic Scale: Harmonics of				
			C	*G*	*D*	*F*	*A*
C	1000	1000	1000	1031	985	1000	1042
C#	1059						
D	1125	1125	1125	1125	1125	..	1146
D#	1189						
E	1260	1250	1250	..	1266	..	1250
F	1355	1333	1375	1312	..	1333	..
F#	1414						
G	1498	1500	1500	1500	..	1500	1458
G#	1587						
A	1682	1667	..	1687	1687	1667	1667
A#	1782						
B	1888	1875	..	1875	..	..	1875
C	2000	2000	2000	2062	1969	2000	2083

divergence of the tempered scale from a theoretically correct scale, and, second the excellence of the harmonies occurring in the harmonic scale between fundamentals and harmonics. In the tempered scale no such fortunate relations exist, since the fundamental intervals are all different from the theoretical values. The harmonics are more and more divergent in notes occurring higher on the keyboard as we go up in frequency.

I have never heard a keyboard instrument played in the just scale but I think there is little doubt that it would give definitely a more pleasing effect than our usual tempered-scale instrument. This would be particularly true on the organ where extremely complicated harmonies both of fundamental and harmonics are obtained. Helmholtz in 1860 commented on this and spoke of the extreme pleasure he got from playing a justly tuned instrument after playing on a tempered-scale piano. Of an organ tuned in the tempered scale he said, "When the mixture stops are played in full chords, a hellish row must ensue and organists must submit to their fate." We still submit to our fate. The just scale gives almost exact harmonies, but can not be played in more than one key without retuning; and the tempered scale

TABLE II

Comparison of Scale of Equal Temperament with Hammond "Tempered Harmonic" Scale

Note	Tempered Scale Frequencies	Frequencies of Harmonics of Notes in Lower Octaves Which Appear in This Octave							
		2nd, 4th, 8th		3rd, 6th		5th		7th	
		Natural	Tempered	Natural	Tempered	Natural	Tempered	Natural	Tempered
C	1000	1000	1000	1001	1000	992	1000	985	1000
C#	1059	1059	1059	1061	1059	1051	1059	1040	1059
D	1125	1125	1125	1124	1125	1114	1125	1102	1125
D#	1189	1189	1189	1190	1189	1180	1189	1168	1189
E	1260	1260	1260	1262	1260	1250	1260	1237	1260
F	1335	1335	1335	1337	1335	1324	1335	1311	1335
F#	1414	1414	1414	1416	1414	1406	1414	1389	1414
G	1498	1498	1498	1500	1498	1486	1498	1472	1498
G#	1587	1587	1587	1589	1587	1575	1587	1559	1587
A	1682	1682	1682	1688	1682	1669	1682	1652	1682
A#	1782	1782	1782	1784	1782	1767	1782	1750	1782
B	1888	1888	1882	1890	1882	1875	1882	1853	1882
C	2000	2000	2000	2003	2000	1984	2000	1969	2000

can be played in all keys, but what should be harmonious relations between notes in the same octave are actually discords. From Table II can be seen an even more important source of discord, particularly noticeable, as it was to Helmholtz, in organs. This is the fact that the 3rd, 5th, 6th, 7th, 10th, and some of the higher harmonics of notes at the lower end of the keyboard do not duplicate notes on the upper end of the keyboard, but are noticeably out of tune with them. In the orchestra then, the 3rd, 5th, 6th, and 7th harmonics of the string basses must cause discord with the violins and woodwind; but the effect is not particularly noticeable, first, because we are used to it, second, because the instruments are all slightly out of tune in various ways, and third, because the source of the discordant sounds is spread over a relatively large angle at the listener's ear. In the pipe-organ, the situation is definitely worse when the mixture stops are played. Mixture stops are those in which rows of pipes representing 2nd, 3rd, 4th, and even up to the 10th harmonic are coupled to the fundamental pipes being played; so clash is inevitable between the natural harmonics of the fundamental notes, which in many cases are very strong, and these synthetic harmonics, which lie strictly in the tempered scale. In the piano, the discord between the natural 7th harmonic and the tempered-scale notes was early recognized as disagreeable, and today all pianos are so arranged that the 7th harmonic is largely suppressed; this is done also in organs and in the brass wind instruments. The oboe, among the orchestra instruments, is characterized by a strong 7th harmonic, and its harsh, penetrating quality may be largely due to the discords thereby produced. Two possibilities of remedying this situation theoretically are not open practically to the constructor of traditional musical instruments. The theoretical possibilities are: First, to supress all natural harmonics and use only tempered ones. This is obviously not possible practically, except to some extent in the case of the pipe-organ. Second, to shift to the just scale, so that in most important instances the natural harmonics appear almost exactly on the scale. This results in the limitation of the instrument to a single key.

By far the best answer to date has been supplied by Laurens Hammond in his electric organ. In this instrument, musical qualities are synthesized from pure sine waves, and *all the frequencies used in the synthesis lie on the tempered scale.* In other words, natural harmonics are entirely suppressed and tempered harmonics substituted. In no other instrument, to my knowledge, is this done, and while the results are not immediately perceptible to the lay ear, the characteristically harmonious effect of the Hammond organ that becomes apparent after some familiarity with it must be ascribed to this basic improvement.

A topic of great importance that we shall consider briefly is that of summation and difference tones. Communication engineers are familiar with the effect of superimposing two different frequencies and transmitting them through a non-linear network. We ordinarily say that side-bands are produced, consisting of sum and difference frequencies. The ear is non-linear to a marked extent, with the result that when two notes are sounded loudly, there become perceptible a number of other tones bearing related frequencies. The most prominent are the 2nd harmonics and the sum and difference frequencies of the two notes. It can be shown that if three tones represented in frequency by the numbers 4, 5, and 6 are sounded, the human ear will respond as if every frequency from 1 to 18 were present. It can be readily demonstrated with an organ, or for that matter with two oscillators, that if two tones of frequencies 2 and 3 are sounded together, a note of frequency 1 is plainly audible. This is the phenomenon that lets us hear the fundamental tones of a man's voice over the telephone, although these tones go down to 90 cycles and the telephone transmits little or nothing below 300 cycles. It lets us hear the low notes of the piano, down to 28 cycles, although acoustically most pianos are quite incapable of radiating a perceptible amount of power at these frequencies. This phenomenon, and particularly the formation of difference tones, is very important in musical instruments. In the pipe-organ where it is particularly noticeable, it is called "acoustic bass." The summation tones, especially, give rise to serious discords. Suppose we have a note sounded with strong 3rd and 4th harmonics. The difference tone of the harmonics is simply a strengthened fundamental, but the summation tone is the 7th harmonic, which is extremely discordant in the tempered scale. In the case of drums, bells, and other instruments in which the partials are not harmonics, difference tones can not be relied on to supply a bass that is not transmitted.

Musical tones, being sounds, are always produced by vibrating mechanical systems, capable of acoustic radiation. The piano, the violin, the pipe-organ, or the human voice are examples in which the radiating element is actuated mechanically. In all these instances, the further feature exists that the radiating element is also the generator. We can conceive of a variety of ways in which a piano, for example, could be modified by the application of electricity. The striking mechanism could be actuated by electromagnets instead of directly by the performer; the strings could be sounded by a microphone-hummer arrangement; the strings could be enclosed and the sound picked up by a microphone and reproduced through an amplifier and loud speaker; or instead of a microphone, a direct electromagnetic or electrostatic coupling to the strings could be used. While all these schemes and combinations involve electricity in the production of musical tones, we are most concerned with the case in which an electric current of the required character is generated; and when this current, after amplification, is passed through a loud speaker, a musical tone is produced.

There are two fundamentally different ways in which such an electronic instrument may be arranged to produce musical tones: The tone can be generated in the first instance as a complete wave of the desired character, which is then amplified and reproduced; or it can be produced as the addition of a group of sine-wave frequencies lying in a harmonic series.

In the Hammond organ the latter arrangement is used. The tone-generator consists of ninety-one miniature tone-wheels. These wheels are made of steel, and each has a sine wave cut in the periphery. A single permanent-magnet pole-piece with a coil wound on it is used with each generator. All the generators are driven from a single synchronous motor with elaborate precautions taken to prevent frequency-modulation flutter. These consist of a damped low-pass mechanical filter in the main drive, and of a similar small section in the drive to each pair of tone-wheels. The generator assembly consists of two groups of jack shafts, on each of which is mounted two tone-wheels, separated in frequency by an integral number of octaves, and a gear and mechanical low-pass filter. These two groups are driven by gears mounted on a main drive-shaft and one group lies on each side of it. It is evident that the limitations of motor speed, and of cutting whole numbers of teeth on gears and tone-wheels, will not permit an exactly precise duplication of the tempered scale. Compromises have been necessary, but they are of negligible importance. This could not be said of such departures from the just scale, if it were in use instead of the equally tempered scale. Note this point, however: if the just scale were used for this organ, no departures would be necessary, since all the frequencies bear simple fractional relations to each other. In the Hammond organ, the octave intervals are maintained precisely, this being the purpose of the small jack shafts, each with two tone-wheels mounted on it.

The output of each pick-up coil is passed through a low-pass filter to reduce it as nearly as possible to a sine wave. In this instrument, provision is made to synthesize tones using a fundamental or 1st harmonic, the 2nd, 3rd, 4th, 5th, 6th, and 8th harmonics; the sub-harmonic, or octave below the fundamental; and the sub-third, a fifth above the fundamental. From these nine partials pipe-organ voices can be imitated, in some cases perfectly, in all cases adequately, and this is true of most of the orchestra instruments. Obviously, tones can be set up that are entirely new qualities, not produced by traditional instruments. It is evident that each generator output appears in a number of places on the keyboard. For instance, if we have a generator that is the fundamental frequency of Middle *C*, it is the 2nd harmonic of the *C* below, the 4th harmonic of the *C* below that, and the 8th harmonic of the *C* below that again. It is the sub-harmonic of the *C* above, the 3rd harmonic of the *F* an octave and a fifth below, and the 6th harmonic of the *F* two octaves and a fifth below. It is the sub-third harmonic of the *F* below and the 5th harmonic of the $G^{\#}$ two octaves and a third below.

Since a tone produced by the organ may include all nine partials, each key carries an assembly of nine contact springs. The moving sides of these contacts connect to the generators, the stationary sides through the switching mechanism that selects the desired harmonics and adjusts their relative strengths to an amplifier contained in the console. The output from this amplifier is fed to as many power-amplifier tone-cabinet units as may be necessary.

The relative amplitudes of the generator outputs are adjusted by sliding the pole-pieces. The output is adjusted to a curve rising steeply from the high-frequency end to the low-frequency end. Aside from the harmonic-suppression filters on each generator, no electrical filters are used. From the previous discussion of the tempered scale, it will be realized that the suppression of natural harmonics is of the greatest importance except in the top octave of the keyboard, where they fall outside the range of any of the generator fundamental frequencies. Accordingly no harmonic filters are employed on the top octave of generators, to permit the added brilliance of an extended harmonic range.

The strength of each harmonic in a tone can be set in eight steps of 3 db. each, or cut out entirely. Controls are provided so that four tones can be set up, two for each manual or keyboard, and can be brought in by pressing a button. In addition, a limited range of tones can be set for the pedals. Eighteen of the usual pipe-organ qualities are permanently adjusted, and nine may be used on each manual by pressing the appropriate switches at the left of the keyboard. The volume-control, operated by a foot-pedal, has a total range of 30 db.

A tremulant is provided by a motor-driven potentiometer, and the effect is variable by means of a manually operated potentiometer connected across it. An effect of great importance that is provided is the so-called "chorus effect." It is this that enables us to tell twenty violins playing in unison from one violin playing loudly, and is particularly noticeable in the pipe-organ, where frequently a great number of pipes of the same pitch may be sounded together. With a number of separate sources, it is inevitable that small frequency differences should occur and this, together with random and changing phase relations, is imitated in Hammond's organ by having, for each generator representing a keyboard note, another generator slightly out of tune with it, whose output is quite low. This second set of generators can be connected at will by a control at the right of the keyboard.

The Hammond organ is widely accepted by musicians and is now in general use throughout the world. Among other electronic instruments that have been commercially exploited is the Everett Orgatron, an instrument that employs wind-blown reeds with electrostatic pick-ups. The reeds are in a sound-proof chamber, and different tone qualities are obtained by using different banks of reeds and by shaping the response curve of the amplifier. This instrument gives the characteristic reed-organ quality. There are several pianos with electrostatic or electromagnetic pick-ups on the strings that are said to be extremely effective, since they permit the elimination of the sounding board, the bass can be enhanced at will, and a wide volume range can be obtained without the necessity of tremendous exertion by the performer or of changing the quality of the sound produced.

A number of organs using vacuum-tube oscillators have been produced commercially, some using a separate oscillator for each note, some using only twelve oscillators, one for each note in the lowest octave, all the upper notes being obtained as harmonics. There appear to be two objections to these instruments: first, the large number of vacuum-tubes involved—in the hundreds—and second, the difficulty of keeping them exactly in tune. These problems are undoubtedly capable of solution, however.

An outstanding example of the principle of the generation directly of a complex tone, instead of synthesis from harmonic components, is the Robb Wave-Organ, designed by Morse Robb and constructed at Belleville, Ontario. This interesting and successful instrument consists of a console connected by a multi-conductor cable to the tone-generating unit, and the usual amplifiers and loud speakers. The generator consists of twelve spindles, one for each note in the octave, each with a number of disks, and driven through belts and pulleys from a single motor. On these disks are cut the complex wave-forms it is desired to reproduce, so that, subject only to the limitations of the amplifier and loud speaker equipment, almost any tone can be accurately reproduced. A very large number of generator disks is required—one for each keyboard note, for each tone color. The total number is substantially reduced, however, by using generators in the form of cylinders, not flat disks; a number of pick-ups are employed on each cylinder, at different points in the height of the wave-form, and different pick-ups and different combinations of pick-ups give wide variations in tone-quality. This organ is provided with a group of standard pipe-organ stops, the disks being cut from oscillograms made from an acoustic pick-up from a pipe-organ. The Robb Wave-Organ embodies a number of ingenious points in its design and must be regarded as a serious musical instrument.

The classical work on electrical musical instruments was carried out by Thaddeus Cahill, between the years 1895 and 1905. All the modern inventors have drawn largely on his work, which is explained and described exhaustively in five patent applications drawn up by him. Cahill appears to have been the first man to conceive the idea of the electrical production of musical tones. He produced several models of an instrument which he called the Telharmonium. To ship one of these instruments from his laboratory at Holyoke, Mass., to New York required forty railway cars; the instrument weighed over 200 tons and cost upward of a quarter of a million dollars! Cahill intended to use his Telharmonium to transmit music over telephone lines to subscribers; the plan finally fell through because of cross-talk into adjacent circuits.

Cahill clearly understood all the theoretical and practical problems involved in the electric organ; he outlines them in great detail, together with the extraordinarily ingenious features of his Telharmonium. Since, of course, he had neither vacuum-tube amplifiers nor modern loud speakers, he had to generate relatively great amounts of power. He employed generators in the form of wound-rotor alternators, commutators (he used the word "rheotomes") and vibrators. The bed-plate of his main generator assembly was sixty feet long. He understood and used low-pass and band-pass filters and matching networks of many configurations, and understood the impedance relations of his circuits and the importance of satisfactory transient characteristics, all these at a time when such knowledge was not general in any branch of communication engineering. Initially he used great multiple loud speakers made of vibrating magnets clamped to hardwood bars; later he used telephone receivers with conical horns. His Telharmonium provided much more complete facilities to the performer than has any electrical or acoustic organ before or since. He employed the methods both of tone synthesis from pure tones, and of the generation of complex tones. An article in 1906 in *The Electrician* describes the performance of the Telharmonium:

> It is evident that the constructional features of the electrical mechanism are exceedingly elaborate. It is believed, however, that the results obtained fully justify the means employed. There can be no doubt as to the absolute accuracy of the relative pitches of the various notes produced, nor as to the beauty and purity of the resultant music. Although the horn of the receiver resembles that of a phonograph, there is nothing about the music itself to suggest the phonograph, the harsh sounds and disagreeable overtones of which are entirely lacking. The quality of the sound is pure and sweet and the volume is such that the largest known auditorium can be served without the use of an excessive number of receivers, while the character and expression of the music is under the control of the musician to an extent not previously reached in any musical instrument.
>
> The question will naturally arise in the mind of the reader as to the practical use of this complicated and expensive apparatus. The plans of the inventor are to distribute music from a central station to hotels, restaurants, theaters, and private homes. The remarkable purity and strength of the sounds produced electrically, enabling a few performers at a central station to produce orchestral music at a thousand places, strikes the imagination and it seems not improbable that at no distant day orchestral music for the dinner table will be as common in the homes of the people as it is now in the great hotels. Music of different sorts during the evening, and slumber music during the small hours of the night coming to the listener by electricity from a central station, seem likely in a few months to be accomplished facts in one or more American cities.

The design of the transmission circuits of an electrical organ such as the Hammond presents a number of problems. The frequency range is from 32 to above 8000 cycles, and the maximum output occurs at the lowest frequency. This involves the design of amplifiers and loud speakers whose efficiency and power-handling capacity are unimpaired at 32 cycles. From the discussion of the tempered scale, it will be realized that the suppression of natural harmonics in the amplifier-loud speaker system is of the greatest importance. This requires careful design of the amplifier, and of the acoustic loading on the loud speaker so that even at the lowest frequencies no break-up occurs.

Another point largely ignored in ordinary transmission systems, of great importance in a system for the transmission of organ tones is that in a wave made up of a harmonic series with random phase relations, the peak value of the wave reaches a relatively high value for a given rms. value. In other words, the power output capacity of the amplifier is largely reduced due to the wave-form of the tone being transmitted. Fig. 2 shows the magnitude of this effect.

What significance can engineers draw from the facts that have been presented? What of the future development of the instrumentalities of music? One possibility that is of overwhelming importance now appears: that is, to abandon the tempered scale in favor of the just scale. It has been seen what inaccuracies of harmony are inherent

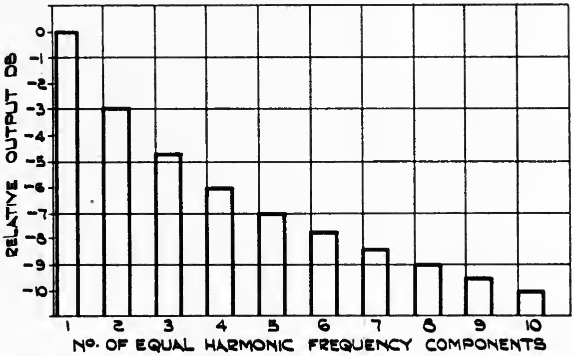

FIG. 2. Decrease of maximum output of amplifiers for wave-form consisting of equal harmonic components.

in the tempered scale. Its main virtue is its convenience, the facility it provides for changing key. The just scale must be retuned for each key, but is the ideal solution to the 7-note scale since it provides the largest number of exact harmonies possible. This makes its use impossible in the traditional keyboard instruments. The stringed instruments in the orchestra can readily play the just scale in any key, since the pitch can be continuously varied; the wind instruments can also, by means of changing the length of the air column with telescoping joints for small changes of pitch and by using different instruments for large changes. With the advent of electrical keyboard instruments a new era in music is initiated. It is now possible to tune such an instrument in the just scale, and to change key electrically by altering the frequency of the generating devices. The implications are too broad to be touched upon in this paper, but from what has been said it will be apparent that the resulting improvement in the harmoniousness of our music would be large.

A COLOR-TEMPERATURE METER*

E. M. LOWRY AND K. S. WEAVER**

Summary.—*The recent advances in color photography have made more apparent than ever before the need for some simple and accurate method for the estimation of the color-temperature of light-sources. Photographers, whether professional or amateur, are only too well aware of the influence which the quality of the illumination has on the color rendering of photographic subjects. For example, the difference in color-temperature between general-purpose tungsten filament lamps, and studio modeling lamps, or between modeling lamps and photoflood lamps, is often the deciding factor between correct and incorrect photographic color reproduction. In order that the photographer may easily determine the quality of lighting which he is using and make the proper adjustments to secure standard lighting conditions, an instrument that is at once compact, simple in operation, and accurate, has been developed in these laboratories. No auxiliary light-source is required for making measurements since each source is tested by means of the radiant energy which it itself emits. In this paper a discussion of the principles applied in construction of the instrument, a description of the instrument, and data showing the probable error of results are given.*

The recent advances in color photography have made more apparent than ever before the need for some simple and accurate method for determining the characteristics of light-sources. If the spectrum of a source such as a tungsten lamp is examined and the relative energy of light of each wavelength determined and plotted against the wavelength, a graph will be obtained known as a spectral energy distribution curve. Fig. 1 is such a graph for a 100-watt tungsten lamp. It has been found that the spectral distribution of energy throughout the spectrum of an incandescent solid, for example, the filament of a tungsten lamp, is practically independent of the material of which it is composed and is dependent only upon the temperature. As the temperature of an incandescent solid is raised, the wavelength at which the maximum energy is emitted moves from the long toward the short-wave region of the spectrum. This shift of the maximum with temperature, illustrated in Table I, gives rise

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to the common experience that as the glowing material becomes hotter it appears whiter. Since the most efficient thermal radiator is a completely black body, the energy distribution may be said to correspond to that of a "black body" at a given temperature. The

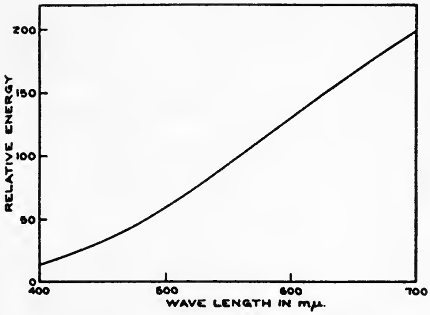

FIG. 1. Graph showing relative spectral distribution of energy for a 100-watt tungsten lamp.

temperature is measured from the absolute zero on the Centigrade scale stated as °K (degrees Kelvin) and is called the "color"-temperature, for our purpose, color-temperature may then be defined as the temperature at which a complete radiator (black body) will match in color that of the source in question.*

TABLE I

Table Showing the Wavelength of Maximum Energy at Various Color-Temperatures

Color Temperature (°K)	Wavelength of Maximum Energy (mμ)
1000	2880
2000	1440
2500	1152
3000	960
3500	823
4000	720
6000	480
8000	360
10000	288

*A more precise definition is: "The color-temperature of a radiator (source, lamp) is the temperature at which a complete radiator must be operated in order to emit energy competent to evoke a color of the same chromaticity as the color evoked by the radiant energy from the source in question."[1]

Photographers, whether professional or amateur, are only too well aware of the influence which the quality of the illumination has on the color rendering of photographic subjects. That is to say, the distribution of energy from the source of light used is extremely important in its effect upon the appearance of objects which it illuminates. Everyone is familiar with the phenomena of color change brought about in many objects when examined under different light sources. The difference in color-temperature between general-purpose tungsten lamps, and studio modeling lamps or between modeling lamps and photoflood lamps may well be the deciding factor between correct and incorrect photographic color reproduction. Variations in the voltage applied to a given lamp, or the length

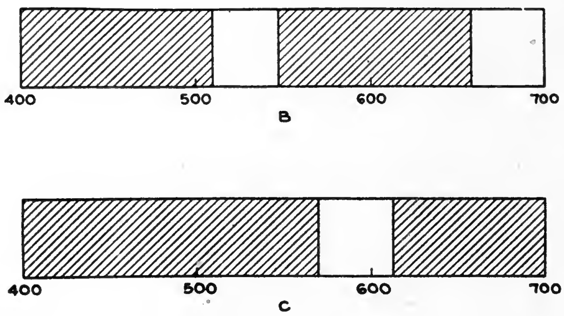

FIG. 2. Diagram showing spectral regions used in the color temperature meter.

of time it has been in operation are by no means negligible factors in securing and maintaining proper lighting.

In order that the photographer may easily determine the quality of lighting which he is using and make suitable adjustments to secure standard lighting conditions, an instrument for that purpose, which is at once compact, simple in operation, and accurate, has been developed in the Kodak Research Laboratories.

In working out the design of the color-temperature meter, use was made of some of the well known principles of color and color mixture. Suppose that in some way we block out or absorb certain components of the light from an incandescent source as represented by the shaded areas in Fig. 2 (*B*). We have left narrow bands in the green and red which, if combined, will produce a visual impression of yellow or orange. This orange will appear to the eye as though the shaded areas in Fig. 2 (*C*) had been removed and only a single narrow strip allowed to pass. In other words, a mixture of a properly selected narrow band of wavelengths from the green region with another from the red will produce the same visual impression as that of a single small group in the yellow-orange portion of the continuous spectrum.

In the Kodak color-temperature meter the selection of the proper portions of the spectrum is accomplished by means of carefully constructed light filters. One of these filters is so made up that it possesses two transmission bands with maximum transmittance at about 520 mμ and at 680 mμ, respectively. The second filter is so composed that the wavelength of its maximum transmittance is at approximately 580 mμ. The relative transmittances of the bands in the two-band or dichroic filter are so adjusted that, when examined by light, for example, that from a tungsten lamp operating at a color temperature of 2100°K, its color will be the same as that of the filter with its maximum transmittance at 580 mμ. For color-temperatures higher than 2100°K, the dichroic filter will appear more green than the monochromatic one, while for temperatures lower than 2100°K, it will appear more red. This property of dichroic materials was shown by Pflüger[2] in his work on anomalous dispersion and was discussed by Wood in his *Physical Optics*.[3]

The reason for this behavior may be explained by reference to Fig. 3. Curve *A* represents the spectrophotometric transmission curve of the two-band filter which has two maxima, at 520 mμ and at 680 mμ, respectively. Curve *B* is that of the monochromatic filter which possesses a transmittance maximum at 580 mμ. As stated above, the relative transmittances of the two bands for filter *A* have been so adjusted that, when examined by light from a source operating at a color temperature of 2100°K, this filter will appear to be the same color as filter *B*. The curve labeled 2100°K represents the relative energy emitted at the various wavelengths of the visible spectrum by the source operating at 2100°K, which is the temperature at which the filters will be color-matched. A source working at a color-temperature of 3200°K will emit energy of somewhat different distribution at the various wavelengths. Examination of the two distribution curves shows that the energy emitted is relatively higher at 520 mμ and relatively less at 680 mμ for 3200°K than for the 2100°K source. This will result in more light passing through the 520 mμ band in *A* and less at 680 mμ, and there will be a change in the color of the filter such that it will appear more green than when examined with the 2100°K source. In the case of filter *B*, however, there will be relatively little change in hue and it will still be yellow. If the color-temperature of the source is reduced below 2100°K, for example, to 2000°K, the filter *A* will appear more red than *B* because the ratio of energies in the regions of the spectrum at the positions of maximum transmittance of the filters has changed so that there is relatively more energy in the red portion than at the original match point, namely, at 2100°K.

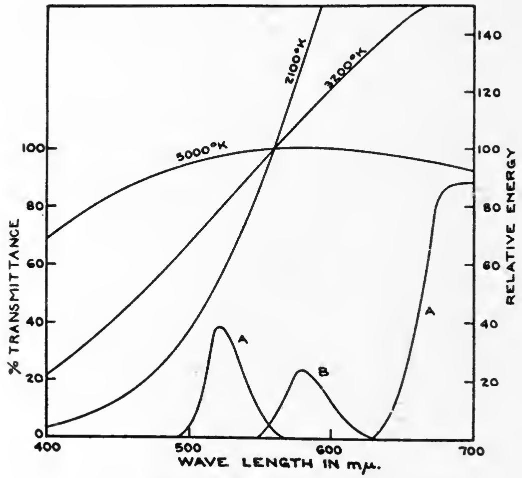

FIG. 3. Spectrophotometric transmittance curves of field filters used in color-temperature meter and relative energy distributions for color-temperatures of 2100°K, 3200°K, and 5000°K.

In order that the two filters shall remain color-matched when the color-temperature of the source is other than 2100°K, it is necessary to modify the energy distribution of the source in some way. This modification may be accomplished by changing the voltage applied to the lamp until its color-temperature is once more that of the original. The necessary change in voltage may be used as a measure of the difference from 2100°K. Another method of accomplishing the desired result is to absorb a portion of the radiant energy selectively with respect to wavelength in such a way that the remainder matches that at the initial temperature. Filters of this type, such as the so-called daylight glasses or the Wratten Photometric Series of filters, are well known. In the present instance, we are interested in reducing the color-temperature, since the match point for the filters is lower than that of most practical light-sources, and we require an amber colored filter. This amber filter is made up in the form of a wedge and the amount of selective absorption is dependent upon the thickness of the wedge at any point. The greater the thickness of the portion of the wedge used, the greater is the reduction in color-temperature of the light transmitted.

In the color-temperature meter, the principles just described have been applied as illustrated in Fig. 4. A circular photometric field *P*, with a fine dividing line across the center, is formed by the narrow band-filters whose absorption characteristics are illustrated in Fig. 3.

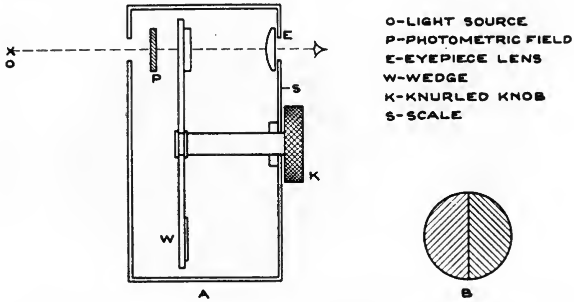

FIG. 4. Illustrative diagram of color-temperature meter.

The left half of the field, which is shown in detail at *B*, is formed by the dichroic filter, and the right half is formed by the monochromatic one. Between the eyepiece lens *E* and the test field is an amber wedge *W*, for the purpose of modifying the energy distribution of the light from the source being examined. This wedge is circular and the portion of the wedge to be used is selected by means of a small knurled knob *K*. The scale of the instrument *S* is so calibrated that it reads directly the color-temperature of the source investigated.

Fig. 5 is a photograph of the instrument depicting both front and side views. Comparison of the reproduction of the meter with the six-inch rule at the bottom of the picture illustrates the compactness and convenient size of the design.

Actual operation of the meter is accomplished by the observer directing the visual axis of the instrument (dotted line in Fig. 4) toward the source in question. He then observes whether the two halves of the field of view are color-matched and, if they are not, adjusts the position of the wedge until such a color-match is obtained. A clockwise motion of the wedge increases the amount of absorption while a counterclockwise motion decreases it. The farther the wedge must be inserted, the higher is the corresponding color-temperature as read from the scale.

Because of the fact that there are certain slight differences between the eyes of different individuals, the dichroic and monochromatic filters are not always color-matched at the same color temperature. For this reason, some means of compensation must be provided if determinations made with the instrument are to be in satisfactory

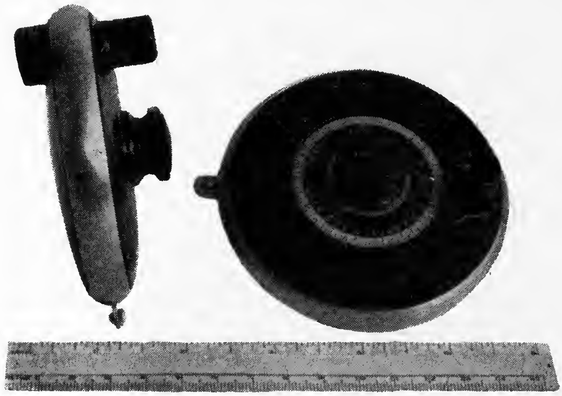

FIG. 5. Photograph of color-temperature meter.

agreement for two or more observers. To overcome this difficulty, an accommodation scale has been provided which enables each individual to select the initial setting of the amber wedge which suits his particular eye. Before making any measurements, each observer must set the scale of the instrument at the value corresponding to a source of known color-temperature. A tungsten lamp which has been calibrated properly would serve admirably for this purpose but, since such a lamp must be operated at constant voltage, auxiliary equipment is required which is not always available. Beeswax candles, such as, for example, the *XXX* Superior Candles made by the Socony Vacuum Oil Company, are easily obtained, and, since they possess fairly uniform temperature characteristics (1935°K ± 10°), they are quite suitable for the purpose of adjusting the accommodation scale, when used with the auxiliary blue filter. This filter, which raises the color-temperature of the candle-flame to a point above 2100°K is supplied in an easily attached mount.

To make the initial adjustment, the operator first sets the point on the scale marked *C* opposite the index. Then, while applying pressure to the scale with the thumb of one hand, to prevent any displacement of the scale relative to the index, he rotates the knob with the other hand until a color-match is obtained in the field of view. During this operation, the candle-flame is the illuminant. After the preliminary adjustment, the meter is in condition for reading the color-temperature of some unknown source.

TABLE II

Table Showing Precision of Measurements with the Color-Temperature Meter

Observer	Temperature °K	Average Departure from Mean of 10 Settings
EML	2360	14
AS	2360	24
KSW	2360	15
EML	2660	15
AS	2660	30
KSW	2660	22
EML	2850	22
AS	2850	26
KSW	2850	28
EML	3200	21
AS	3200	35
KSW	3200	34

The precision of the measurements made with the color temperature meter depends upon certain fundamental requirements. In the first place, the operation of the instrument is based upon the ability of an observer to do color-matching and therefore assumes his color vision to be normal; that is, he must not be color-blind or have any noticeable deficiencies in color vision. In the use of the meter, as in all operations requiring the application of optical instruments, the precision of setting is considerably improved by practice. The first few attempts to balance the field by an individual unskilled in this type of measurement are likely to show very erratic results, but as he becomes accustomed to the manipulations necessary, his repeatability will improve and his results will be quite satisfactory.

In Table II are shown the average deviations from the mean of ten settings made by each of three observers at the color temperatures indicated.

A number of devices embodying somewhat the same principles as those applied in the Kodak color temperature meter have been developed over a period of years.[4,5,6,7] Among them is the Harrison color meter, manufactured by Harrison and Harrison, Hollywood, Calif., which appeared on the market several years ago. This instrument is said to be useful for selecting the proper compensating filter, several of which are supplied with the instrument, to be used over the camera lens in order that the quality of light reaching the film may be properly adjusted to give correct color rendering. In the Harrison meter, rotation of a dial causes the field of view to change from a blue through a pink to a deep magenta. A setting for the selection of the correct filter is based upon the ability of the operator to decide when the field "just turns pink."

Another appliance is that described in U. S. Patent 1,865,878, issued to Gerhard Naeser and assigned to the Kaiser Wilhelm Institute in Germany. The Kodak color temperature meter possesses the advantage of providing automatic control of the brightness match in the field of view, whereas in the Naeser instrument, the brightness, if matched at one color-temperature, will not match at any other. The Kodak meter has a further advantage not provided by Naeser's arrangement. This is that the hue in the two halves of the photometric field matches at all temperatures within the range of the instrument while that of Naeser does not.

It is the opinion of the authors that the instrument described in this paper provides a means whereby the photographer may easily and accurately estimate the color-temperature of his light-sources.

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CHEMICAL ANALYSIS OF AN MQ DEVELOPER*

R. M. EVANS AND W. T. HANSON, JR.**

Summary.—*The maintenance of developer activity over a long period of time is among the most important problems of a motion picture laboratory. The developer is oxidized by the silver halide in the emulsion and by air. When known amounts of these two oxidizing materials react with the developer, simple calculations (presented in a previous paper) are sufficient to determine the equilibrium condition of the developer as well as the replenisher formula to give a chosen equilibrium. Under ordinary conditions there are large variations in the amount of developer oxidation. A chemical analysis immediately detects any deviation from the correct equilibrium and permits readjustment of the replenisher formula. Chemical analyses are presented which require a minimum of equipment and time. In most cases ease of manipulation and speed have been considered as more important factors than a high degree of accuracy but in all cases the methods are capable of giving results to an accuracy of five per cent or better. Whenever possible the analyses are colorimetric in nature, the measurements being made on an instrument called an opacimeter. One operator can make a complete analysis in about half an hour. Analysis for any one constituent may be made in a much shorter time. It is emphasized that no one control variable is significant for specifying the activity of a developer. Sensitometric curves are included demonstrating the time lag in pH equilibrium but not in photographic equilibrium when hydroxide is added to or released in the developer. The aim of chemical control is to insure a constant condition of the developer and thus constant photographic quality, rather than to determine the degree of development.*

In the continuous processing of motion picture film the developer can not be fresh for each roll of film but must be used continuously. For this reason the developer must be kept at constant activity by continuous addition of fresh developer and removal of old. The problems of keeping this developer at the correct activity and of determing whether it is at the correct activity are among the most important problems which confront a motion picture laboratory.

During the use of a developer solution, some of it is oxidized by the film being developed and some by air. If each of these reactions is taking place at a constant rate and the developer is being replenished

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

at a constant rate, the concentrations of the ingredients of the solution, both those added in the replenisher and those formed by the reactions, will reach an equilibrium concentration. These equilibrium concentrations can be calculated easily by means of equations presented by the senior author in a previous paper.[1] From similar calculations, it is possible to determine the formula and rate of addition of a replenisher which will give almost any desired equilibrium condition. Consequently, if the relative ratio of silver halide development and oxidation by air can be kept constant, the developer solution can be brought to the correct condition with ease and will remain in this condition. The resulting photographic quality will be correct and constant.

The problem is not quite as simple as this, however. A 1000-ft. roll of motion picture positive film contains about 75 to 80 grams of silver bromide and, depending on the type of scenes included on such a roll, 5 to 60 per cent of it may be developed. At other times it may be necessary to run leader rather than exposed film through the machine. In addition to the variation in the amount of silver bromide which is developed in a given time, there will be variations in the amount of aeration of the developer. A small amount of air is always carried into the developer by the film and by general surface agitation, but this amount of aeration may be increased suddenly to 10 to 15 times its original value by a leak in the pumping system. Even after a few days of continuous processing, these inconsistencies make it impossible to know the concentration of the important ingredients of a developer solution without the aid of chemical analyses. An analysis of such a partially exhausted developer immediately detects any deviation from the proper equilibrium condition and a new and correct replenisher formula can be calculated and put into use. By frequent analysis and replenisher correction, accurate developer maintenance can be accomplished.

The number of analyses necessary for such developer maintenance is relatively small compared with the total number of constituents of a partially exhausted developer solution because many of the materials formed during the oxidation of the developer are interrelated and are formed in amounts which have a constant ratio to each other. For example, in an ordinary *MQ* developer, the amount of bromide formed is related to the amount of elon used up, the amount of sulfate formed is proportional to the amount of oxygen which the solution has absorbed from the air, which in turn is almost proportional to the hydroquinone which is used up. In addition, most of the oxidation products of the developer solution play an insignificant part in the development process (excepting bromide and acid or alkali) and need not be determined.

In the case of an ordinary *MQ* developer, the most important variables are elon, hydroquinone, bromide, sulfite, alkaline salts, and *p*H. Analyses for these will tell the general condition of the bath and indicate what changes in the replenisher are necessary. In certain special cases, there may be other important ingredients which should be determined, but such cases are rare. The usual case does not even require repeated analyses for all of the materials mentioned above. Frequent checks of two or three of these variables, alternating so that no one is omitted for a long period will give sufficient information to enable correct developer maintenance. In this way, the problem of developer maintenance can be made relatively simple.

If attempts are made to carry the simplification too far, the value of analytical methods may be destroyed. The action of a developer compound is affected by a large number of variables which are by no means independent. In fact, it is safe to say that there is no *single* variable which may be used alone to control a photographic developer. The action of all developers is normally a steep function of *p*H and bromide concentration and even at a given *p*H, different developers behave so differently that no developer formula can be devised which may be specified by a knowledge of one of the constituents. In an earlier paper[2] the authors showed that *p*H, which has at times been considered as a significant single variable, may vary in the opposite direction to the developing properties of a given solution. Another example of the lack of correlation between *p*H and developer action is shown in Fig. 1. The curves in (*a*) were obtained from sensitometric strips of motion picture positive developed in fresh *D16* developer. The *p*H of this solution was 9.9. To a liter of this solution 2 grams of sodium hydroxide were added and more strips were developed immediately (curves *b*). The *p*H at this time was 10.1 and the activity of the developer had increased appreciably, as may be seen by a comparison of (*a*) and (*b*). After this solution had stood for 7 hours, strips (*c*) were developed and the *p*H was found to be 10.3. A comparison of (*b*) and (*c*) will show that the photographic action of the developer had not changed at all, while its *p*H had changed 0.2 units. Hydroxide and acid are released continuously during the use of a bath. The above test shows that hydroxide comes to an immediate photographic equilibrium with the bath but that this equilibrium does not have its full effect on the *p*H of the solution for several hours. Under these conditions a measurement of *p*H is not even significant as a measure of the released hydroxide when it is measured during the use of the bath.

On the other hand, as complete a chemical analysis of a developer as is possible at the present time will not specify its exact photographic properties. Traces of materials, such as sulfide, which may be formed in the solution by bacteria, will cause fog even if present in quantities much too small to be detected by any available analytical methods. Small traces of certain materials, such as hypo or

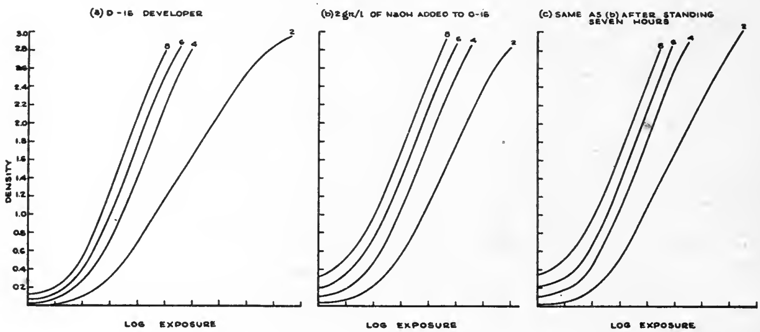

FIG. 1. Sensitometric curves of strips of motion picture positive film developed (*a*) in *D16;* (*b*) in *D16* plus sodium hydroxide; (*c*) same as (*b*) after standing 7 hours.

iodide, may accelerate development. On the other hand, certain decomposition products of gelatin may act as inhibitors, slow down development, and decrease fog. Many other materials may inadvertently enter a developer solution and affect the development characteristics. An analysis which would detect such traces would not only be extremely tedious but also unnecessary since the usual sensitometric control strip gives that information quite simply and directly.

Chemical analyses, then, are not satisfactory when used in place of photographic tests but are a necessary supplement to them. Their role is not to determine the time of development or the temperature that is required to give a given contrast but to insure constant and reproducible photographic quality. No matter to what extent changes in the ingredients of a developer solution may affect the photographic results, the following statement must certainly be true: If all of the important constituents of a developer solution are held constant, the photographic quality of images developed in that solution will be constant. Thus, the aim of the processing control should be to control the developer solution itself as well as to control the degree of development as indicated by sensitometric test strips.

The analytical methods presented below have been worked out at the Kodak Research Laboratories and most of them have been in use over two years. In most cases, ease of manipulation and speed have been considered as more important factors than a high degree of accuracy. In all cases, the methods are capable of giving results to an accuracy of 5 per cent or better. A 500-cc. sample of developer solution is sufficient for a complete analysis and one operator can make a complete analysis in about half an hour. Analysis for any one constituent may be made in a much shorter time. The laboratory space required for these tests is small and little equipment is necessary. Most of the tests depend on colorimetric measurements and may be run very efficiently in an optical instrument called an *opacimeter*. In this instrument a high-aperture lens system provides a light-beam of fixed characteristics. In this beam, glass vessels containing the products of the color-forming reactions can be placed. The change in light-intensity is measured by means of a photosensitive cell whose output is measured directly by a microammeter. Test reactions can be run either in Kohle flasks in the instrument, or, when it is desirable to use small amounts of reaction solutions, in calibrated test tubes. The opacimeter provides a sufficiently high level of illumination so that narrow-band color-filters can be placed in the light-beam in order to enhance the effect on the photocell when a weaky colored reaction mixture is used. This instrument is more fully described in an accompanying paper.

The presence of iodide in a developer solution has been mentioned but no test for it is given. Although it is known that small amounts of iodide do have a photographic effect, an analysis for the small amounts present in an ordinary developer solution is tedious and time-consuming. Analyses made at these Laboratories by Ballard and Yutzy have shown that the equilibrium amount of iodide in a developer which is used for positive film is only about 0.0005 gram per liter (expressed as potassium iodide) and for negative film is only 0.0015 to

0.0020 gram per liter. In both cases, equilibrium is reached when less than 5 feet of film per liter of solution has been developed. In the usual case, the equilibrium is rapidly established and the total amount of iodide present does not vary appreciably. There is no real necessity for analysis. It is recommended, however, that when entirely fresh solutions are placed in a machine, an amount of potassium iodide approximately equivalent to the above figures should be added to the solution and a small amount of fogged film (perhaps one foot per gallon) should be run through the solution.

Elon.—The analysis for elon is based on the formation of a yellow solution when elon reacts with furyl acrolein. Since elon sulfonate which is present as an oxidation product undergoes the same reaction, the elon must be separated from the developer solution by extraction. Lehmann and Tausch[3] have published an analytical method for elon in which the elon was extracted for several hours in a continuous extraction apparatus and then determined by iodometric titration. This method gives accurate results but is too time-consuming to be used as a control method. While the method outlined here is not as accurate as the Lehmann and Tausch method, it has the merit that it is rapid and it is felt that in many cases rapidity is more important than extreme accuracy. One objection to the present method is that the results are affected by small deviations from the exact procedure and the analyst must become thoroughly familiar with the details of the method before satisfactory results can be obtained. However, satisfactory results *can* be obtained and in the absence of a more easily controlled analysis the present method is presented.

STOCK SOLUTIONS AND CHEMICALS

(*1*) Buffer at *p*H 8.4

Trisodium phosphate	150 gm.
Water	960 cc.
Conc. hydrochloric acid	40 cc.

(*2*) Furyl Acrolein 10 gm.

Ethyl ether	200 cc.

Filter

(This solution is stable only a few weeks and should not be made up in large amounts nor should the solid be stored for long periods of time.)

Ethyl acetate

Concentrated hydrochloric acid

Solid sodium carbonate

Phenolphthalein

Solid sodium chloride

EQUIPMENT

One 250-cc. separatory funnel
One 250-cc. Erlenmeyer flask
One 125-cc. Erlenmeyer flask
Two test tubes
Pipettes 1, 2, 5, and 10 cc.
One 50-cc. graduated cylinder
One mechanical shaker
Two storage bottles
One No. *47* Wratten filter
Opacimeter or its equivalent

Procedure.—To 50 cc. of developer solution in a 250-cc. Erlenmeyer flask are added a few drops of phenolphthalein and sufficient concentrated hydrochloric acid to destroy the pink color. An addition of solid sodium carbonate to just restore this color is made and then 50 cc. of the stock buffer solution No. *1*, 30 gm. of solid sodium chloride, and 50 cc. of ethyl acetate are added. This is sufficient sodium chloride to form a saturated solution. The mixture is shaken for five minutes on a mechanical shaker. The pink color of the phenolphthalein disappears during this shaking. The mixture is poured into a separatory funnel and, after a few minutes, the water layer is drawn off. From 2 to 10 cc. of the ethyl acetate solution are added to 25 cc. of water and 2 cc. of concentrated hydrochloric acid in a 125-cc. flask to which is also added 10 cc. of the furyl acrolein stock solution No. *2*. This is shaken for five minutes on the mechanical shaker and then allowed to stand for five minutes in a separatory funnel. The water layer at the bottom is poured into a standard test tube and its transmission is read on the opacimeter through a No. *47* Wratten filter. The elon concentration is determined from an empirical calibration curve made up by analyzing known fresh solutions.

The total amount of elon plus elon sulfonate which is present can be determined by allowing 1 to 5 cc. of the original developer solution (in place of the ethyl acetate extract) to react with the furyl acrolein. A calibration curve must be prepared following this procedure.

Because of the sensitivity of this test to small changes in the conditions under which it is carried out, each step in the procedure must be carefully controlled. The extraction of elon is a function of both *p*H and total salt content, so both of these factors must be reproduced accurately. The *p*H of the stock buffer solution must not vary more than 0.1 from 8.4 and the amount of sodium chloride added before the extraction must be sufficient to saturate the solution. The reaction between elon and furyl acrolein procedes slowly and sufficient time for its completion can not be allowed, so the time of shaking at this stage of the analysis as well as the time of standing in the separatory funnel after shaking must be carefully reproduced. With these precautions properly followed and a calibration curve prepared for a given developer formula, an accuracy of about five per cent can be achieved. If the analysis must be made on an unknown developer formula, less accurate results can be expected, but, if necessary, the first rough analysis can be followed by a calibration curve and another analysis.

Such a procedure takes about two or three hours and should be necessary only in rare cases. Under ordinary conditions the test takes about 15 minutes.

Hydroquinone and Hydroquinone Sulfonate.—The test for these compounds is based on the measurement of the intensity of the color formed when they are oxidized by potassium ferricyanide in the presence of sodium sulfite. Both hydroquinone and hydroquinone sulfonate give the same color but can be separated by acidifying the developer solution and extracting the hydroquinone with ethyl acetate. The sulfonate remains in the water layer. From the stoichiometry of the titration with ferricyanide it appears that the colored product is a semiquinone of hydroquinone disulfonate but no definite proof of this has been undertaken. The exact procedure is as follows:

STOCK SOLUTIONS AND CHEMICALS

(*1*) Sodium sulfite 30 gm.
Sodium carbonate 20 gm.
Water to 1 liter
(*2*) Potassium ferricyanide 0.2 molal (approximately)
(*3*) Bromophenol blue (0.1 per cent water solution)
Concentrated hydrochloric acid
Ethyl acetate

All solutions are fairly stable and can be kept for several weeks. None of them need be standardized.

EQUIPMENT

One 250-cc. separatory funnel
One 50-cc. graduate

Pipettes 1, 2, and 5 cc.
One 300-cc. Kohle flask with side arm for air agitation
One No. *44* Wratten filter
Two storage bottles
Compressed air (low pressure)

Procedure.—Hydroquinone. To 50 cc. of developer solution are added a few drops of bromphenol blue and then concentrated hydrochloric acid is added until the solution just turns yellow. Fifty cc. of ethyl acetate are added and the mixture shaken by hand for one minute in a separatory funnel. This is then allowed to stand until two layers have separated. One to 5 cc. of the ethyl acetate layer (the upper layer) are added to 275 cc. of water and 25 cc. of stock solution No. *2* in the Kohle flask. This solution is placed in the opacimeter and agitated by air introduced through a glass tube inserted in the flask. The No. *44* filter is placed in the beam of light, the microammeter set so that the reading is at a maximum, and ferricyanide solution is poured in slowly and uniformly until the deflection of the galvanometer needle is a minimum. This point of minimum deflection, when read on the calibration curve, gives the amount of hydroquinone present.

If, instead of using 1 to 5 cc. of the ethyl acetate layer in the above procedure, an equal amount of the water layer is used, the hydroquinone sulfonate rather than the hydroquinone causes the color, and from the proper calibration curve its concentration can be determined. The total amount of hydroquinone and hydroquinone sulfonate can be checked by running the test on the original developer solution without extraction.

In order to achieve the greatest accuracy, calibration curves should be obtained for each developer formula because, although the test is specified for hydroquinone in an ordinary *MQ* developer, different total salt concentrations affect the extraction and, consequently, the determination of free hydroquinone. Under the proper conditions, the test gives analyses with an error of much less than 5 per cent.

Sodium Sulfite.—The test for sulfite is based on the fact that certain dyes are quantitatively bleached by sulfite solutions.

STOCK SOLUTIONS

(1) Isopropyl alcohol	100 cc.
Water	900 cc.

Glacial acetic acid	1 cc.
Acid green *L* (No. *764*)	1 gm.
Filter through No. *42* filter paper	
pH = 3.9	
(2) Sodium carbonate	30 gm.
Sodium bicarbonate	30 cc.
Water to make	1 liter
*p*H = 9.4	

Both solutions are stable for several months.

EQUIPMENT

Two storage bottles
One small filter funnel and paper
Pipettes, 1 and 10 cc.
Two test tubes
One No. *23* Wratten filter

Procedure.—To 1 cc. of the developer solution are added 10 cc. of stock solution No. *2* and 10 cc. of stock solution No. *1*. This order of addition of these solutions must be followed because the bleaching of the dye is affected by *p*H and must be carried out in a well buffered solution. Since the dye is not stable for long periods of time if dissolved in the buffer itself, it must be kept in the acid solution as recommended. The transmission of this partially bleached dye solution is measured on the opacimeter through a Wratten No. *22* or *25* filter and the sulfite concentration is determined from a calibration curve.

Bromide.—Bromide is determined by titrating with a standardized silver nitrate solution, using metanil yellow as an adsorption indicator.* Chloride or any other material which forms a salt less soluble than silver chloride will be included by this test and in the presence of unknown amounts of such materials the method can not be used. A method which eliminates these objections has been worked out by Ballard of these Laboratories and has been used quite successfully, but since it is more time-consuming than the present method, it will not be included here. Iodide may be considered constant, as was pointed out above.

*This method was worked out at the Kodak West Coast Laboratories (Hollywood, Calif.) by Atkinson, Shaner, and Huse.

STOCK SOLUTION AND CHEMICALS

(1) Silver nitrate (standardized) about 0.03 N
(2) Metanil yellow (0.1 per cent water solution)
Concentrated sulfuric acid

EQUIPMENT

One 50-cc. burette and holder
One 15-cc. pipette
One 250-cc. Erlenmeyer flask

Procedure.—To 15 cc. of developer solution are added 5 to 10 cc. of concentrated sulfuric acid. This is then diluted to about 100 cc. and cooled. Two or three drops of metanil yellow are added and then titrated with standard silver nitrate solution until the solution changes from purple to red. The usual volumetric calculations can be used to determine the amount of halide present or a calibration curve can be prepared. The change of color at the end point is sometimes rather difficult to distinguish but with a little experience under the proper lighting conditions the titration can be controlled to an accuracy of two or three per cent.

Carbonate.—The analysis for carbonate is based on the measurement of the pressure developed in a nearly constant volume system held at constant temperature, when carbon dioxide is released from the developer by the addition of a strong acid. In order to avoid the formation of sulfur dioxide from the sulfite in the solution, quinone must be added. This reacts with the sulfite to form hydroquinone monosulfonate.

CHEMICALS

Concentrated hydrochloric acid
Solid quinone

EQUIPMENT

One 500-cc. Erlenmeyer flask (calibrated)
One stopper bucket (as shown in Fig. 2)
One open-end manometer (filled with CCl_4)
One burette
Pipettes, 5 and 10 cc.
Constant-temperature water bath
Rubber tubing

Procedure.—Five cc. of developer solution and 10 cc. of water are pipetted into the calibrated Erlenmeyer flask and about 0.5 gram of solid quinone is added. Shake thoroughly. Two cc. of concentrated hydrochloric acid are run into the stopper bucket from a burette and the stopper is inserted in the flask. This is then immersed in a constant temperature bath and allowed to come to temperature equilibrium. The manometer is then connected to the arm of the stopper bucket and the flask is tilted so that the acid is poured into the developer solution. After it has been shaken thoroughly, the flask is again brought to temperature equilibrium and the pressure read from the manometer. The carbonate concentration is determined from a calibration curve.

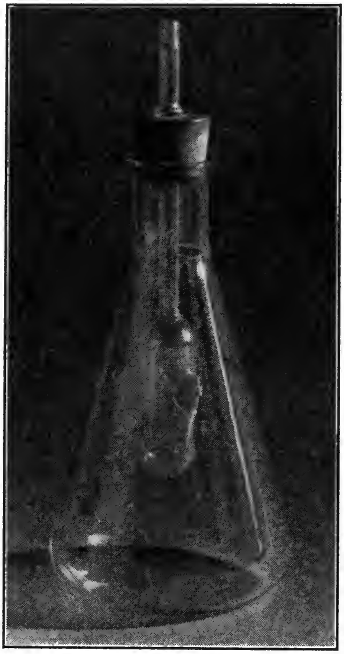

FIG. 2. Stopper bucket and flask for use in carbonate analysis.

The exact size of the flask used in the analysis and the temperature at which it is carried out are immaterial as long as the calibration curve is prepared under the same conditions. For this reason, it might be desirable to prepare calibration curves at several temperatures and then to use an ordinary sink with hot and cold water mixed to give a fairly constant temperature, as the constant temperature bath. Under such conditions, where the temperature might vary 0.1° the test is accurate to better than 10 per cent. In most cases this accuracy is quite sufficient, especially if the *p*H of the solution is determined. However, an accuracy of 3 to 4 per cent can be obtained by carefully controlling the condition of the test.

Sulfate.—The sulfate analysis is based on the precipitation of barium sulfate by the addition of barium chloride after removal of the sulfite and carbonate from the developer solution. The amount of barium sulfate formed is determined turbidimetrically by means of the opacimeter.

STOCK SOLUTION AND CHEMICALS

(1) Barium chloride dihydrate 10 gm.
Water 1 liter
Concentrated hydrochloric acid

EQUIPMENT

One 50-cc. graduate
One 50-cc. burette
Two test tubes
Pipettes 2, 10, and 25 cc.
One 125-cc. Erlenmeyer flask
Low-pressure steam (if available) or hot plate
One filter funnel and filter paper

Procedure.—To 25 cc. of developer solution in an Erlenmeyer flask 10 cc. of concentrated hydrochloric acid are added and the solution is boiled or bubbled with steam for two or three minutes in order to remove sulfur dioxide and carbon dioxide. This is cooled and diluted to 100 cc. in the graduated cylinder and, if the solution is turbid at this point, it must be filtered. Two cc. of this solution are pipetted into 25 cc. of stock solution No. *1* in a standard test tube, a cork stopper is inserted, and the tube is inverted, three or four times. Its transmission is then read on the opacimeter and the sulfate concentration determined from a calibration curve.

*p*H.—The *p*H of developer solutions can sometimes be measured colorimetrically by means of indicators but, in many cases, the solutions are colored to such an extent that colorimetric observations are impracticable and electrometric methods must therefore be used. The usual types of glass electrodes used in conjunction with a standard reference electrode and an ordinary potentiometer are quite satisfactory. At the present time, most glass electrodes have a fairly large sodium-ion error at high *p*H values but there is now enough information in the chemical literature so that corrections for such errors can be made with sufficient accuracy. In any case where variations of *p*H rather than absolute values are desired, the errors may be neglected. The most important use of *p*H in developer analysis is to obtain a quick check in cases where large errors of mixing are suspected or where it is desired to distinguish between too greatly different formulas such as those used for a negative and a positive film.

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DISCUSSION

MR. DEPUE: What is the best length of time for processing positive film in the machine, two minutes or three and a half?

MR. EVANS: That depends a good deal upon the machine and the precision with which you wish to repeat results. At two minutes, of course, it is much more difficult to repeat results than at five or six. I do not think it can be stated whether one is to be preferred to the other.

MR. SCHMIDT: I understand that upon the addition of alkali to the developer a certain time is required for the *p*H to reach the definite value that corresponds to the equilibrium.

MR. EVANS: Yes. In some cases half a day is required before the *p*H equilibrium is established so it can be read.

MR. SCHMIDT: Do you propose an explanation of that? I expected that the reaction between the ions would take place in a shorter time.

MR. EVANS: We expected that also, but it does not appear to be. Perhaps it has to do with the organic constituents that are present.

MR. CRABTREE: Do you estimate the sulfonates formed in the developer?

MR. EVANS: The sulfonates are included in the analysis. They are not strictly necessary unless it is desired to know what the original formula was. The sum of acting developing agents and their sulfonates is equal to the concentration in the replenisher of the original compound, and accordingly it is sometimes interesting to know whether a change in the bath is due to the concentration in the replenisher.

AN OPACIMETER USED IN CHEMICAL ANALYSIS*

R. M. EVANS AND G. P. SILBERSTEIN**

Summary.—*The opacimeter is an optical instrument designed to measure the light-transmission of a colored or turbid solution. A Loewenthal photronic type light-sensitive cell connected to a microammeter is used to measure the intensity of the light transmitted by the solution under test. The light-intensity falling on the sensitive cell is kept within a fixed range by varying the distance of the cell from the source. The instrument is arranged so that a 30-cc. test tube or a 300-cc. Kohle flask may contain the reaction mixture. The results of analyses are determined from calibration curves prepared from known solutions.*

A great many quantitative tests for the chemical constituents of solutions lend themselves readily to measurements based on the change in light-transmission of the solution after addition of suitable reagents. A wide variety of optical instruments designed to make measurements of this sort have been in use for a long time. The purpose of this article is to describe a new design of such an instrument which possesses several advantages.

The name "opacimeter" seems a suitable one to give to the instrument shown in Fig. 1. A Loewenthal photronic type light-sensitive cell (chosen because of its stability and high sensitivity) is used to measure the intensity of the light transmitted by the solutions under test. This cell is color-selective, and its sensitivity depends upon the intensity level of the incident light. For these reasons, the optical system shown diagrammatically is designed to work at a constant color-temperature of the light-source. The light-intensity falling on the Loewenthal cell is kept within a fixed range by varying the distance of the cell from an opal glass diffusing disk illuminated by the light passing through the solution under test. In order to cut out the infrared sensitivity of the light-receiver and also to prevent heat-rays from reaching the test solutions, a flask containing a 4-per cent copper sulfate solution is placed on the light-source side of the flask

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

used in making the tests. A high-aperture lens system maintains a parallel beam of light passing through the solution in the test flask, thus permitting a more efficient system. As long as the liquid level is a small distance above the top of the light-path, changes in this level have no effect on the amount of light reaching the light-receiver.

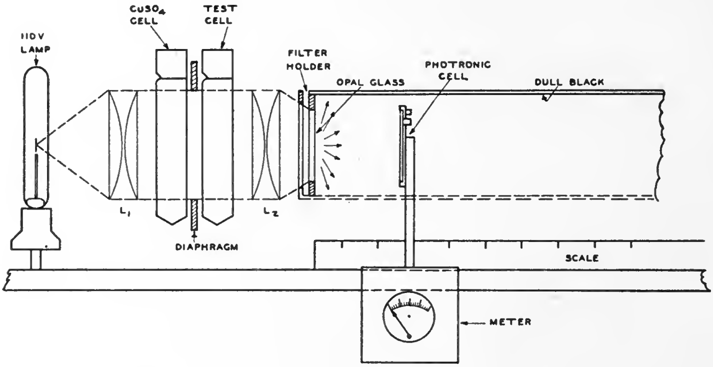

FIG. 1

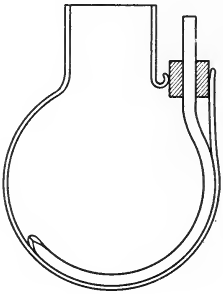

FIG. 2

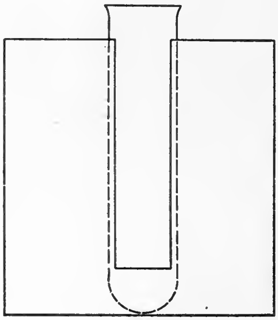

FIG. 3

FIG. 1. Diagram of optical system.
FIG. 2. Diagram showing scheme for air agitation within Kohle flask.
FIG. 3. Test-tube holder.

The opacimeter is designed to use Kohle culture flasks as test cells, these being readily available, easily cleaned, and quite uniform in dimensions. The procedure followed is to make the calibration run on any given test in the same flask as that to be used in testing the solution. In case of breakage, a new flask may be calibrated easily. In Fig. 2 is shown an air-stirring system built into one of the Kohle flasks. This consists of a bent glass tube ending in a fine orifice. The large end of the tube is attached to a source of compressed air, the fine air-jet producing very efficient circulation in the solution in the flask, air bubbles passing around the outside of the flask and not entering that portion of the solution lying in the light-path. As can be seen from the photograph (Fig. 4) the test flasks do not need to be removed from the instrument in order to introduce test liquids; thus, continuously stirred titrations can be run by using a burette held in place above the opening of the air-stirring flask just mentioned. When it is desirable to use a small amount of solution in making a test, the Kohle flask can be replaced by a test-tube holder, such as

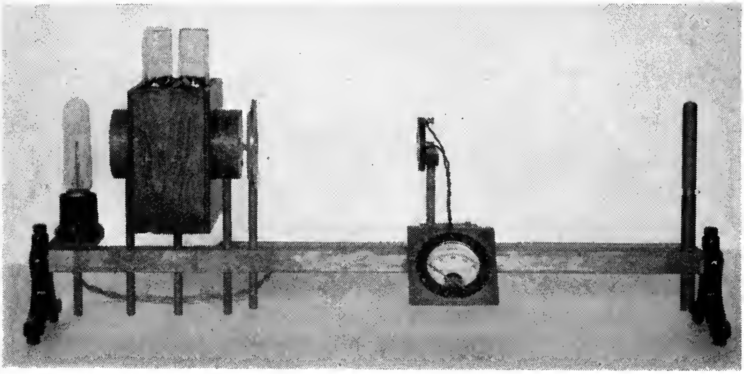

FIG. 4. Photograph of instrument, with light guards removed.

shown in Fig. 3. The test tube when filled with solution forms a cylindrical lens which, in conjunction with the main optics, covers the opal-glass diffusing disk with light. Ordinary test tubes can be used for this purpose, provided each one is calibrated for the particular test with which it is to be used.

In most cases, tests are run by adjusting the position of the light-receiver so that the microammeter in series with it gives a deflection of 200μ with a blank solution in the test flask and with a suitable Wratten light-filter in the holder shown in Fig. 1. The decrease in transmission of the solution after the test reaction has taken place is read on the meter scale in microamperes. This reading can then be converted into the amount of the particular ingredient by the use of a calibration curve. If it is desired to measure the optical density of the solution, meter readings can be converted to densities from the relation:

$$\text{Density} = \log \frac{200}{\text{reading}}$$

A 200-watt, 110-volt projection lamp (with a prefocus base to minimize adjustment when replacing a burned out lamp) gives sufficient light for most tests, even when such a low-transmission light filter as Wratten No. *53* is used. The meter used in conjunction with the Loewenthal cell is a Weston model No. *301 DC* microammeter, reading μ at full scale.

The use of the instrument is not restricted to chemical reactions giving rise to a clear, colored solution. In practice, it has been found that the amount of constituent present can be reliably determined by measuring the change in light-transmission arising from the formation of uniformly dispersed precipitates, especially if settling of the precipitates is prevented by use of suitable dispersing agents.

In making measurements on nonscattering colored solutions, the use of colored filters in the light-beam greatly increases the sensitivity of the particular test being made. Common procedure in these cases is to choose a filter having a strong absorption band in the spectral region where the transmission of the colored solution being measured is a maximum. In the case of reactions giving several transmission bands owing to the presence in solution of constituents other than the one under test, the use of a proper color-filter makes it possible to separate the useful transmission band from the others.

NEW MOTION PICTURE APPARATUS

During the Conventions of the Society, symposiums on new motion picture apparatus are held in which various manufacturers of equipment describe and demonstrate their new products and developments. Some of this equipment is described in the following pages; the remainder will be published in subsequent issues of the Journal.

A NEW PROJECTOR MECHANISM*

H. GRIFFIN**

During the past few years the Research and Engineering Departments of this company have been searching for a device or devices that would permit changes in the design of projection equipment that would result in greatly improved film presentation. Many ideas were considered and rejected, some because of extreme complications, and all because nothing was found that would compare favorably so far as screen results were concerned, with equipment of our earlier designs. After making this decision approximately two years ago, it was decided to improve, so far as we possibly could, upon what were our earlier conceptions of the best available mechanisms, with the result that about two months ago there was released to the industry the company's latest development in motion picture projectors, the Simplex *E-7* mechanism (Fig. 1).

In considering the design of modern motion picture projection equipment it is necessary to deal with two major requirements: (*1*) greater screen illumination, without increasing the light coming from the arc or other illuminating means, and (*2*) increased steadiness of the projected picture. The means whereby these have been accomplished, together with a brief summary of other changes and improvements, constitute the subject of this paper.

In the conventional motion picture projector mechanism there are a revolving shutter either in the front or in the rear which cuts off the light as the film is pulled down past the aperture plate by the intermittent movement, and openings in the shutter, either front or rear, which allow the light-beam to pass through the film to the screen while the film is at rest in front of the aperture plate. Increased illumination obtained from the *E-7* projector has been brought about by placing a second shutter in front of the lens (Fig. 2), this shutter being attached to the same shutter shaft and revolving in the same direction as the rear shutter or the shutter between the illuminant and the aperture plate. By this design it is possible to cut off half of the light-beam behind the aperture plate, and half of the picture at

* Presented at the 1938 Spring Meeting at Washington, D. C.; received April 14, 1938.

** International Projector Corp., New York, N. Y.

the same instant in front of the lens, since the image is inverted after passing through the lens. We are thus able (since it is not then necessary, as in the case of one shutter, to cut the entire picture from the screen before moving the next one into position) to cut the top and bottom halves of the picture at the same instant and eliminate approximately 20 degrees from each shutter blade, and hence pass that much more light to the screen. This results in an approximate increase of from 12 to 15 per cent in screen illumination.

FIG. 1. Simplex *E-7* projector.

This result is obviously attained without increasing the speed of any part of the mechanism since, as before stated, both shutters revolve at the same speed (1440 rpm.), being attached to the same shutter shaft. Both shutters are housed in suitable protective guards, and means are provided for the easy removal of these guards when necessary for cleaning purposes. Attached to the rear shutter, between the source of illumination and the aperture plate, are specially designed vanes, the function of which is to create a partial vacuum in and around the aperture plate and remove therefrom at high velocity the heat created by the illuminated spot and keep the entire rear of the projector cool enough to touch with the fingers even when using high-intensity arcs.

To set the shutters in exact synchronism and in proper relation to the intermittent movement, a shutter-setting device is supplied with each pair of mechanisms. With this device the shutters may be set in an extremely simple manner and with a greater degree of accuracy than was possible with earlier equipment.

A steadier picture is obtained both vertically and laterally, first, through new developments in intermittent movement design, which allow far greater accuracy in manufacture, plus a hardened and ground intermittent sprocket on which the 64 radii of the teeth are ground to extreme accuracy; and, second, by the addition of edge-guiding in the film-trap, which maintains the film in a constant lateral position and does not allow the film to weave slightly as in former designs.

To eliminate the possibility of improper or inadequate lubrication, the equipment is provided with the Bijur one-shot oiling system (Fig. 3). This system has proved its merit in the finest types of accounting machines, sewing machines, electric lamp machinery, *etc.;* it is incorporated in the best American trucks and ambulances, and in the highest grade foreign automobiles.

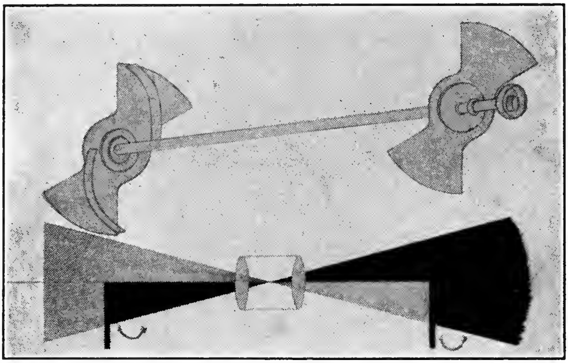

FIG. 2. Synchronized front and rear shutters.

As applied to the new projector, this system consists of a piston pump which delivers at each impulse a metered quantity of filtered oil to a distribution system where, by means of meter units, this measured quantity is proportioned to each bearing in predetermined quantities. Check-valves in the meter units prevent draining the oil lines between "shots." The system is provided with a double set of dense felt filters, the one in the pump being the denser and serving to filter the reservoir oil; the other set of filters is in the individual meter units and is for protection of the units against chips and dirt before and during assembly. This combination of filtering assures a clean supply of oil at every bearing. The Bijur Company advise that they have as yet found no indication of a limit to the life of the filters when used with a straight mineral oil. The pump develops a pressure of 35 pounds per square inch.

The small tubes leading from the meter units to the bearings are so proportioned, as to ratio of wall thickness to bore, that they will not collapse even when bent double in a vise, so there is no way in which they could be stopped up without a type of handling that would also damage the mechanism as a whole. With

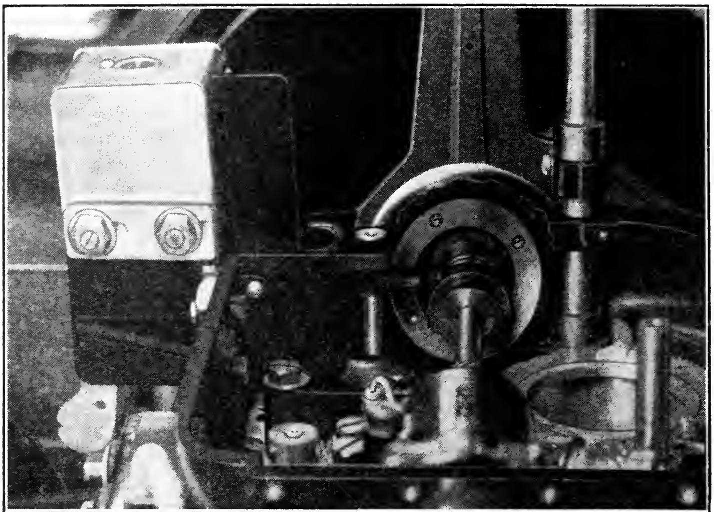

FIG. 4.

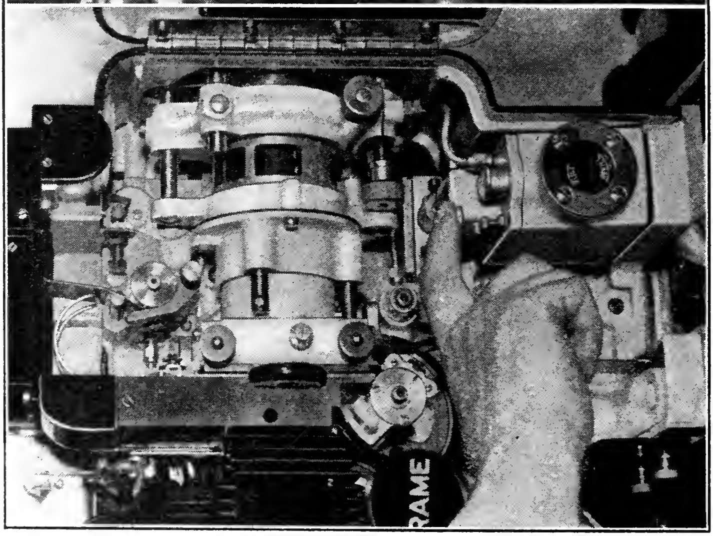

FIG. 3.

FIG. 3. Operating the Bijur one-shot oiling system.
FIG. 4. Centrifugally operated disk on shutter-shaft for actuating fire-shutter between rear shutter and film aperture.

a lubricating system such as this the only place in which it is necessary to see the oil is in the pump unit, and a sight-glass is provided for this purpose.

Such bearings as are not reached by this lubricating system are the ball bearings that carry the shutter-shaft assembly and the lower bearing of the oblique shaft. These are of the sealed, grease-packed, dustproof type, and do not need attention for a number of years. Oil-can lubrication is required only to fill the oil reservoir of the Bijur system and the intermittent movement, which will be discussed later.

Considering fire protection of paramount importance, the equipment is supplied with a positive-acting fire-shutter between the rear shutter and the film aperture (Fig. 4), which is operated through a centrifugally operated disk mounted on the revolving shutter-shaft. When the projector is at rest this disk lies at an

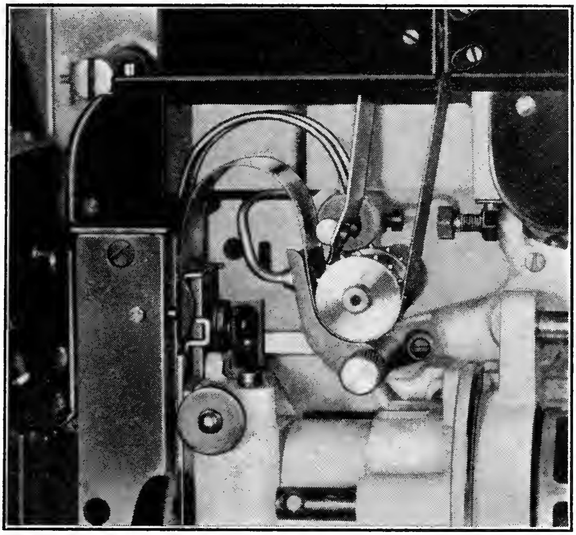

FIG. 5. Automatic fire-shutter safety trip.

angle with relation to the shutter-shaft and when the projector is in operation, centrifugal motion straightens up, so to speak, and through a unique linkage device raises the fire-shutter out of the beam of light.

It is well known that on a properly designed projector mechanism, and one that is kept in good repair, it is not possible under normal circumstances to burn more than one frame of film at the aperture plate should a splice part at the intermittent sprocket, and this, incidentally, is the only time it is possible during normal operation of a projector for any kind of fire to occur. However, to eliminate even this cause of fire, the apparatus is provided with an automatic fire-shutter safety trip (Fig. 5), which operates in connection with the automatic fire-shutter and instantaneously drops the latter should a splice part at the intermittent sprocket. The unit is operated by the slightest increase in size of the upper loop, and the action is instantaneous, the fire-shutter dropping before the film has a chance to ignite. This means increased protection to the projectionist and theater owner. The device is simply attached and may readily be removed and replaced.

A newly designed film-gate has been provided, of much heavier construction than any of its predecessors and readily removable by simply removing two thumb-nuts and sliding it from its two supporting studs (Fig. 6). This gate is now formed from one heavy steel stamping which supports along its entire length pressure pads of new design, the tension on all of which, through self-equalizing cone

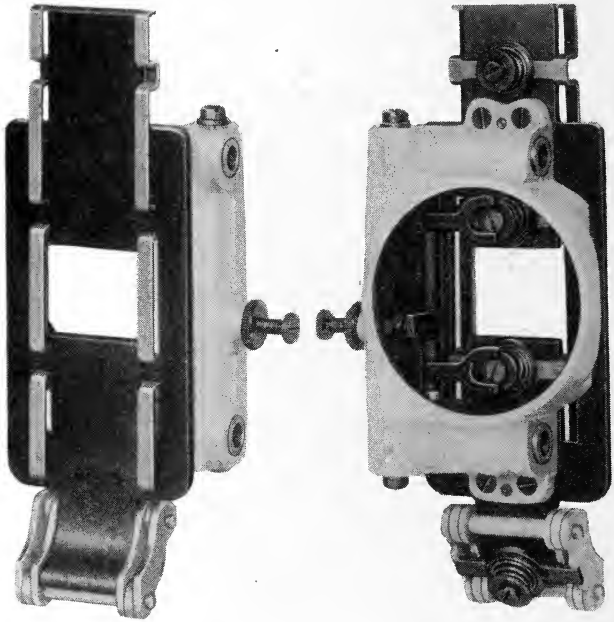

FIG. 6. Film gate: (*left*) rear view; (*right*) front view.

springs, is readily adjusted by the projectionist while the projector is in operation. The base of the gate supports the intermittent sprocket tension shoe which also is provided with an adjustable tension unit. With this type of gate, and due to the proper placement of tension shoes, it has been found possible to lessen the tension considerably and at the same time maintain a much steadier picture than heretofore.

The gate is mounted on an opening and closing unit of entirely new design and is locked solidly in both its open and closed position. Provision is made for removing entirely any lateral displacement of the gate due to wear, and this combination definitely prevents any "jiggling" of the gate such as was sometimes evident in earlier models. The entire gate is provided with a very simple

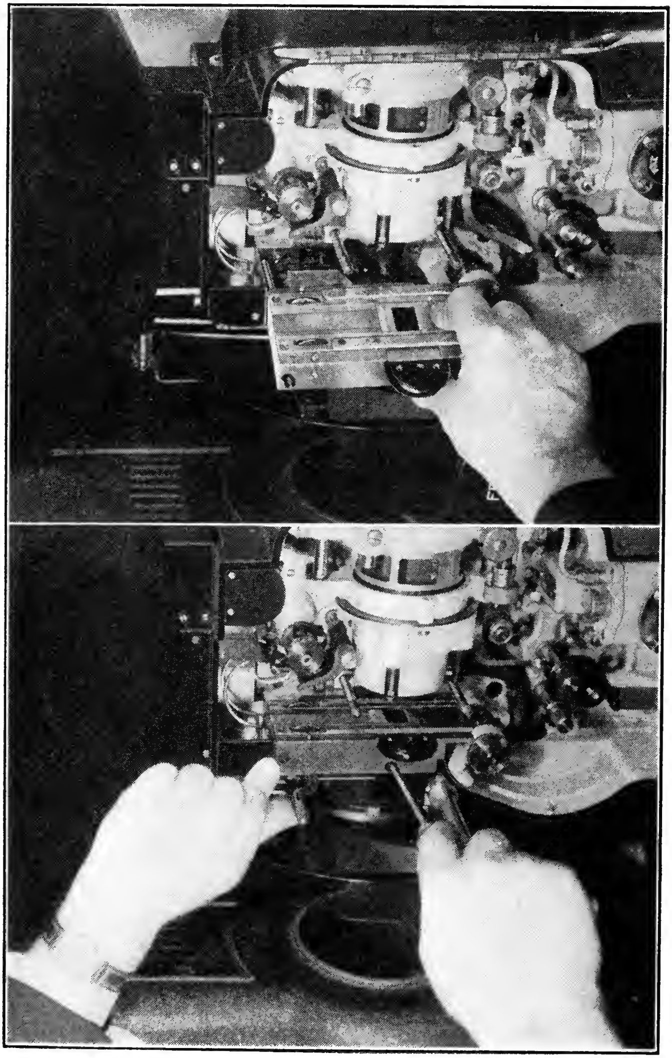

FIG. 7. Showing construction and method of removing film-trap.

lateral adjustment by means of which it may be correctly aligned with the runners on the film-trap.

The film-trap is of completely new and original design and may now be removed entirely for cleaning purposes as may the gate (Fig. 7). This is accomplished simply by the removal of two screws, whereupon the film-trap may be slid off toward the projectionist. The film-trap is provided with the conventional lateral guide-rollers, but, in addition thereto, edge-guiding channels have been added which, in coöperation with the lateral guide-rollers, maintain the edge of the film steadily against the edge of the guide, thus eliminating all sidesway during film travel. The film-handling parts of both the gate and film-trap are readily removable for replacement when wear becomes apparent, and it is no longer necessary to tear down the entire projector when such is the case.

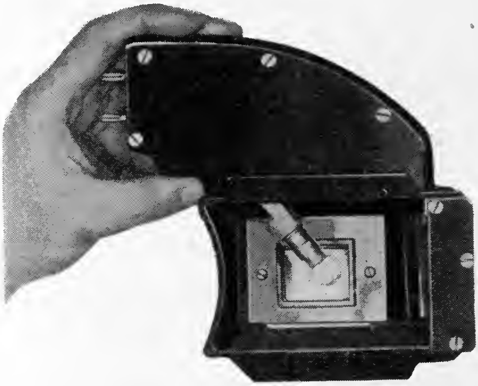

FIG. 8. Framing lamp and spot sight box.

As in the case of previous film-trap and gate design in Simplex projectors, the emulsion side is always toward the film-trap runners; thus, variations in film thickness, as between standard production film and newsreel stock, will not affect the definition of the projected picture; thus, it is not necessary to re-focus the lens to compensate for the difference in the position of the emulsion as is the case with the old Powers projector mechanism and other equipment of similar design.

An ingenious framing lamp and spot sight box assembly is mounted between the rear shutter and the film-trap (Fig. 8). A small incandescent lamp of the bayonet type is pivotally mounted in this assembly and operable only when the fire-shutter is raised manually during the process of threading the film into the projector; thus, a strong, direct beam of light is projected through the aperture plate by means of which the projectionist may accurately select the frame of film to be placed over the latter. The lamp is lighted through a small mercoid switch and extinguished upon release of the fire-shutter lever which automatically takes the framing lamp assembly out of the path of the projection lamp beam and extinguishes it at the same time.

The spot sight box in which this assembly is mounted is provided with a number of air-cooled fins for rapid dissipation of heat from the projection lamp-beam. A highly polished nickel-plated copper baffle, together with two additional copper baffles, form part of the heat-reflecting unit in this assembly, and this helps further to cool the rear of the mechanism. The entire assembly is readily removable for cleaning, and engages the electrical circuit by means of pin plugs when in its proper operating position.

The intermittent movement in this equipment is of the conventional double-bearing type, similar to that provided in earlier Simplex mechanisms (Fig. 9). It has been greatly improved, however, as to oil sealing, and is provided with

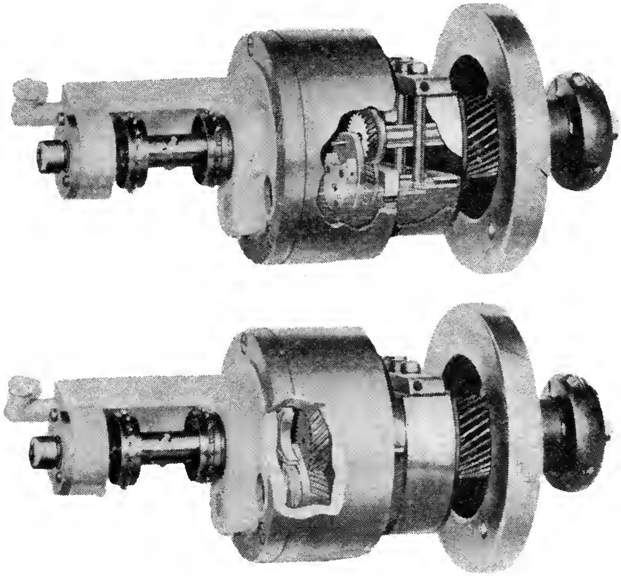

FIG. 9. Cut-away views of intermittent movement.

means whereby it is impossible to insert a greater quantity of oil than is required for proper operation. This eliminates the possibility of the projectionist's overfilling the oil-well and thus allowing the lubricant to spill over; and at the same time makes it possible at all times for him to see through the sight glasses in the movement, that the oil level is correctly maintained.

The entire movement is of considerably heavier construction throughout, and its design, as before stated, allows for far more accurate construction than was possible in any previous movement. In addition to being leakproof it is practically bindproof, since properly designed spiral grooves in connection with oil channels are provided in the revolving shafts and bearings which carry oil to all parts needing constant lubrication. In addition to this, perfect lubrication between the cam ring and the star radius is assured, since oil is forced through two channels in the cam forming a cushion of oil between the star radius and the cam ring when they lock together while the picture is being projected. This also cushions the blow between the two units and makes for a quiet-running unit. The movement may be lubricated from either the non-operating or operating side.

One of the important features in connection with this intermittent movement is the fact that it may be readily removed for cleaning, or parts replaced without disturbing any of the major parts of the projector mechanism or sound-reproducing unit—and this from the operating side of the mechanism.

Positive synchronism, without backlash or lost motion, is assured between the intermittent movement and the revolving shutters when framing by the uniquely designed assembly now performing this function. The shutter-shaft passes through an assembly similar to a cylinder and piston in automobile design (Fig. 10), and fastened to the piston through a ball-race is the shutter driving gear by means of which the shutter-shaft is driven through a woodruff key. Attached

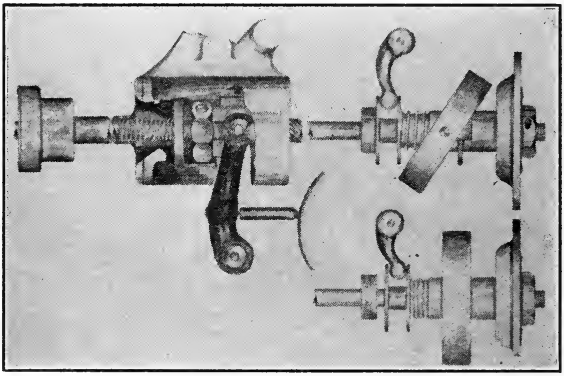

FIG. 10. New ring type governor.

also to the piston is a pivoted arm, the lower end of which fetches up solidly against a plunger pin operated by the framing cam of the intermittent movement assembly.

The entire assembly is held under substantial tension by means of a heavy coiled spring, one end of which is held under tension by a collar on the shutter-shaft and revolving with it, and the other end of which fetches up solidly against the ball-race attached to the gear. This spring performs two functions: it forces the piston rearward at all times, and at the same time removes any slight end-play in the shutter shaft and framing device synchronizing assembly.

In operation, when the framing handle is turned in one direction, the intermittent movement, complete with its framing cam, revolves in its housing, forces the plunger against the pivoted arm, which in turn moves the piston and gear assembly forward against the spring compression, thus revolving the spiral gear and shutter-shaft the exact amount necessary to maintain synchronism between the intermittent movement and the revolving shutters. When the framing handle is turned in the opposite direction, the entire assembly performs exactly the same function, except that the compression spring forces the piston and gear assembly rearward, and thus the same synchronism is obtained with any position of the framing handle and intermittent sprocket.

All bevel gears have been eliminated and, as a matter of fact, the number of gears has been greatly reduced. Spiral gears alone now form the driving equipment, and thus the noise-level during operation has been tremendously reduced. The face of the main drive gears has been increased in cross-section as a protection against the high starting torque of the modern sound-head, and these gears now operate on hardened and ground studs rigidly attached to the center frame. The area of the bearings of the gears that revolve upon these studs has also been greatly increased, and lubrication is provided through the Bijur one-shot oiling system to the center of the studs, forcing in clean oil all the time and washing any dirty lubricant out on the non-operating side of the projector only; thus rebushing of the main frame in this connection has been eliminated, and much longer life is assured and cost of maintenance reduced.

Wherever the finest accuracy is not required non-scoring bearing material is used; but where extreme accuracy is required, and this material can not be relied upon satisfactorily, the type of bearings best suited for their proper function, such as ball bearings on the shutter shaft, and burnished cast-iron bearings for hardened and ground shafts, are used.

Lens focusing is accomplished from either inside or outside the mechanism, making it possible at all times to control readily the definition of the projected picture.

The mechanism is designed to fit any existing standard sound-reproducing apparatus. The interior is finished in pearl-gray enamel, to facilitate observation of the film travel. This light interior also lends itself to cleanliness, and is brightly illuminated by the additional threading lamp provided in the upper right-hand corner of the operating side of the mechanism. This latter lamp eliminates the need for the old-fashioned trouble-lamp heretofore necessary for checking during threading operations.

1939 SPRING CONVENTION

SOCIETY OF MOTION PICTURE ENGINEERS

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APRIL 17th–21st, INCLUSIVE

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O. F. NEU

Headquarters

Headquarters of the Convention will be the Hollywood Roosevelt Hotel, where excellent accommodations are assured. A reception suite will be provided for the Ladies' Committee, and an excellent program of entertainment will be arranged for the ladies who attend the Convention.

Special hotel rates, guaranteed to SMPE delegates, European plan, will be as follows:

One person, room and bath	$ 3.50
Two persons, double bed and bath	5.00
Two persons, twin beds and bath	6.00
Parlor suite and bath, 1 person	8.00
Parlor suite and bath, 2 persons	12.00

Indoor and outdoor garage facilities adjacent to the Hotel will be available to those who motor to the Convention.

Members and guests of the Society will be expected to register immediately upon arriving at the Hotel. Convention badges and identification cards will be supplied which will be required for admittance to the various sessions, the studios, and several Hollywood motion picture theaters.

Railroad Fares

The following table lists the railroad fares and Pullman charges:

City	Railroad Fare (round trip)	Pullman (one way)
Washington	$132.20	$22.35
Chicago	90.30	16.55
Boston	147.50	23.65
Detroit	106.75	19.20
New York	139.75	22.85
Rochester	124.05	20.50
Cleveland	110.00	19.20
Philadelphia	135.50	22.35
Pittsburgh	117.40	19.70

The railroad fares given above are for round trips, sixty-day limits. Arrangements may be made with the railroads to take different routes going and coming, if so desired, but once the choice is made it must be adhered to, as changes in the itinerary may be effected only with considerable difficulty and formality. Delegates should consult their local passenger agents as to schedules, rates, and stop-over privileges.

San Francisco Fair

On February 18, 1939, the Golden Gate Exposition opened at San Francisco, an overnight trip from Hollywood. The exposition will last throughout the summer so that opportunity will be afforded the eastern members of the Society to take in this attraction on their Convention trip. Special arrangements have been made with the Hotel Empire at San Francisco for Convention delegates visiting the Fair, at the following daily rates:

One person, room and bath	$3.50
Two persons, double bed and bath	5.00
Two persons, twin beds and bath	6.00

Suites:

Parlor and bedroom for two persons	8.00 and up
Two large bedrooms, each with private bath and a living room; for four persons	16.00

Reservations can be made either by writing directly to the Hotel Empire or by addressing Mr. W. C. Kunzmann, *Convention Vice-President*, Box 6087, Cleveland, Ohio.

Technical Sessions

The Hollywood meeting always offers our membership an opportunity to become better acquainted with the studio technicians and production problems, and arrangements will be made to visit several of the studios. The Local Papers Committee under the chairmanship of Mr. L. A. Aicholtz is collaborating closely with the General Papers Committee in arranging the details of the program. Complete details of the program will be published in a later issue of the JOURNAL.

Studio Visits

On the afternoon of Tuesday, April 18th, Paramount Pictures, Inc., will act as hosts of the Convention at their Hollywood Studio. The program will be in charge of Messrs. L. L. Ryder and H. G. Tasker. On the afternoon of Thursday, April 20th, the delegates of the Convention will be entertained at the studio of Warner Brothers First National, Inc., at Burbank. The program of the afternoon will be under the supervision of Mr. N. Levinson.

Semi-Annual Banquet and Dance

The Semi-Annual Banquet of the Society will be held at the Hotel on Thursday, April 20th. Addresses will be delivered by prominent members of the industry, followed by dancing and entertainment. Tables reserved for 8, 10, or 12 persons; tickets obtainable at the registration desk.

New Equipment Exhibit

An exhibit of newly developed motion picture equipment will be held in the *Bombay and Singapore* Rooms of the Hotel, on the mezzanine. Those who wish to enter their equipment in this exhibit should communicate as early as possible with the general office of the Society at the Hotel Pennsylvania, New York, N. Y.

Motion Pictures

At the time of registering, passes will be issued to the delegates to the Convention, admitting them to the following motion picture theaters in Hollywood, by courtesy of the companies named: Grauman's *Chinese* and *Egyptian* Theaters (Fox West Coast Theaters Corp.), Warner's *Hollywood* Theater (Warner Brothers Theaters, Inc.), Pantages *Hollywood* Theater (Rodney Pantages, Inc.). These passes will be valid for the duration of the Convention.

Ladies' Program

An especially attractive program for the ladies attending the Convention is being arranged by Mrs. N. Levinson, *hostess*, and the Ladies' Committee. A suite will be provided in the Hotel, where the ladies will register and meet for the various events upon their program. Further details will be published in a succeeding issue of the JOURNAL.

Points of Interest

En route: Boulder Dam, Las Vegas, Nevada; and the various National Parks. *Hollywood and vicinity:* Beautiful Catalina Island; Zeiss Planetarium; Mt.

Wilson Observatory; Lookout Point, on Lookout Mountain; Huntington Library and Art Gallery (by appointment only); Palm Springs, Calif.; Beaches at Ocean Park and Venice, Calif.; famous old Spanish missions; Los Angeles Museum (housing the SMPE motion picture exhibit); Mexican village and street, Los Angeles.

In addition, numerous interesting side trips may be made to various points throughout the West, both by railroad and bus. Among the bus trips available are those to Santa Barbara, Death Valley, Agua Caliente, Laguna, Pasadena, and Palm Springs, and special tours may be made throughout the Hollywood area, visiting the motion picture and radio studios.

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.

SMPE Standards.—The revised edition of the *SMPE Standards and Recommended Practice* was published in the March, 1938, issue of the JOURNAL, copies of which may be obtained for one dollar each.

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

Lapel Buttons.—The insignia of the Society, gold filled, with safety screw back. One dollar each.

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

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

SOCIETY ANNOUNCEMENTS

HOLLYWOOD CONVENTION

As outlined in the preceding section of this issue, and also as announced on the inside front cover, the next Convention of the Society will be held on April 17th–21st, inclusive, at Hollywood, Calif., with headquarters at the Hollywood Roosevelt Hotel. Full details concerning the program will be published in the next issue of the JOURNAL.

ATLANTIC COAST SECTION

At a meeting held at the Hotel McAlpin, New York, N. Y., on Wednesday, February 15th, Mr. Clinton P. Veber, Research Associate of the Department of Biophotography at Rutgers University, presented a paper describing "The Time Telescope."

A demonstration of the instrument accompanied the paper, which discussed the use and history of time-lapse photography, and also the control, design, and operation of the new equipment used at Rutgers University. Films were shown illustrating the use of machines in producing spectacular pictures showing the life histories of plants and other botanical subjects.

MID-WEST SECTION

The first meeting of the year was held on January 24th in the meeting rooms of the Western Society of Engineers at Chicago. Mr. E. F. Lowry, Research Director of the Continental Electric Company, Chicago, gave an interesting talk on "The Theory and Operation of Rectifier Tubes and Cathodes." Briefly tracing the history of vacuum-tubes from the beginning to the present day, the paper turned to the subject of rectifier tubes, in particular, those of the mercury-vapor type.

Following the talk, Mr. J. G. Black gave a demonstration of a 6-phase mercury-vapor rectifier.

AMENDMENTS

At the Detroit Convention of the Society, on October 31, 1938, the following amendment of the Constitution was proposed:

Article IV, Officers

It is proposed that the term of office of the Executive Vice-President be extended to two years, in view of the fact that the terms of all the other vice-presidents are two years.

Original wording:

The officers of the Society shall be a President, a Past-President, an Executive Vice-President, an Engineering Vice-President, an Editorial Vice-President, a Financial Vice-President, a Convention Vice-President, a Secretary, and a Treasurer.

The term of office of the President and Past-President shall be two years; of the Engineering, Editorial, Financial, and Convention Vice-Presidents, two years; and of the Executive Vice-President, Secretary, and Treasurer, one year. Of the Engineering, Editorial, Financial, and Convention Vice-Presidents, two shall be elected alternately each year or until their successors are chosen. The President shall not be immediately eligible to succeed himself in office.

Proposed wording:

The officers of the Society shall be a President, a Past-President, an Executive Vice-President, an Engineering Vice-President, an Editorial Vice-President, a Financial Vice-President, a Convention Vice-President, a Secretary, and a Treasurer.

The term of office of the President, the Past-President, the Executive Vice-President, the Engineering Vice-President, the Editorial Vice-President, the Financial Vice-President, and the Convention Vice-President shall be two years, and the Secretary and the Treasurer one year. Of the Engineering, Editorial, Financial, and Convention Vice-Presidents, two shall be elected alternately each year, or until their successors are chosen. The President shall not be immediately eligible to succeed himself in office.

Adhering to the procedure for voting upon amendments of the Constitution, voting ballots were mailed to the voting membership shortly after the Convention, and a recent count of the ballots by the Secretary indicated practically unanimous approval of this amendment.

ADMISSIONS COMMITTEE

At a recent meeting of the Admissions Committee at the General Office of the Society, the following applicants for membership were admitted to the Associate grade:

Ackley, A.
270 North Michigan,
Chicago, Ill.

Bailward, P.
6 Pall Mall,
London, England.

Barua, P. C.
14 Ballygunge Circular Rd.,
Calcutta, India.

Bergstedt, F. H.
2780 Dewey Ave.,
Rochester, N. Y.

Birch, H.
609 Stratford Pl.,
Chicago, Ill.

Bradshaw, C. H.
12708 Littlefield St.,
Detroit, Mich.

Brandt, J. S.
448 Lincoln Ave.,
Orange, N. J.

Cohen, C.
1821 Roselyn St.,
Philadelphia, Penna.

Coleman, J. A.
13553 Artesian Ave.,
Detroit, Mich.

Colton, H. C.
119–40 Union Turnpike,
Kew Gardens, N. Y.

Cooper, H. G.
1015 N. Edinburgh,
Los Angeles, Calif.

Danuff, I. R.
1050 Anderson Ave.,
Bronx, N. Y.

Federici, M.
Corti 12,
Milan, Italy.

Grant, S.
35 E. Wacker Dr.,
Chicago, Ill.

HALL, F.
119 LeRoy St.,
New York, N. Y.
HALL, H. W.
Beeville, Tex.
JAPIKSE, A. B.
22 Tulpweg,
Wassenaar, Holland.
JENNINGS, B. D.
245 W. 55th St.,
New York, N. Y.
KENNEDY, F. M.
231 S. Witmer St.,
Los Angeles, Calif.
KENNEDY, J. D.
14668 Abington Rd.,
Detroit, Mich.
KNIFFEN, L. D.
Kincardine, Ontario, Canada.
KRAMER, L.
1513 Field St.,
Detroit, Mich.
KUTTNAUER, L. V.
1223 S. Wabash Ave.,
Chicago, Ill.
MENLEY, F. A.
931 Ogden Ave., S. E.,
Grand Rapids, Mich.
MORANZ, J.
Breslin Bldg.,
Louisville, Ky.
MORELOCK, O. J.
614 Frelinghuysen Ave.,
Newark, N. J.
MUDGE, M. L.
P. O. Box 41, Linwood Station,
Detroit, Mich.
NILLESEN, H. A.
N. V. Philips,
Eindhoven, Holland.
OLIN, N. E.
126 W. 73rd St.,
New York, N. Y.
OWNBEY, L. C.
255 Golden Gate Ave.,
San Francisco, Calif.
PARK, W. C.
278 N. Fulton Ave.,
Mt. Vernon, N. Y.
POLLOCK, J. R., JR.
590 HAMILTON St.,
Vancouver, B. C.
POLLACK, S. M.
Box 4—969 Hoe Ave.,
New York, N. Y.
SCHOLES, J. J.
100 Gibbs St.,
Rochester, N. Y.
SONKIN, D.
12 Dongan Pl.,
New York, N. Y.
THOMPSON, F. E.
932 Collingwood Ave.,
Detroit, Mich.
THOMPSON, J.
4552 Camellis Ave.,
N. Hollywood, Calif.
TOENNIES, J. F.
404 E. 55th St.,
New York, N. Y.
VANDERFORD, H. L.
195 Broadway,
New York, N. Y.
VOELKER, C. M.
66 Sibley St.,
Detroit, Mich.
WALL, C. R.
39 Nassau Ave.,
Malverne, N. Y.
WOLFE, H.
2719 Hyperion Ave.,
Los Angeles, Calif.

In addition the following applicant was approved by the Board of Governors for transfer from the Active grade to the grade of Fellow:

LINDSAY, W. W., JR.
6625 Romaine St.,
Hollywood, Calif.

CONSTITUTION AND BY-LAWS
OF THE
SOCIETY OF MOTION PICTURE ENGINEERS*

CONSTITUTION

Article I
Name

The name of this association shall be SOCIETY OF MOTION PICTURE ENGINEERS.

Article II
Object

Its objects shall be: Advancement in the theory and practice of motion picture engineering and the allied arts and sciences, the standardization of the equipment, mechanisms, and practices employed therein, the maintenance of a high professional standing among its members, and the dissemination of scientific knowledge by publication.

Article III
Eligibility

Any person of good character may be a member in any class for which he is eligible.

Article IV
Officers

The officers of the Society shall be a President, a Past-President, an Executive Vice-President, an Engineering Vice-President, an Editorial Vice-President, a Financial Vice-President, a Convention Vice-President, a Secretary, and a Treasurer.

The term of office of the President, the Past-President, the Executive Vice-President, the Engineering Vice-President, the Editorial Vice-President, the Financial Vice-President, and the Convention Vice-President shall be two years, and the Secretary and the Treasurer one year. Of the Engineering, Editorial, Financial, and Convention Vice-Presidents, two shall be elected alternately each year, or until their successors are chosen. The President shall not be immediately eligible to succeed himself in office.

Article V
Board of Governors

The Board of Governors shall consist of the President, the Past-President, the five Vice-Presidents, the Secretary, the Treasurer, the Section Chairmen, and five elected Governors. Two, and three, of the Governors shall be elected alternately each year to serve for two years.

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* Corrected to January 1, 1939.

Article VI

Meetings

There shall be an annual meeting, and such other meetings as stated in the By-Laws.

Article VII

Amendments

This Constitution may be amended as follows: Amendments shall be approved by the Board of Governors, and shall be submitted for discussion at any regular members' meeting. The proposed amendment and complete discussion then shall be submitted to the entire Active, Fellow, and Honorary membership, together with letter ballot as soon as possible after the meeting. Two-thirds of the vote cast within sixty days after mailing shall be required to carry the amendment.

BY-LAWS

By-Law I

Membership

Sec. 1.—The membership of the Society shall consist of Honorary members, Fellows, Active members, Associate members, and Sustaining members.

An **Honorary member** is one who has performed eminent services in the advancement of motion picture engineering or in the allied arts. An Honorary member shall be entitled to vote and to hold any office in the Society.

A **Fellow** is one who shall not be less than thirty years of age and who shall comply with the requirements of either (*a*) or (*b*) for Active members and, in addition, shall by his proficiency and contributions have attained to an outstanding rank among engineers or executives of the motion picture industry. A Fellow shall be entitled to vote and to hold any office in the Society.

An **Active member** is one who shall be not less than 25 years of age, and shall be:

(*a*) A motion picture engineer by profession. He shall have been engaged in the practice of his profession for a period of at least three years, and shall have taken responsibility for the design, installation, or operation of systems or apparatus pertaining to the motion picture industry.

(*b*) A person regularly employed in motion picture or closely allied work, who by his inventions or proficiency in motion picture science or as an executive of a motion picture enterprise of large scope, has attained to a recognized standing in the motion picture industry. In case of such an executive, the applicant must be qualified to take full charge of the broader features of motion picture engineering involved in the work under his direction.

(*c*) An Active member is privileged to vote and to hold any office in the Society.

An **Associate member** is one who shall be not less than 18 years of age, and shall be a person who is interested in or connected with the study of motion picture technical problems or the application of them. An Associate member is not privileged to vote, to hold office or to act as chairman of any committee, although he may serve upon any committee to which he may be appointed; and, when so appointed, shall be entitled to the full voting privileges of a committee member.

A **Sustaining member** is an individual, a firm, or corporation contributing substantially to the financial support of the Society.

Sec. 2.—All applications for membership or transfer, except for honorary or fellow membership, shall be made on blank forms provided for the purpose, and shall give a complete record of the applicant's education and experience. Honorary and Fellow membership may not be applied for.

Sec. 3.—(*a*) An **Honorary** membership may be granted upon recommendation of the Board of Governors when confirmed by a four-fifths majority vote of the Honorary members, Fellows, and Active members present at any regular meeting of the Society. An Honorary member shall be exempt from all dues.

(*b*) Fellow membership may be granted upon recommendation of at least three-fourths of the Board of Governors.

(*c*) Applicants for **Active** membership shall give as reference at least three members of Active or of higher grade in good standing. Applicants shall be elected to membership by the approval of at least three-fourths of the Board of Governors.

(*d*) Applicants for **Associate** membership shall give as reference at least one member of higher grade in good standing. Applicants shall be elected to membership by the approval of at least three-fourths of the Board of Governors.

By-Law II

Officers

Sec. 1.—An officer or governor shall be an Honorary, a Fellow, or Active member.

Sec. 2.—Vacancies in the Board of Governors shall be filled by the Board of Governors until the annual meeting of the Society.

By-Law III

Board of Governors

Sec. 1.—The Board of Governors shall transact the business of the Society between members' meetings, and shall meet at the call of the president.

Sec. 2.—A majority of the Board of Governors shall constitute a quorum at regular meetings.

Sec. 3.—When voting by letter ballot, a majority affirmative vote of the total membership of the Board of Governors shall carry approval, except as otherwise provided.

Sec. 4.—The Board of Governors, when making nominations to office, and to the Board, shall endeavor to nominate persons, who in the aggregate are representative of the various branches or organizations of the motion picture industry, to the end that there shall be no substantial predominance upon the Board, as the result of its own action, of representatives of any one or more branches or organizations of the industry.

By-Law IV

Meetings

Sec. 1.—The location of each meeting of the Society shall be determined by the Board of Governors.

Sec. 2.—Only Honorary members, Fellows, and Active members shall be entitled to vote.

Sec. 3.—A quorum of the Society shall consist in number of one-tenth of the total number of Honorary members, Fellows, and Active members as listed in the Society's records at the close of the last fiscal year.

Sec. 4.—The fall convention shall be the annual meeting.

Sec. 5.—Special meetings may be called by the president and upon the request of any three members of the Board of Governors not including the president.

Sec. 6.—All members of the Society in any grade shall have the privilege of discussing technical material presented before the Society or its Sections.

By-Law V

Duties of Officers

Sec. 1.—The **President** shall preside at all business meetings of the Society and shall perform the duties pertaining to that office. As such he shall be the chief executive of the Society, to whom all other officers shall report.

Sec. 2.—In the absence of the president, the officer next in order as listed in Article 4 of the Constitution shall preside at meetings and perform the duties of the president.

Sec. 3.—The five vice-presidents shall perform the duties separately enumerated below for each office, or as defined by the president:

(*a*) The **Executive Vice-President** shall represent the president in such geographical areas of the United States as shall be determined by the Board of Governors, and shall be responsible for the supervision of the general affairs of the Society in such areas, as directed by the president of the Society.

(*b*) The **Engineering Vice-President** shall appoint all technical committees. He shall be responsible for the general initiation, supervision, and coördination of the work in and among these committees. He may act as chairman of any committee or otherwise be a member ex-officio.

(*c*) The **Editorial Vice-President** shall be responsible for the publication of the Society's JOURNAL and all other technical publications. He shall pass upon the suitability of the material for publication, and shall cause material suitable for publication to be solicited as may be needed. He shall appoint a papers committee and an editorial committee. He may act as chairman of any committee or otherwise be a member ex-officio.

(*d*) The **Financial Vice-President** shall be responsible for the financial operations of the Society, and shall conduct them in accordance with budgets approved by the Board of Governors. He shall study the costs of operation and the income possibilities to the end that the greatest service may be rendered to the members of the Society within the available funds. He shall submit proposed budgets to the Board. He shall appoint at his discretion a ways and means committee, a membership committee, a commercial advertising committee, and such other committees within the scope of his work as may be needed. He may act as chairman of any of these committees or otherwise be a member ex-officio.

(*e*) The **Convention Vice-President** shall be responsible for the national conventions of the Society. He shall appoint a convention arrangements committee, an apparatus exhibit committee, and a publicity committee. He may act as chairman of any committee, or otherwise be a member ex-officio.

Sec. 4.—The **Secretary** shall keep a record of all meetings; he shall conduct the correspondence relating to his office, and shall have the care and custody of records, and the seal of the Society

Sec. 5.—The **Treasurer** shall have charge of the funds of the Society and disburse them as and when authorized by the financial vice-president. He shall make an annual report, duly audited, to the Society, and a report at such other times as may be requested. He shall be bonded in an amount to be determined by the Board of Governors and his bond filed with the secretary.

Sec. 6.—Each officer of the Society, upon the expiration of his term of office, shall transmit to his successor a memorandum outlining the duties and policies of his office.

By-Law VI

Elections

Sec. 1.—*(a)* All officers and five governors shall be elected to their respective offices by a majority of ballots cast by the Active, Fellow, and Honorary members in the following manner:

Not less than three months prior to the annual fall convention, the Board of Governors, having invited nominations from the Active, Fellow, and Honorary membership by letter form not less than forty days before the Board of Governors' meeting, shall nominate for each vacancy several suitable candidates. The secretary shall then notify these candidates of their nomination, in order of nomination, and request their consent to run for office. From the list of acceptances, not more than two names for each vacancy shall be selected by the Board of Governors and placed on a letter ballot. A blank space shall also be provided on this letter ballot under each office, in which space the names of any Fellows or Honorary members other than those suggested by the Board of Governors may be voted for. The balloting shall then take place.

The ballot shall be enclosed in a blank envelope which is enclosed in an outer envelope bearing the secretary's address and a space for the member's name and address. One of these shall be mailed to each Active, Fellow, and Honorary member of the Society, not less than forty days in advance of the annual fall convention.

The voter shall then indicate on the ballot one choice for each office, seal the ballot in the blank envelope, place this in the envelope addressed to the secretary, sign his name and address on the latter, and mail it in accordance with the instructions printed on the ballot. No marks of any kind except those above prescribed shall be placed upon the ballots or envelopes.

The sealed envelope shall be delivered by the secretary to a committee of tellers appointed by the president at the annual fall convention. This committee shall then examine the return envelopes, open and count the ballots, and announce the results of the election.

The newly elected officers and governors of the general Society shall take office on the January 1st following their election.

(b) The first group of vice-presidents, *viz.*, the executive vice-president, engineering vice-president, editorial vice-president, financial vice-president, convention vice-president, and a fifth governor, shall be nominated by the Board of Governors at its first meeting after the ratification of the corresponding provisions

of the Constitution; and the membership shall vote on the candidates in accordance with the procedure prescribed in these By-Laws for regular elections of officers so far as these may be applicable.

By-Law VII
Dues and Indebtedness

Sec. 1.—The annual dues shall be fifteen dollars ($15) for Fellows and Active members and seven dollars and fifty cents ($7.50) for Associate members, payable on or before January 1st of each year. Current or first year's dues for new members, dating from the notification of acceptance in the Society, shall be prorated on a monthly basis. Five dollars of these dues shall apply for annual subscription to the JOURNAL. No admission fee will be required for any grade of membership.

Sec. 2.—(*a*) Transfer of membership may be made effective at any time by payment of the pro rata dues for the current year.

(*b*) No credit shall be given for annual dues in a membership transfer from a higher to a lower grade, and such transfers shall take place on January 1st of each year.

(*c*) The Board of Governors upon their own initiative and without a transfer application may elect, by the approval of at least three-fourths of the Board, any Associate or Active member for transfer to any higher grade of membership.

Sec. 3.—Annual dues shall be paid in advance. All Honorary Members, Fellows, and Active Members in good standing, as defined in Sec. 5, may vote or otherwise participate in the meetings.

Sec. 4.—Members shall be considered delinquent whose annual dues for the year remain unpaid on February 1st. The first notice of delinquency shall be mailed February 1st. The second notice of delinquency shall be mailed, if necessary, on March 1st, and shall include a statement that the member's name will be removed from the mailing list for the JOURNAL and other publications of the Society before the mailing of the April issue of the JOURNAL. Members who are in arrears of dues on June 1st, after two notices of such delinquency have been mailed to their last address of record, shall be notified their names have been removed from the mailing list and shall be warned unless remittance is received on or before August 1st, their names shall be submitted to the Board of Governors for action at the next meeting. Back issues of the JOURNAL shall be sent, if available, to members whose dues have been paid prior to August 1st.

Sec. 5.—(*a*)Members whose dues remain unpaid on October 1st may be dropped from the rolls of the Society by majority vote and action of the Board, or the Board may take such action as it sees fit.

(*b*) Anyone who has been dropped from the rolls of the Society for non-payment of dues shall, in the event of his application for reinstatement, be considered as a new member.

(*c*) Any member may be suspended or expelled for cause by a majority vote of the entire Board of Governors; provided he shall be given notice and a copy in writing of the charges preferred against him, and shall be afforded opportunity to be heard ten days prior to such action.

Sec. 6.—The provisions of Section 1 to 4, inclusive, of this By-Law VII, given above may be modified or rescinded by action of the Board of Governors.

By-Law VIII

Emblem

Sec. 1.—The emblem of the Society shall be a facsimile of a four-hole film-reel with the letter *S* in the upper center opening, and the letters *M*, *P*, and *E*, in the three lower openings, respectively. In the printed emblem, the four-hole openings shall be orange, and the letters black, the remainder of the insignia being black and white. The Society's emblem may be worn by members only.

By-Law IX

Publications

Sec. 1.—Papers read at meetings or submitted at other times, and all material of general interest shall be submitted to the editorial board, and those deemed worthy of permanent record shall be printed in the JOURNAL. A copy of each issue shall be mailed to each member in good standing to his last address of record. Extra copies of the JOURNAL shall be printed for general distribution and may be obtained from the General Office on payment of a fee fixed by the Board of Governors.

By-Law X

Local Sections

Sec. 1.—Sections of the Society may be authorized in any state or locality where the Active, Fellow, and Honorary membership exceeds 20. The geographic boundaries of each Section shall be determined by the Board of Governors.

Upon written petition, signed by 20 or more Active members, Fellows and Honorary members, for the authorization of a Section of the Society, the Board of Governors may grant such authorization.

MEMBERSHIP

Sec. 2.—All members of the Society of Motion Picture Engineers in good standing residing in that portion of any country set apart by the Board of Governors tributary to any local Section shall be eligible for membership in that Section, and when so enrolled they shall be entitled to all privileges that such local Section may, under the General Society's Constitution and By-Laws, provide.

Any member of the Society in good standing shall be eligible for non-resident affiliated membership of any Section under conditions and obligations prescribed for the Section. An affiliated member shall receive all notices and publications of the Section but he shall not be entitled to vote at Sectional meetings.

Sec. 3.—Should the enrolled Active, Fellow, and Honorary membership of a Section fall below 20, or should the technical quality of the presented papers fall below an acceptable level, or the average attendance at meetings not warrant the expense of maintaining the organization, the Board of Governors may cancel its authorization.

OFFICERS

Sec. 4.—Each Section shall nominate and elect a chairman, two managers, and a secretary-treasurer. The Section chairmen shall automatically become members of the Board of Governors of the General Society, and continue in that position for the duration of their terms as chairmen of the local Sections.

ELECTION OF OFFICERS

Sec. 5.—The officers of a Section shall be Active, Fellow, or Honorary members of the General Society. They shall be nominated and elected to sectional office under the method prescribed under By-Law VI, Section 1, for the nomination and election of officers of the General Society. The word *manager* shall be substituted for the word *governor*. All Section officers shall hold office for one year, or until their successors are chosen, except the Board of Managers, as hereinafter provided.

MANAGERS

Sec. 6.—The Board of Managers shall consist of the Section chairman, the Section past-chairman, the Section secretary-treasurer, and two Active, Fellow, or Honorary members, one of which last named shall be elected for a two-year term, and one for one year, and then one for two years each year thereafter. At the discretion of the Board of Governors, and with their written approval, this list of officers may be extended.

BUSINESS

Sec. 7.—The business of a Section shall be conducted by the Board of Managers.

EXPENSES

Sec. 8.—(*a*) As early as possible in the fiscal year, the secretary of each Section shall submit to the Board of Governors of the Society a budget of expenses for the year.

(*b*) The treasurer of the General Society may deposit with each Section secretary-treasurer a sum of money, the amount to be fixed by the Board of Governors, for current expenses.

(*c*) The secretary-treasurer of each Section shall send to the treasurer of the General Society, quarterly or on demand, an itemized account of all expenditures incurred during the preceding interval.

(*d*) Expenses other than those enumerated in the budget, as approved by the Board of Governors of the General Society, shall not be payable from the general funds of the Society without express permission from the Board of Governors.

(*e*) A Section Board of Managers shall defray all expenses of the Section not provided for by the Board of Governors, from funds raised locally by donation, or by fixed annual dues, or by both.

(*f*) The secretary of the Society shall, unless otherwise arranged, supply to each Section all stationery and printing necessary for the conduct of its business.

MEETINGS

Sec. 9.—The regular meetings of a Section shall be held in such places and at such hours as the Board of Managers may designate.

The secretary-treasurer of each Section shall forward to the secretary of the General Society, not later than five days after a meeting of a Section, a statement of the attendance and of the business transacted.

PAPERS

Sec. 10.—Papers shall be approved by the Section's papers committee previously to their being presented before a Section. Manuscripts of papers presented before a Section, together with a report of the discussions and the proceedings of the Section meetings, shall be forwarded promptly by the Section secretary-treasurer to the secretary of the General Society. Such material may, at the discretion of the board of editors of the General Society, be printed in the Society's publications.

CONSTITUTION AND BY-LAWS

Sec. 11.—Sections shall abide by the Constitution and By-Laws of the Society, and conform to the regulations of the Board of Governors. The conduct of Sections shall always be in conformity with the general policy of the Society as fixed by the Board of Governors.

By-Law XI

Amendments

Sec. 1.—These By-Laws may be amended at any regular meeting of the Society by the affirmative vote of two-thirds of the members present at a meeting who are eligible to vote thereon, a quorum being present, either on the recommendation of the Board of Governors or by a recommendation to the Board of Governors signed by any ten members of active or higher grade, provided that the proposed amendment or amendments shall have been published in the JOURNAL of the Society, in the issue next preceding the date of the stated business meeting of the Society, at which the amendment or amendments are to be acted upon.

Sec. 2.—In the event that no quorum of the voting members is present at the time of the meeting referred to in Sec. 1, the amendment or amendments shall be referred for action to the Board of Governors. The proposed amendment or amendments then become a part of the By-Laws upon receiving the affirmative vote of three-quarters of the Board of Governors.

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A MOTION PICTURE DUBBING AND SCORING STAGE*

C. L. LOOTENS,** D. J. BLOOMBERG,** AND M. RETTINGER†

Summary.—*A new dubbing (re-recording) and scoring (music recording) building recently completed on the Republic lot consists of a recording stage, scoring monitor room, machine room, projection booth, power room, maintenance room, and a recording truck testing platform.*

The recording equipment consists essentially of two complete RCA high-fidelity recording channels, together with their associated equipment of film recorders, film phonographs, amplifier racks, power rectifiers, dubbing and scoring consoles, "acetate" recorder and projection equipment.

The stage is of the live-end-dead-end type, and has dimensions which conform to the recommended 1:2:3 ratio. The live-end is provided with permanent side wall and ceiling reflecting panels which increase the reverberation and diffusion of sound. The remainder of the stage is treated with 4-inch rockwool battens, placed between the studs and retained in place by a dual muslin covering. The measured reverberation characteristic of the stage, fulfilling recommended requirements, is between 0.95 and 1.00 second for the frequency band of 540 to 7000 cps. The stage is equipped also with an eight-position mixer console so that dubbing may be monitored in a room having approximate theater sound characteristics.

Republic's recently completed dubbing (re-recording) and scoring (music recording) building was designed and constructed essentially for sound recording. The building is located adjacent to the sound-cutting building and readily accessible to the film vaults and loading rooms. The complete unit (Fig. 1) consists of a recording stage, scoring monitor room, machine room, projection booth, power room, maintenance room, and recording-truck testing platform.

When designing the building, acoustical considerations and accessibility between rooms were given preference. Reinforced concrete footings and foundations are used for all walls and supporting columns making the building rigid and free from vibration. The stage footings and foundation are isolated from those of the remainder of the building by a 6-inch space filled with granulated cork. All ground

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** Republic Productions, Inc., North Hollywood, Calif.

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floors are constructed of fine gravel and sand asphalt laid hot within the foundation walls. Asphalt was used in preference to concrete because the asphalt has a lower sound-transmission rate and is comparatively non-homogeneous. The walls and roof structure of the workrooms adjacent to the stage are of wood construction. The outsides of the walls are covered with 1-inch diagonal sheathing and a 1-inch finish of exterior cement stucco. The interior walls are of plaster board and cement plaster finish. The ceilings of all rooms and the hallway, with the exception of the truck-testing platform, are of plaster board—$^1/_2$-inch brown plaster finished with $^1/_2$-inch "Acoustite" rockwool composition plaster.

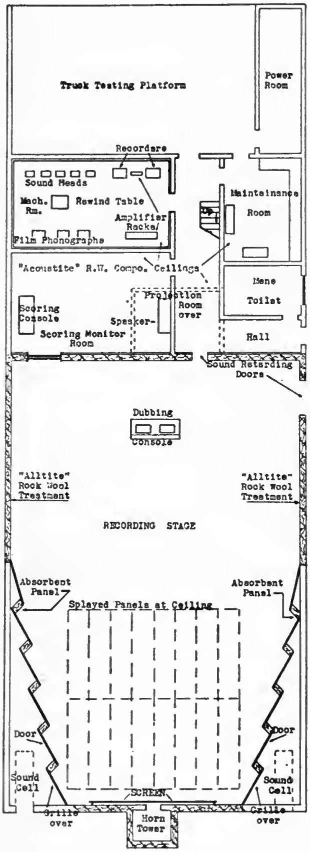

FIG. 1. Plan of buildings.

Recording Stage.—The recording stage, which was constructed essentially as a unit, is 25 feet high, 50 feet wide, and 75 feet long, satisfying the well known criterion that, for a stage of this size, the ratio of height, width, and length should be 1:2:3. The ratio of 2:3:5 for the above dimensions is sometimes recommended, but a little consideration will quickly show that an enclosure of such size will not only make an undesirably high ceiling and narrowly spaced side walls, but will also cause the "mean free path" (average length of one reflection) to be longer. This condition produces fewer reflections per second at any point in the room, resulting in decreased diffusion of sound in the room.

Forty musicians represent the optimum number of performers in this stage for maximum quality and best illusion, while eighty musicians represent the largest number that can be crowded into the space and still provide reasonably satisfactory recordings. In this connection it should be remembered that it is practically impossible to imitate the acoustics of a large room in an enclosure that is actually small. On the other hand, the acoustics of a small room can be imitated easily in a large enclosure by the judicious use of flats and other reflecting surfaces.

Only two materials, rockwool and wood, are used for the interior finish of this live-end-dead-end stage. In Figs. 1, 2, and 3, it is seen that wood is used as a reflective material around the band-shell (live-end) to produce sufficient localized reverberation to permit the musicians, long accustomed to playing in reverberant concert halls, to keep more easily in tune, to determine without undue effort precisely the true pitch of the following note while perceiving the present one, and to retain proper balance between bass and treble. Wood instead of

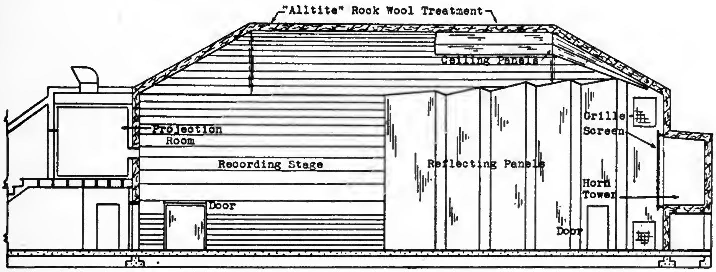

FIG. 2. Elevation of stage, monitor room, and projection room.

some other material such as plaster or hard pressed-board was selected because of its well liked and practically inimitable quality of resonating over a wide range of musical pitch, as evidenced by its use in concert halls of avowedly superior acoustics.

Because of the reverberant character of this band-shell it became important to make arrangements for the prevention of echoes and for an effective dispersion of the sound to obtain uniform distribution of it in the stage. This object was achieved by providing suitably orientated corrugations of sufficient depth to become effective also as diffusers of sound for lower frequencies. The absorbent panels at reversed angles to the reflective ones are necessary to prevent the sound from being returned into the shell in too great a measure.

The orientation of the reflective side-wall and ceiling splays is such as to obtain not only sufficient localized reverberation in the band-shell but also to achieve a desirably directed efflux of the sound into the dead end of the stage. Reflecting surfaces close to the performers are, therefore, positioned so as to secure enough short-time reflections at the microphone to preserve the naturalness of the instruments, while more distant reflecting surfaces are utilized to produce in the band-shell a sufficient amount of the long-time reflections which musically are so pleasing and without which the music would tend to sound flat, as in the open air. The problem, on close inspection, will be found to be exceedingly complex, not only because it is essentially three-dimensional in character, but also because not one but many sources of sound must be taken into consideration. A solution was obtained by drawing many diagrams depicting the travel of sound

FIG. 3. Interior of recording stage.

from various parts in the stage and for several angles of splay-slope, and then choosing a splay orientation that gave the most desirable results for the largest number of considered imaginary point-sources representing the musicians.

The absorbent regions surrounding the microphone, as well as the dead end of the stage are, of course, necessary to provide placement of sufficient damping material to give the desired reverberation period in the stage and to permit the smoothing out of whatever interference pattern may exist there. Interference, it is well known, may be of the nature of a space or a time-effect. The first enters most clearly during sustained passages, when the transmitter may be at a region of reduced or enhanced sound-intensity. The time-effect makes itself known in the form of irregular fluctuations of the sound-pressure during growth or decay of the sound in the room. The more reverberant a room, the more pronounced are the two effects, and the more disturbing do they appear in a recording.

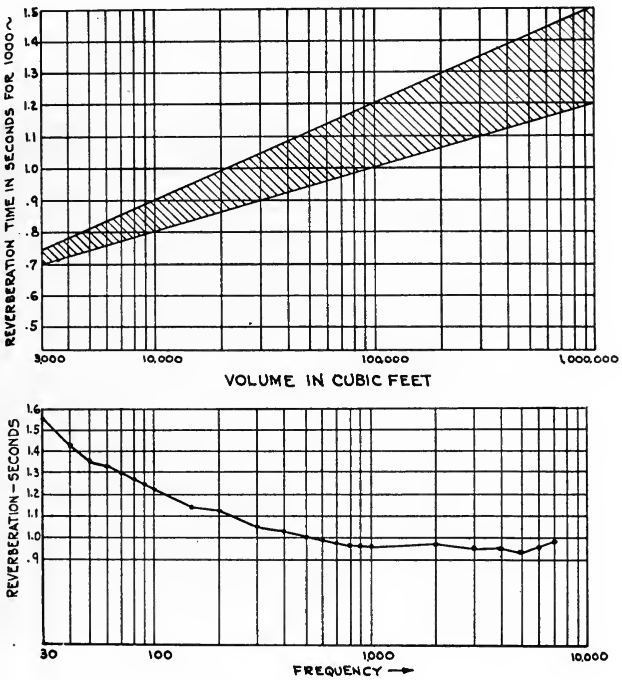

FIG. 4. (*Upper*) Reverberation-volume curve.
FIG. 5. (*Lower*) Republic stage reverberation-frequency curve.

Recording studios should have a reverberation-time at 1000 cycles of about two-thirds of that found satisfactory for a room of equal volume used for binaural hearing. Fig. 4 shows the limits of variation of reverberation time with volume for scoring stages, and illustrates that it is not readily possible to speak of the optimal time of reverberation of a room as a definite figure unless one mentions at the same time the type of activity for which the room is being used, such as for speech, piano recitals, or songs. The optimal time, in general, is therefore a range, with the upper limit pertaining to organ oratoria and the lower limit to speech. A mean value of reverberation at 1000 cycles of 0.97 second was chosen as being the time most suitable for the type of music to be most frequently played on this stage. A number of portable hinged panels, 4 by 7 feet, absorbent on one side and reflective on the other, are used to provide acoustical isolation or special reverberation effects for small groups of performers.

The variation of reverberation time with frequency, called the reverberation characteristic, has been widely discussed in the literature.[1,2,3,4] However, none of the criteria so far proposed for the reverberation characteristic in rooms appears to be completely tenable for scoring stages. Even MacNair's criterion,* which for the lower frequencies makes for reverberation-times shorter than those obtained by any other criterion, when applied to a scoring stage still produces recordings marred by a little "boominess." Fig. 5 shows the reverberation characteristic of this scoring stage, and all tests made so far—direct listening tests as well as recording tests—show that the studio is remarkably free from any boominess or prolonged reverberation for the lower frequencies.

It may be of interest to determine for this stage the value of the M. O. Strutt equation for the ratio of the "useful" to delayed sound. By "useful" sound is meant the direct sound plus that sound that comes to an auditor within $^1/_{16}$ second after it was emitted; by delayed sound is meant the sound that comes to an auditor $^1/_{16}$ second after it was emitted. The value of this equation depends, of course, on the distance between the auditor and the source of sound; for this purpose an average distance D equal to $V^{1/3}/2$ (V = volume of stage) was chosen. The M. O. Strutt[5] equation is:

$$Q = \frac{\dfrac{P}{4\pi c D^2} + \dfrac{P}{V}\displaystyle\int_0^{t={}^1/_{16}} e^{-13.8t/T}\,dt}{\dfrac{P}{V}\displaystyle\int_{t={}^1/_{16}}^{t=\infty} e^{-13.8t/T}\,dt}$$

where P = power output of source of sound.
c = velocity of sound.
T = time of reverberation (the reverberation time for a given frequency is the time required for the average sound-energy density, initially in a steady state, to decrease, after the source is stopped, to one-millionth of its initial value).

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* By this criterion the loudness level of all frequency components in speech and music should decay at the same constant rate.

V = volume of room.
t = time.
D = distance between source of sound and position of listener or microphone.

This equation may be written as:

$$Q = \frac{0.86}{e^T}\left[\frac{0.004\ V^{1/3}}{T} + 1\right] - 1$$

if T = 1 second, V = 90,000 cubic-feet; Q equals 1.78, showing that the amount of "useful" sound is quite large at this average distance of $90{,}000^{1/3}/2$ or 22.5 ft.

All construction in the stage was made exceedingly rigid to avoid structural resonances. The wall-studs are 2 by 6 inch, covered on the outside with 1-inch diagonal sheathing and 1-inch exterior cement stucco. The entire wall area in the dead-end half is treated with 4-inch long-fiber rockwool battens placed between the studs and held in place by a retaining layer of 40–44 muslin stapled to the interior side of the studs (Fig. 8). On top of this layer of muslin, 1 by 2-inch wood retaining strips are nailed at right angles to the studs. The strips are spaced on 9-inch centers from the floor to a 5-ft. height. From this point the spacing is graduated from 18-inch centers to 12-inch centers at the plate line. On top of the wood strips, a layer of fire-proofed and color-dyed muslin is tacked. The tacks and muslin joints are covered with $^3/_4$-inch wood half-round. Fig. 3 shows the finished appearance of the absorbent treatment.

The roof of the stage consists of a Lamella roof resting on 8 by 10-in. sills anchored to the 2 by 6-in. side walls. The crown of the roof is approximately $34^1/_2$ feet above the finished floor. The roof sills are tied together by four $1^1/_2$-in. steel tie-rods to absorb the roof thrust. The Lamellas consist of segments of an arc milled so as to intersect continuously and uniformly as the "skew arch" crosses the roof.

These intersecting arches (Fig. 6) form the familiar diamond pattern of the Lamella roof. Each diamond in the stage is 8 feet long and 36 inches wide, with each intersection joint bolted with one $^5/_8$-inch bolt. The diamond-patterned Lamella roof is used to carry the center 43-ft. section of the roof with diagonal sheathed rafters closing the 16-foot end-sections, and spanned from the end-walls to the end arch of the Lamella web.

The height of the roof from the floor, the high degree of fire resistance, the absence of intermediate supports for the roof, and the freedom from large structural members requiring sound-deadening treatment were all factors guiding the selection of the roof as the best suited for this modern recording stage. The entire roof area is acoustically treated with 4-inch rockwool battens (Fig. 6) in the same manner as the wall area with the exception of the spacing of the retaining strips, which is graduated from 26 inches at the sill line to 8 inches at the center of the ceiling.

The interior of the live-end wall area of the stage is covered with 1-inch fiber insulation board. The reflective side-wall splays (Figs. 1,

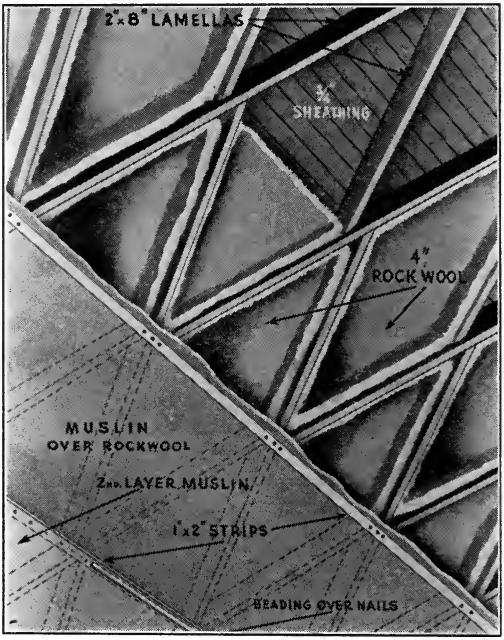


FIG. 6. Roof construction and treatment.

2, 3) reaching from floor to ceiling consist of alternate wood panels parallel to each other and separated by angular absorbing panels 2 feet in width. The panel construction consists of 2 by 6-inch studs and cross-pieces, spaced on 2-ft. centers covered with 1-inch diagonal sheathing surfaced with $^3/_4$-inch grooved T & G ceiling lumber. The rear of the panels is braced at $6^1/_2$-ft. intervals to the wall of the stage. Eight 35-ft. angular ceiling splays (Fig. 3) are anchored to the ceiling between the side-wall panels. These panels are of 1-inch plywood lumber, screwed to 2 by 12-in. supporting joists and cross-pieces spaced on 2-ft. centers and bolted to the roof rafters. The surfaces of all wood panels are stained and finished with three coats of transparent varnish.

The stage floor consists of 2 by 6-in. joists laid flat on the 4-inch asphalt ground floor. The space between the joists is filled to the surface with fine aggregate asphalt. A subfloor of 1-inch T & G diagonal sheathing is securely nailed to the joists. A 1-inch T & G-finished floor is nailed directly on top of the sheathing. This construction results in a very rigid non-resonant type of floor.

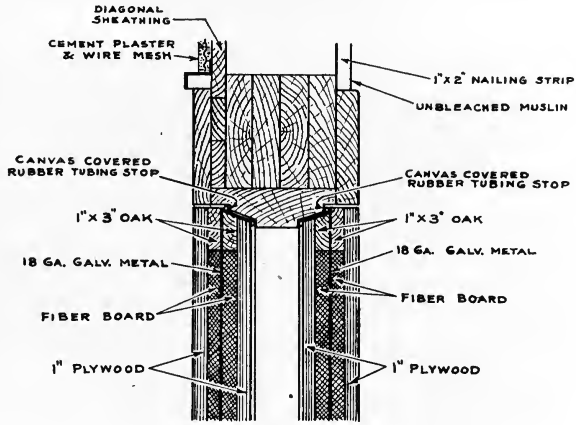


FIG. 7. Detail of sound retarding doors.

A horn-tower (Figs. 1, 2) 6 feet wide by 9 feet long is provided in back of the projection screen. The interior walls and ceiling of the horn-tower are treated with 4-inch rockwool battens. The horn-tower floor, which is 6 feet above the stage floor, is of wood construction covered with 1-inch fiber insulation board. Entrance to the tower is through a trap-door in the floor. The sound-reproducing system is the well known RCA two-way loud speaker system employing two high-frequency and four low-frequency units. The width of the horn-tower allows only a 4-inch space between the low-frequency units and the side wall. This space and the area around the high-frequency speaker is closed in with 1-in. fiber insulation board. This construction prevents the generation of backstage resonance in the loud speaker cavity.

All openings leading into the stage are closed with massive double doors made of dual sections of 1-inch plywood, 1-inch insulation board, and 18-gauge sheet-metal, as shown in Fig. 7. The doors are held tightly closed against rubber weather-stripping by special non-slipping clamps.

Recording wiring for scoring activities terminates on the stage in conveniently located panels consisting of a 6-position microphone outlet panel, head-phone outlet panel, signal-light panel, and mobile acetate recorder-outlet panel. The music director's stand is equipped with a built-in *PA* microphone, speaker, and head-phone volume control. A general *PA* speaker is mounted on the rear wall of the stage.

FIG. 8. Republic dubbing console.

The stage is used also as a monitoring room for dubbing. For this purpose an 8-position mixer console is located in the dead end of the stage, as shown in Figs. 1 and 3. The dubbing console (Fig. 8) will seat three mixer operators, and is designed with a group of special equalizer controls located in the center of the console. High-, low-, and middle-frequency attenuation and equalization, with the various telephone, *PA*, and special equalizers are provided. Eight single-stage booster amplifiers, used with the equalizers, are mounted in the console, and are accessible through panels in the side or rear. A variable high-pass filter is included with five cut-off frequencies between 80 and 150 cycles. Telephone, *PA*, and signal facilities connecting with all stations, are located within easy reach of all the mixers.

Jack bays provide connections to the machine room amplifier bays, scoring console, and for patching a reproducer through any desired equalizer in any mixer position. A neon volume indicator and an electric clock are mounted in the line of screen vision on the front of the console. Three remote controls for changing the location of the

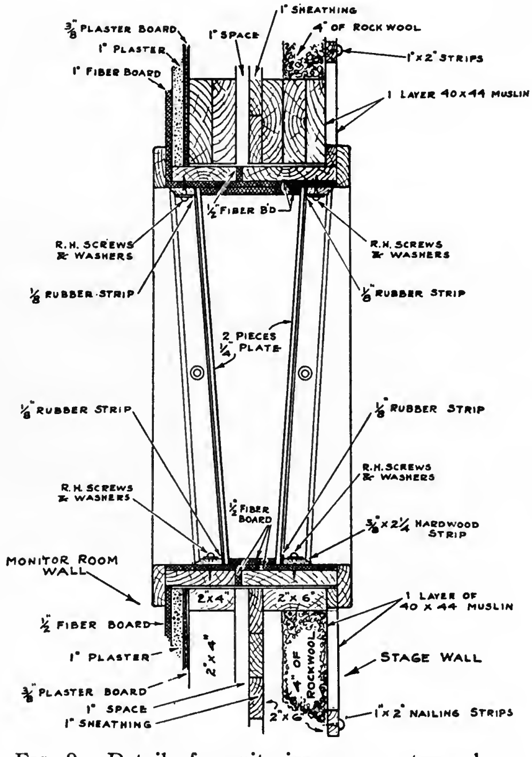


FIG. 9. Detail of monitoring room; stage observation window.

"breakaway point" (post) of the electronic compressor amplifiers are installed conveniently near the dialog mixer. Remote volume control of the projection reproducing system is provided on the console. A projected footage counter is placed below the picture screen, and a reset button is located on the dubbing console.

Scoring Monitor Room.—Special consideration was given to the design of the scoring monitoring room, which is usually a small room ranging in volume from 500 to 5000 cubic-feet. Adjunct to a more voluminous and expensive stage, they do not always receive the same attention during the design period that the larger enclosure receives, and often are accorded only such space as fits in conveniently with the grounds. They are important rooms, however, since arrangement of orchestra and tonal balance are usually regulated by the mixer in these rooms.

It is well known that enclosures, the dimensions of which are not large compared with the wavelength of the sound, exhibit a phenomenon known as room resonance. Under such condition one or more of the lower modes of vibration of the room may be prominently stimulated, causing intensification of the low-frequency components of the sound emanating from the monitoring speaker. It is often thought that by providing irregularities in the room, such as pilasters or corrugations, or by making the enclosure non-rectangular, room resonance can be eliminated. Such, of course, is not the case. It is more difficult to determine theoretically the frequencies of the eigentones or damped free vibrations in a non-rectangular room, but the number of them occurring within a certain frequency-interval is certainly not increased. For that reason, also, cubical rooms, or even rooms having two dimensions alike, are less to be recommended than oblong rooms, since their eigentones may superimpose, causing an even greater intensificiation of a certain frequency in the room. It is the number of resonant vibrations within a given frequency band that is important in a room, since the larger this number the more will every forced vibration in that interval coincide with a natural mode of vibration of the room. If the room is not too small, one can calculate the number of eigentones within a band by the Rayleigh-Jeans formula[6] for the optical case. This is:

$$N = \frac{4\pi V F^2}{c^3} \Delta F$$

where F = frequency.
V = volume of room.
c = velocity of sound.
N = number of eigentones in the interval ranging from F to $F + \Delta F$.

This equation shows that the number of eigentones within a certain frequency-band is proportional to the volume of the room, so that pilasters, corrugations, *etc.*, exert no effect in changing this number except so far as the room is made smaller by them—an undesired condition.

For this reason the scoring monitoring room, of 4500 cubic-feet volume, was kept rectangular in shape with dimensions of 9 feet high, 18 feet wide, and 28 feet long (ratio 1:2:3) (Figs. 1, 2). The monitoring room floor is covered with a hair-felt pad and a heavyweight broadloom carpet. The walls are treated with $^1/_2$-inch fiber insulation board applied directly over 1 inch of cement plaster. The ceiling is of plaster board, $^1/_2$-inch brown plaster finished with $^1/_2$-inch "Acoustite" plaster.

Another important property of a monitoring room is adequate sound insulation between it and the adjoining studio. The wall adjacent to the stage is structurally separated from the stage wall and is

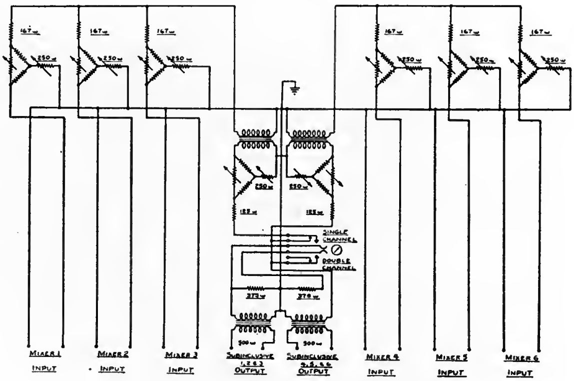


FIG. 10. Diagram of scoring mixer.

supported by a separate footing. The matter of sufficient insulation through the observation window deserves particular attention. Such windows often consist of two panes of glass separated by a small air space (1 to 3 inches) with one sheet of glass sometimes thicker than the other. Work by J. E. R. Constable[7] has shown that such an arrangement is invariably less insulative for the lower frequencies than a single pane having the combined thickness of the two panes. Increased insulation by means of two sheets of glass is achieved only if the panes are at least 4 inches apart, and when the wall space between the panes is treated with a sound-absorbing material such as fiberboard or acoustic plaster.

The observation window (Fig. 9) for this monitoring room consists of two double panes of $^1/_4$-inch plate-glass, with one pair inclined to the other at a small angle and the pairs separated from each other as shown. The wall space between the pairs of sheets is treated with $^1/_2$-inch fiberboard, and the rebate around the edges of the pane is closed tightly against the pane with weather-stripping between rebate and glass.

The equipment in the scoring monitoring room consists of a 6-position mixer console and a RCA two-way theater loud speaker system. The mixer circuit (Fig. 10) utilizes a switching arrangement for dividing the six mixers into two groups of three, connected to two separate recording channels. A soloist and an orchestra accompaniment if isolated with acoustic baffles can be recorded simultaneously on two separate films. Whenever the channel is used as described, the scoring monitor is connected to both recording systems. A neon volume

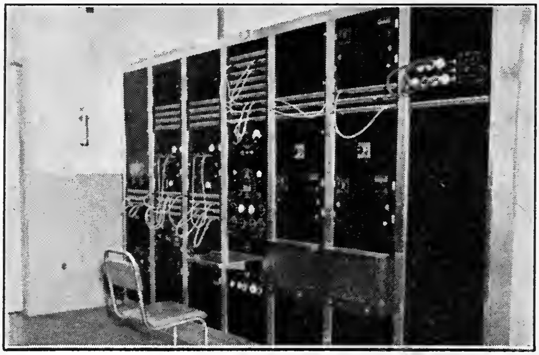


FIG. 11. Amplifier rack; Bays *1* to *7*.

indicator and a high-speed Weston meter volume indicator are used as level indicators. High- and low-frequency attenuation is supplied in four mixer positions. A patch bay is furnished with the necessary trunks to the dubbing console amplifier bays and associated equipment.

A signal and *PA* panel is provided with the additional feature of a separate *PA* switch connecting directly with a *PA* microphone and speaker on the music director's stand enabling the mixer to converse privately with the music director. A remote variable *H*-pad control (Figs. 13, 15) is provided to raise or lower the "breakaway point" of No. 4 compressor amplifier (post) used in the scoring channel. A reset button for the projected footage counter is conveniently located on the console.

Ventilation and Heating.—The ventilating and heating system consists of filters, fan, and gas heater all mounted on cork insulation pads on the roof adjacent to the projection room. In order to reduce wind noises and fan vibration, a fan normally rated at 20,000 cfm. is driven at a speed to produce 6000 cfm. The duct leading from the heater to the discharge into the rooms, is lined with 2-inch rock-wool blankets, the surface of which is covered with a double thickness of 40–44 muslin. Staggered acoustic absorbing panels of 2-inch rock-wool are placed at right angles to the air travel at 2-ft. intervals throughout the length of the duct. The discharge openings from the monitoring room and stage are designed so that the maximum velocity of the air does not exceed 300 feet per minute. To prevent external noise from entering the room, acoustic insulating panels of $^1/_2$-inch fiber insulation board are installed at right angles to the air-flow.

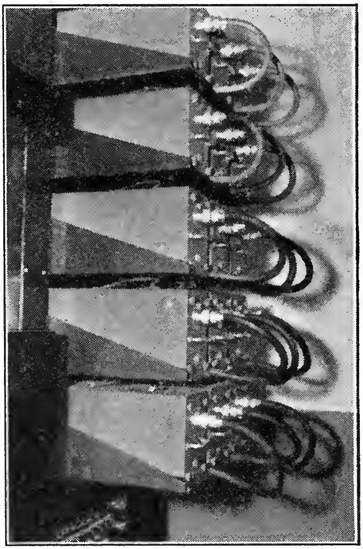


FIG. 12. Mountings for microphone and phototube pre-amplifiers.

Machine Room.—The machine room (Fig. 1) contains the amplifier racks, recorders, film phonographs, sound-heads, and portable acetate recorder. Two complete recording channels are provided either for scoring or dubbing. There are eight amplifier bays containing the following equipment:

Bay No. *1* (Fig. 11) contains six microphones and eight photocell pre-amplifiers mounted in the upper portion of the rack. The microphone pre-amplifier is a two-stage amplifier with an overall gain of 47 db. at 1000 cycles. The first stage of this amplifier utilizes the new RCA *1603* tube,[8] fed by a specially designed input transformer. Equalization for film-transfer losses is incorporated in these pre-amplifiers and consists of a rising characteristic starting from 1000 cycles and rising to 6 db. at 6000 cycles. The phototube pre-amplifier is also a two-stage amplifier using the RCA *1603* in the first stage. The overall gain is 43 db. at 1000 cycles. Equalization for re-recording transfer-losses is incorporated in these pre-amplifiers. Both types of pre-amplifiers are mounted in rectangular cases which fit in shelves at the rear of the rack (Fig. 12). The male output receptacle at one end of the amplifier case connects with the female receptacle on the rack, and the input receptacle on the amplifier is connected by a short piece of cable from the rack. Power switches, metering jacks, and meter are supplied on the front face of the rack.

A section of jack rows, immediately below, contains high- and low-level trunks to the dubbing and scoring consoles, the circuit-test lab., the inputs and outputs of two electronic compressor amplifiers, and the fixed pads and variable controls associated with the operation of

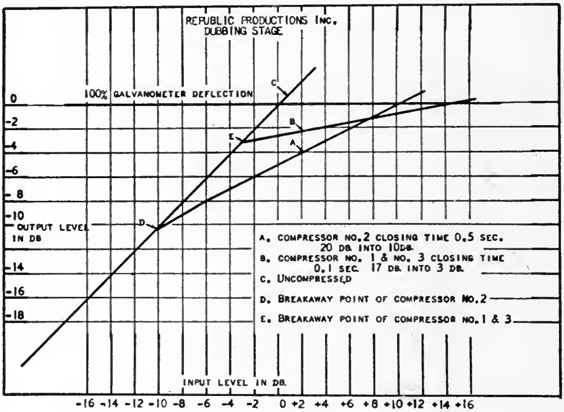


FIG. 13. Compressor curves.

the compressors. The compressors and pads are mounted below the jack rows.

Compressor amplifier No. *1* is designed to work in the music-dubbing channel. The compressor consists of a two-stage push-pull amplifier, the first stage of which is a pair of variable-mu tubes *6K7*, the gain of which is controlled by the output of the rectifier (*6H6*). The rectifier is fed by a one-stage amplifier (*6C5*) which is bridged across the output of the compressor. The harmonic distortion introduced by the compressor at an output of plus 10 db. is less than 1 per cent. The frequency-response is flat within plus or minus $^1/_2$ db. from 30 cycles to 10,000 cycles. The timing characteristics used in this compressor are two milliseconds for operating and approximately 100 milliseconds for release. The operating characteristic is such that it requires a 17-db. increase of input to raise the galvanometer the final 3 db. of modulation (curve *B*, Fig. 13). This compressor is operated in this manner to prevent peak voltages from overloading the sound-track without affecting the normal volume changes in the music.

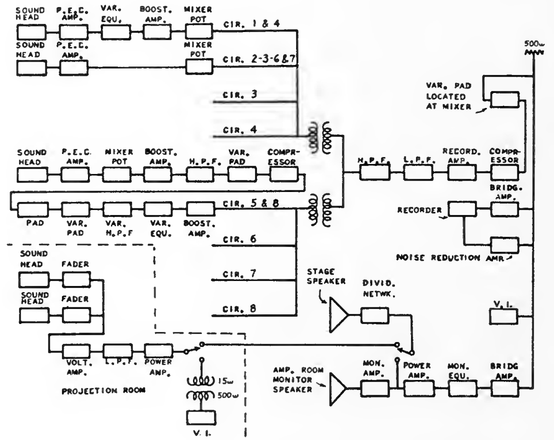
No. *2* compressor amplifier is designed to work in the dialog dubbing channel (Fig. 14). The timing characteristics used are 2 milliseconds for operating and approximately 500 milliseconds for release. The operating characteristic is such that it requires a 20-db. increase of input to raise the galvanometer the final 10 db. of modulation, as illustrated by curve *A* of Fig. 13. A variable *T*-pad in 1-db. steps in the output of the compressor is provided on the dubbing console and is used to raise or lower the "breakaway point."

Bays Nos. *2* and *3* (Fig. 11) each contains a complete recording amplifier channel with a balanced low-pass filter, 45-cycle high-pass, recording amplifier, and d-c. bridging amplifier (Figs. 14 and 15). The balanced low-pass filter has variable cut-off frequencies. Speech recording is done with the 6500-low-8000, and music recording with the 8000-low-10,000. The 45-cycle high-pass with operating characteristics of 40-high-60 is inserted in the recording channel for both music and speech recording.

The *108* recording amplifier is used as the main gain-amplifier and serves to bring the signals from the low-level mixer circuits to a zero level at the bridging bus. It employs four stages of amplification and has an overall gain of 84 db. at 1000 cycles. The frequency-response is flat from 30 cycles to 10,000 cycles, within $\pm 1/2$ db. A third compressor, which has the operating characteristics of compressor No. *1*, is inserted between the *108* amplifier output and the bridging bus, preventing excessive peak voltages from overloading the galvanometer. A three-stage bridging amplifier completes the circuit between the bridging-bus and the galvanometer. The overall gain of this amplifier is 40 db. The frequency response is flat from 30 cycles to 10,000 cycles within $\pm 1/2$ db. All these amplifiers are provided with metering jacks and a meter for measuring operating voltages.

Jacks are provided in both bays for the input and output of each individual amplifier and its associated equipment and also high and low-level trunks to the different bays and the dubbing and scoring consoles. The noise level of the overall channel at the recording galvanometer is maintained to -60 db. below "O" db., and the overall distortion at 400 cycles is 0.4 per cent at 100 per cent galvanometer deflection.

Bay No. *4* (Fig. 11) is the circuit-test lab. and contains an oscillator, distortion-factor meter, gain set, and a patch-bay containing



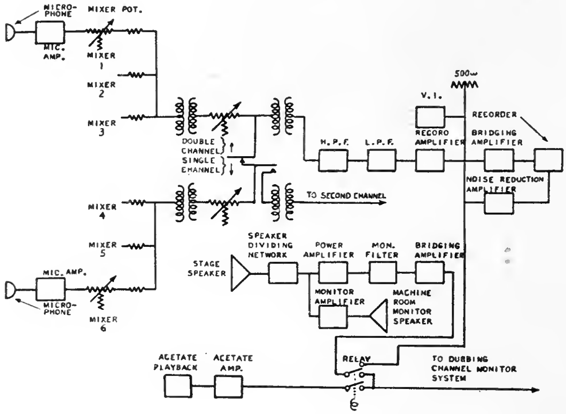


FIG. 14. (*Upper*) Diagram of dubbing channel.
FIG. 15. (*Lower*) Diagram of scoring channel.

trunks to all bays. The jack bay provides connections to various loss pads, transformers, band-pass filters and trunk terminations useful in making transmission runs. A test-panel at the lower section of the bay is directly connected to a test-panel in the truck-testing platform with high- and low-level trunks. It also contains power-supply and provision for checking pre-amplifiers. Connections for a portable *PA* system or a telephone hand-set are provided for communication between the truck platform, maintenance room, and circuit lab.

Bay Nos. *5* and *6* (Fig. 11) contain the monitoring amplifiers and associated equipment used with the scoring and dubbing channels. Each monitor system consists of a 40-watt amplifier fed by a three-stage bridging amplifier the input of which is connected across the bridging bus. The monitoring equalization is connected between these two amplifiers. The bridging amplifier is similar in operating

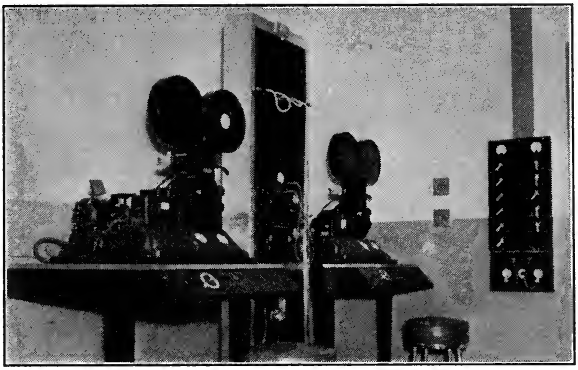


FIG. 16. Noise reduction amplifier—Bay 8, recorders, and motor switching panel.

characteristics to those described in Bays *2* and *3*. The output of the power amplifier feeds the two-way speaker system through its dividing network. The total harmonic distortion in the monitoring system is less than 1 per cent at a power output of 40 watts.

Bay No. *7* (Fig. 11) contains the *PA* amplifiers and signal systems. The *PA* system includes 5 stations: *viz.*, recorder No. 1, recorder No. 2, scoring console, dubbing console, and projection room.

Two voltage and two power-amplifiers supply amplification for the *PA* system. A *PA* switching panel is provided for making the connections to and from the selected stations. A signal patch panel makes it possible to select any station for controlling the signal and warning-light system. A portable *PA* amplifier is provided for use with a portable *PA* microphone and speaker which can be used for test communication. A patch-bay is furnished containing the inputs and outputs of these amplifiers with trunks to the other bays.

Bay No. *8* contains the noise-reduction amplifiers (Fig. 16) associated with the recording channels, mounted between the two recording machines. These noise-reduction amplifiers contain new developments in operating characteristics. The timing characteristics used are 19 milliseconds opening and approximately 220 milliseconds closing. The frequency characteristic of the amplifier is flat from 30 to 10,000 cycles within $\pm 1/2$ db.

A meter and metering jacks are provided for measuring operating voltages. A patch-bay is furnished with the inputs and outputs of the amplifiers and trunks to the circuit lab. and recording-channel bays. This rack contains also an RCA modulated oscillator for use in determining optimum negative and printing densities for processing control.[9]

The machine room also contains three film-phonographs, five sound-heads, two film-recorders, and mobile acetate recorder. The three film-phonographs are of the RCA magnetic-drive type and are used for reproducing master dialog and music tracks. The five sound-heads are of the RCA rotary-stabilizer type, and are used for sound-effects tracks. A loop arrangement is mounted above the sound-heads providing for film loops up to 300 feet in length. All reproducers are equipped with switches for reproducing either standard or push-pull tracks. Automatic motor-driven rewinds are furnished on all reproducers so that it is unnecessary to remove the film from the machines for rewinding. An inspection bench is provided with motor-driven rewinds and illuminated inspection plates.

In the rear of the machine room is a panel with outlet for a mobile "acetate" recorder which is self-contained in a steel cabinet mounted on pneumatic tires. The mechanism is provided with both selsyn and synchronous motors driving the turntable at a speed of 78 rpm. An RCA *72A* cutting mechanism, the new RCA pick-up, tone-arm, associated filters and equalizer, microscope, and record-spotting mechanism complete the operating accessories. The amplifying equipment consists of an amplifier system and associated filament rectifier. A meter volume-indicator is provided in the cutter circuit. The external speaker is the new RCA all-metal exponential horn with a power handling capacity of 24 watts. A microphone input is furnished so that the mobile unit may be used as a *PA* system on the production set. For immediate playback purposes when operating with the recording channel, a switch on the acetate control panel operates a relay connecting the acetate reproducer and network to the monitoring two-way horn system in both the scoring stage and scoring monitoring room.

Two RCA ultraviolet film recorders of the magnetic-drive type are equipped with a photographic slating device and film-punch operated simultaneously by a hand-lever. An exposure meter, corrected for temperature variations and which gives accurate photometric readings for controlling exposure, is mounted on the front of the optical systems. The recorders are mounted on tables (Fig. 16) the front of which contains a control panel with a *PA* microphone, telephone hand-set, interlock control switches, signal-control switches, and signal lights.

Alongside the recording tables on the front wall (Fig. 16) is the selsyn distributor control panel which contains twelve specially designed six-pole double-throw switches, enabling the operator to switch any or all of the reproducer and projection interlock motors from one distributor to the other. A convenience outlet is installed near each reproducer to provide a connection for variable-speed shots. A remote portable variable-speed control is provided for operation near the dubbing console.

Projection Booth.—The projection room, which is located above a section of the hallway and one end of the monitor room (Figs. 1, 2) is supported by columns which are structurally separated from the stage and the monitor room walls and ceiling. The projection room floor consists of a 2-inch layer of asphalt on top of which is cemented $1^1/_2$-inch cork insulation pads. One-quarter inch cork carpet is cemented to the top of the cork pads. This construction eliminates the possibility of footfalls being heard in the monitoring room and stage. The ceiling and the upper 3 feet of the projection room walls are finished with $^1/_2$-in. "Acoustite" plaster.

The projection booth contains two Simplex *E-7* projection heads with removable aperture plates, two high-intensity Peerless Magnarcs and RCA *PG118* double sound-head projection system with one head driven by a synchronous motor and the second head by a selsyn motor, and two RCA preview attachments. Both heads are push-pull or standard. Each arc lamp is supplied by a General Electric copper-oxide rectifier of 65-ampere capacity. The amplifier rack contains a patch-bay with the inputs and outputs of the voltage and power amplifiers, and trunk lines to the dubbing and scoring consoles and the amplifier bays. A volume indicator meter is mounted on the panel and is connected by a switch and transformer across the output to the stage speakers to check the level and make frequency runs. The photocell output of either sound-head can be plugged into photocell pre-amplifier No. *9*—Bay 1, in the machine room, through a 5-pin Cannon receptacle mounted on the wall in front of the sound-heads. A signal telephone and *PA* panel are mounted on the wall between the two projectors. A *PA* and monitor speaker are mounted in the end of the booth. A motor-driven rewind cabinet, a film-storage cabinet and an inspection table with hand rewinds completes the equipment. On the rear wall is a remote switch which turns on all the rectifiers in the power room supplying the projection amplifiers, exciter lamps, and field supplies. A table-switch on each projector controls the relay supplying alternating current to the arc rectifiers.

Power Room.—The power room contains all the rectifiers supplying the filament and plate voltages of all recording and reproducing amplifiers, exciter lamp supplies, and field supplies. Two selsyn distributors and an emergency truck-battery charging generator are also located in the power room. Control panels, starting relays, and all associated switches are mounted conveniently on the wall. The rectifiers are mounted in specially built racks on one side of the power room, and all the wiring is contained in easily accessible gutters. Telephone or a portable *PA* outlet provides communication to the truck platform, maintenance room, projection booth, and machine room.

Maintenance Room.—The maintenance room (Fig. 1) contains a work-bench along two side-walls, with cupboards, drawers, and cabinets for storing accessories and spare parts. A test and patch-panel is located above the work-bench with filament and plate supply for any amplifier tests and high and low-level trunks to the truck platform and the circuit lab. telephone; and portable *PA* communication with the truck platform, machine room, projection booth and power room, is available. Selsyn interlock and 220-volt 3-phase connections are furnished for testing motors. A complete complement of testing instruments, meters, and accessories is provided for all testing.

Recording Truck Platform.—The truck platform contains stalls for four sound trucks. In each stall is a 220-volt 3-phase outlet for supplying the tungar battery-chargers in each truck. Each stall contains a 16-volt and an 8-volt d-c. charging outlet, supplied by a generator in the power room for giving the 16- and 8-volt batteries in the sound-trucks an emergency boost charge. In the center rear wall of the truck platform is a test-panel with facilities for making audio, continuity, and megger tests of all cables used. A patch-bay in the test-panel provides high- and low-level lines to the maintenance room or the circuit test lab. Thus any truck amplifier can be patched to the circuit-test lab. for frequency runs. Telephone or portable *PA* communication is provided between the sound-trucks or the truck test-panel, maintenance room, power room, and circuit-test lab.

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DISCUSSION

MR. MACNAIR: The expression "closing time" is used with respect to the compressor. Exactly what does that mean?

MR. WOLFE: A more nearly correct term would be "restoring time." What was meant was obviously the time required for the gain of the compressor to restore to its normal conditions. The term "closing time" was borrowed from noise-reduction terminology.

MR. MACNAIR: Sooner or later, in working with noise-reduction units and compressors, we must agree on these terms. Theoretically, the circuit never restores except in an infinity of time, and some of us choose to talk about $1/e$, because we used to be scientists. Others talk about the 99-per cent point, and so on. I think sooner or later we must agree on something.

MR. WOLFE: In our company we are trying to standardize on the 90-per cent point, as the point at which the restoring or closing time is measured.

MR. KELLOGG: I have often wondered what difference in impression you get in a small room as compared with a large room if both of them have the same reverberation time for all frequencies. That is theoretically quite possible, and no doubt it is quite often moderately well approached. I do not believe many of us would be fooled into thinking we had a larger room, but I have never seen the point brought out quite as well as I think the authors do.

The authors mention the fact that the small room has a shorter mean free path for the sound, and therefore the echoes come much more frequently. You get many more echoes in the same time, and if the absorption is adjusted so the total reverberation time is the same, then the dying away of the sound takes place in smaller jumps. In other words, the sound is chopped up a great deal finer.

It is of some interest that with a large orchestra we seem to want the rather slower chopping that we can get with the large room. With a smaller orchestra it is obvious that since there are fewer instruments you might need more chopping up of the echoes. In other words, the large number of players does very much in one way what the frequent echoes do in the other. That may have something to do with our preference for a large room where we have a large number of players.

MR. BUTLER: I believe distribution of frequency in a room is the answer to Mr. Kellogg's question. If we have a definite reverberation from one end of the room to the other and can distribute it, it is all right; but if we can distribute the frequent small echoes, I feel we would have a better overall condition.

UNIDIRECTIONAL MICROPHONE TECHNIC*

J. P. LIVADARY** AND M. RETTINGER†

Summary.—*After describing the constructon of a unidirectonal microphone several desirable factors are discussed connected with the use of such a transmitter for recording sound in motion picture studios. Six illustrations show how the microphone may be used to advangate under specific set conditions, and four diagrams illustrate its use in recording various types of music.*

A unidirectional microphone is a microphone that is operated partly by sound pressure and partly by a pressure gradient, or difference, in sound pressure between the two sides of the part so driven. The moving element in the most commonly used unidirectional microphone is a light corrugated metallic ribbon suspended in the magnetic field of a permanent magnet and divided into two parts. One section, freely accessible to air vibrations from both sides, acts as a so-called velocity microphone, because the induced emf. in the ribbon is, within practical limits, directly proportional to the particle velocity of the driving sound-wave. The other section of the ribbon, exposed to pressures from sound-waves on one side only, has its other side terminated into an acoustic labyrinth, and responds as a pressure-operated device, the induced emf. in the ribbon being proportional to the pressure of the driving sound-wave. Because the ribbons are in series, the combined output from the microphone is

$$E_u = E_p + E_v \cos\theta \qquad (1)$$

where E_u = Voltage output of the unidirectional microphone for sound originating in the direction θ.

E_p = Voltage output of pressure-driven element for sound originating in any direction.

E_v = Voltage output of pressure-gradient element for sound originating in the direction $\theta = 0$, which corresponds to the direction of a normal to the flat part of the ribbon.

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* Presented at the 1938 Fall Meeting at Detroit, Mich.; received September 23, 1938.

** Columbia Pictures Corp., Ltd., Hollywood, Calif.

† RCA Manufacturing Co., Inc., Los Angeles, Calif.

Assuming that emf. generated by each ribbon is adjusted to be the same for zero degree incidence ($\theta = 0$), then $E_p = E_v = E_o$, and

$$E_u = E_o (1 + \cos \theta) \tag{2}$$

The directional characteristic of the unidirectional microphone as expressed by eq. *2* is a cardiod of revolution, with the axis of revolution normal to the plane of the ribbon. This characteristic is shown in Fig. 1 for the two-dimensional case.

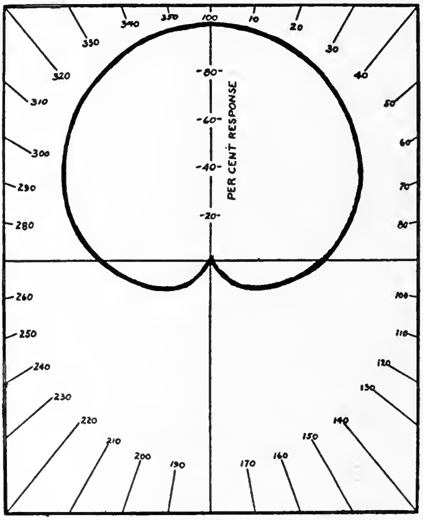

FIG. 1. Directional characteristic of unidirectional microphone.

Four definite advantages for sound recording are expressed by such a directional characteristic.

The fact that the sound striking the microphone from the rear is greatly attenuated prevents recording such undesirable sounds as camera noise, back-stage reflections, and what incidental noises might occur from that direction during a recording.

The large solid angle of reception over which the microphone receives sound without appreciable attenuation indicates that practically any action can be covered with a single microphone. This, of course, eliminates what interference is produced by the microphones when two or more units are used in covering an action, since the identical results are produced when the voltages from the microphones are out of phase as when sound-waves unite to produce near or complete cancellation of the vibrations in space. Much smoother dialog may therefore be expected with the use of one unidirectional microphone in place of two or more microphones of different types.

The energy response of the unidirectional microphone to sound originating in random directions is one-third that of a nondirectional microphone. This means that for the same allowable reverberation, the unidirectional microphone can be used at 1.7 times the distance of a nondirectional mirophone.[1] No loss in intelligibility occurs when this greater distance is used, since the per cent syllable articulation of recorded sound is dependent only upon the amount of recorded reverberation* in a room free from noise and echoes.[2]

The directional characteristic of the unidirectional microphone is independent of frequency within all practicable reception angles. One of the most objectionable qualities of a pressure-operated microphone used in recording sound is the directional response that such a transmitter may exhibit for frequencies above 2000 cycles. While the polar response-frequency characteristic of an ideal pressure-operated microphone is a circle, as far as a plane through the transducer is concerned, in practice the response at the higher frequencies becomes noticeably attenuated for angles larger than 30 degrees on either side of the normal, or zero degree, incidence axis through the microphone. While such undesirable effects can be reduced by recording all dialog at some angle off the normal, such practice is greatly dependent on the experience and skill of the man who is entrusted with the handling of the transmitter during a recording. Considering, moreover, the manifold situations of a recording, the several sources of sound that either simultaneously or in quick succession must be recorded with a minimum of delay and hazard, it stands to reason that a microphone having a directional response independent of frequency will greatly reduce these objectionable abrupt loudness and quality variations.

It may be stated at this point that a pressure-operated microphone, such as used in practice, tends toward a ratio of direct to reflected sound in the recording that is larger for the high frequencies than for the low ones, if the microphone is used "beam on," because reflected high frequencies striking the microphone at large angles of incidence are attenuated by the microphone. While this has a ten-

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* Recorded reverberation is defined as the ratio of generally reflected to direct sound energy.

dency to lend greater "presence" to the sound recorded by a pressure-operated microphone, the increased amount of low frequencies recorded may exert a masking effect on this sound. Only experience will be able to state how important these two factors are, whether they neutralize each other, or whether the absence of one of them in the unidirectional microphone will be noticed in recordings made with such a microphone.

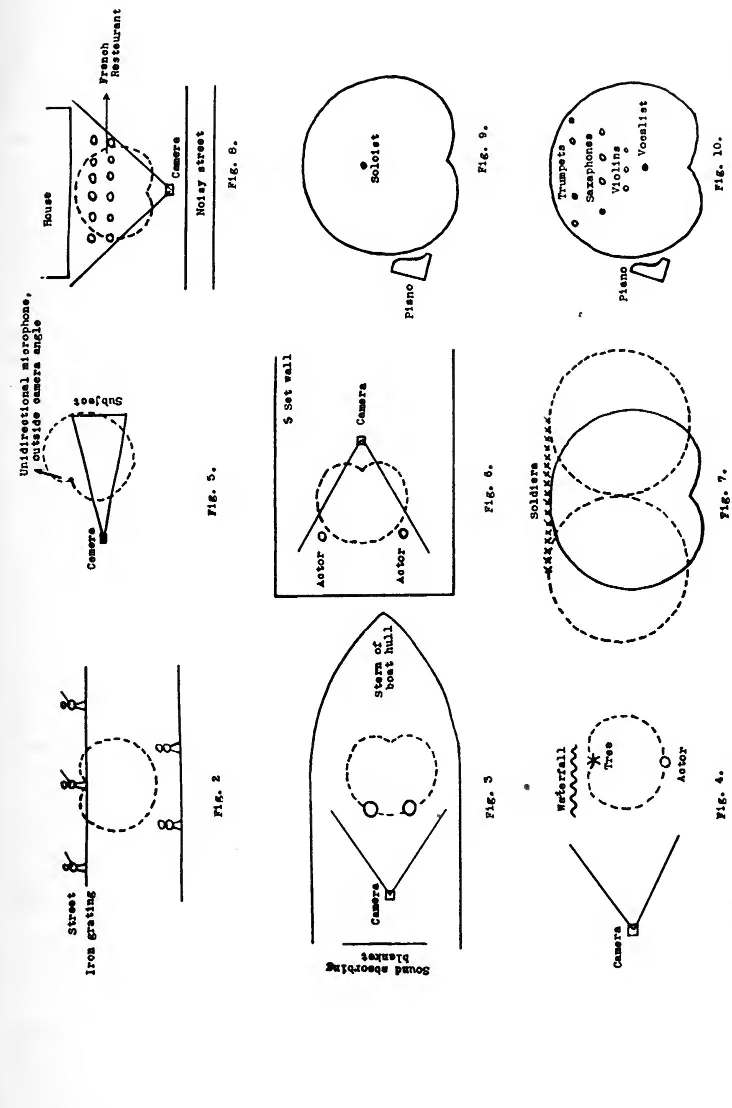
In the following it is intended to describe a number of scenes that lend themselves particularly well to the use of a unidirectional microphone. These scenes are specific, but by no means infrequent, and certainly have variations that can be covered equally well.

Screening of Undesirable Sounds.—Fig. 2 shows a subway tunnel the "ceiling" of which consists of iron grids opening to the sidewalk of the street above. It is intended to record only the dialog of the two persons in the tunnel, but not the footfalls of the passers-by above. The camera, on the other hand, is to photograph the entire scene, the actors speaking as well the actors overhead. A unidirectional microphone, skillfully concealed in the grating and oriented with the "dead plane" toward the sidewalk, represents an ideal solution for this difficult scene, since footfalls may later be "dubbed in" to an extent that will not mar the dialog but yet permit the auditor in the theater to hear actual, if faint, footsteps.

Fig. 3 shows the hull of a ship in which two actors, at some distance from one end, are talking. The hull, which is that of a real boat, is very "live," and considerable reflected sound comes from the end being photographed. A unidirectional microphone so oriented that its zero-degree incidence axis points toward the camera, will eliminate much of the undesirable reflected sound from the pictured end.

Fig. 4 shows an actor being photographed near a tree and a waterfall, where the rush of the water is to be "dubbed in" in re-recording. A unidirectional microphone so placed that the 180-degree axis is directed toward the waterfall will reduce the sound of the water by approximately 20 db., which represents the difference in response between the front and the rear of the unidirectional microphone.

Use of Greater Microphone Distance.—Fig. 5 represents a medium shot. Good recording practice calls for an "acoustic perspective" conforming to the visual perspective of the picture seen on the screen.[3] This means that, if a microphone may be said to have "focal length," its value should be equivalent to the optical focal length of the camera



FIGS. 2–10. Scenes, described in the text, lending themselves well to the use of the unidirectional microphone.

lens in order to achieve effective visual and aural coördination. In practice, however, it is not only difficult in many cases to position the microphone so as not to be within the camera angle, but cameras are often equipped with lenses of greater focal length, which calls for an even shorter distance between the speaker and the microphone than between the speaker and the camera. If a pressure microphone is placed barely outside the camera angle when such a condition exists, the auditor in the theater may gain the impression that the source of sound is not on the screen but behind it. A unidirectional microphone, however, having similarly a large "acoustic focal length," when placed at the position of the pressure microphone will create the effect of a pressure microphone situated at a distance six-tenths of that between the speaker and the unidirectional microphone. Indeed, with some care a position can be chosen for the unidirectional microphone that will not only maintain a high degree of intelligibility in the recorded sound when the transmitter is placed outside the view of the camera, but also the "acoustic perspective" can be made fully commensurate with the depth of the image on the screen—a condition often referred to as "screen presence."

Directional Response Independent of Frequency.—Fig. 6 shows two actors engaging in rapid diaglog. If a "boom man" were to attempt to orient a pressure microphone so that its zero-degree incidence axis would point to each of the actors whenever he was speaking, several "takes" would probably be required to insure good intelligibility in the reproduced sound, if it can be had at all. On the other hand, if the pressure microphone remains stationary, with the zero-degree incidence axis pointing midway between the speakers, a type of recording can result that is sorely lacking at the high frequencies because of the narrow directional characteristic that so many pressure-operated transmitters exhibit. This deficiency in high frequencies can, of course, later be remedied during re-recording by high-frequency equalization in the dubbing channel. Such post-equalization is, of course, necessary only when parts of the picture are recorded with the zero-degree incidence axis pointing directly at a speaker. If all dialog is recorded at a certain angle off this zero axis, only the amount of pre-equalization is used in the recording channel that will result in maximum intelligibility and naturalness of speech. Oversight on the part of a boom man, however, as well as almost unavoidable speaker configurations, tending to produce "beam-on" recording, make such a microphone difficult to manipulate, particularly when a crew is pressed for time. A unidirectional microphone, however, even as a velocity microphone, preserves the balance between the high and low frequencies in a recording up to very large angles of reception.

Large Solid Angle of Reception.—The use of two or more microphones to cover a large scene has several disadvantages. The level from the different microphones must at all times be balanced properly by the mixer, who is already called upon to control the overall gain to the amplifiers. Two or more men may be necessary to manipulate the microphones, causing additional difficulties in maintaining a

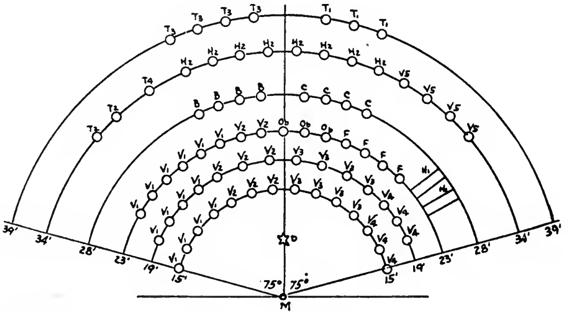


FIG. 11. Arrangement of microphone and symphony orchestra.

D, Director
M, Microphone

———————

B, 4 Bassoons
C, 4 Clarinets
F, 4 Flutes
H_1, 2 Harps
H_2, 8 French Horns
Ob, 3 Oboes
T_1, 3 Trumpets
T_2, 2 Tympani and Traps
T_3, 4 Trombones
T_4, 1 Tuba
V_1, 12 First Violins
V_2, 10 Second Violins
V_3, 8 Violas
V_4, 6 'Cellos
V_5, 4 String Bass

————————

Total: 75 Musicians

constant orientation of the microphones if they are of the pressure-operated type. Interference effects caused by the voltages from the the microphones being out of phase because of the spatial separation of the transmitters, may produce a blurred or "bumpy" recording not always readily detected by the mixer. Fig. 7 shows how a row of soldiers can be covered well by a single unidirectional microphone; for the sake of illustration there is also indicated the directional response of two pressure-operated microphones so placed to give similar coverage. Fig. 8 is a similar application of the unidirectional microphone covering a large garden party near a house by a noisy street.

In the ordinary motion picture set consisting of a floor and three walls, the main part of the reflected sound which adds to the illusion of an interior setting is that reflected from the set walls. Reflections from the absorbent walls of the sound-stage are either too weak or, if noticeable, are usually delayed too long in time to contribute pleasingly toward such an illusion. Hence, if the atmosphere of an interior setting is to be preserved within its proper limits, it becomes necessary to collect as much as possible these reflections from the set walls before they strike the walls of the sound-stage. In this matter also a unidirectional microphone with its wide pick-up angle is an effective device toward the more realistic representation of the picture shown on the screen.

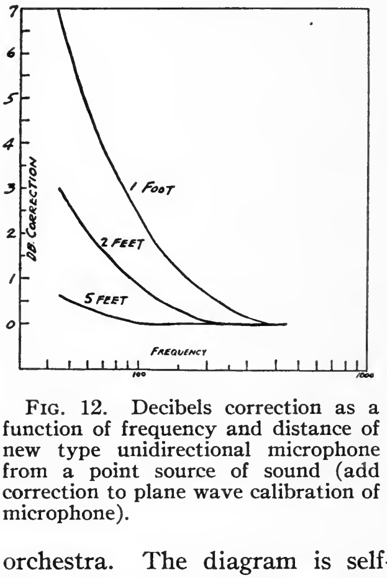


FIG. 12. Decibels correction as a function of frequency and distance of new type unidirectional microphone from a point source of sound (add correction to plane wave calibration of microphone).

Finally, when recording music, a satisfactory balance can often be achieved by the use of one unidirectional microphone and a judicious placement of the instrument. Fig. 9 shows the recording of a soloist accompanied by a piano. The distance between the vocalist and the microphone should be determined by the strength of his or her voice, and the piano should be placed accordingly for proper balance. Fig. 10 shows a set-up for recording a small band, such as a dance orchestra. The diagram is self-explanatory, the only precaution necessary being to keep the soloist at least two feet, and preferably three, from the microphone. Fig. 11 shows microphone and orchestra arrangement for a symphony orchestra.

There are also situations, however, that lend themselves less successfully to the use of a unidirectional microphone. Such scenes usually involve several actors, all of whom are speaking, while it is intended to record very clearly the voice of only one. Obviously, instead of using a microphone having a wide pick-up angle, a transmitter with a narrow solid cone of reception should be used. Likewise, when for some reason or other very close talking is necessary it is advisable to use a microphone that will not cause an increase in the low-frequency response when the distance between the speaker and the microphone is decreased. This low-frequency build-up is by no means so pronounced in a unidirectional microphone, however, as it is in a velocity microphone. Fig. 12 shows the variation of low-frequency response of a unidirectional microphone with variation in microphone distance.

This variation in low-frequency response with angle of incidence may be calculated as follows: Let

E_p = Voltage output on a nondirectional microphone.
C_p = Sensitivity constant of this nondirectional microphone.
E_v = Voltage output of a bidirectional microphone.
C_v = Sensivity constant of this bidirectional microphone.
d = Microphone distance.
F = Frequency.
w = $2\pi F$.
λ = Wavelength.
t = Time.
θ = Angle between the direction of the incident sound and the normal to the ribbon.

then $$E_p = \frac{C_p \sin wt}{d}$$

$$E_v = C_v \left(\frac{\sin wt}{d} - \frac{\lambda \cos wt}{2\pi d^2} \right) \cos \theta$$

If $C_p = C_v$ (unidirectional microphone having cardiod directional frequency response), then the output of the unidirectional microphone compared to that of a nondirectional microphone is given by:

$$Q = \sqrt{\left[\left(\frac{1}{d} + \frac{\cos \theta}{d} \right)^2 + \left(\frac{\lambda \cos \theta}{2\pi d^2} \right)^2 \right] \frac{d^2}{4}}$$

If $\theta = 0$ (normal incidence), this reduces to:

$$Q^1 = \sqrt{1 + \frac{0.0063\lambda^2}{d_2}}$$

or, expressed in decibels:

$$DB = 10 \log_{10} \left(1 + \frac{0.0063\lambda^2}{d^2} \right)$$

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ARTIFICIALLY CONTROLLED REVERBERATION*

S. K. WOLF**

Summary.—*In the recording, acoustical, and electrical transmission of sound, the control of reverberation for purposes of speech articulation, musical quality, and acoustic illusion has been one of the problems confronting architects, broadcasting, recording, and acoustic engineers for some time. The paper discusses briefly the phenomenon of reverberation, and describes two methods of reverberation control:* (1) *reverberation chambers and* (2) *a practical machine employing magnetic recording.*

High-quality recording and reproducing require a wider and more accurate control of all acoustic characteristics, particularly reverberation, in the never-ending quest for perfect illusion in sound motion pictures and radio broadcasting. Reverberation chambers for adding a fixed amount of reverberation to a sound recording or to a broadcast are already being used by the leading recording and broadcasting studios. These reverberation chambers introduce an additional liveness into the sound that is not present in the studio where the original sound is being picked up.

Such a reverberation chamber is normally a sizable room, approximately 10,000 cubic feet, with walls of a glazed hard-surface material, and having a reverberation time of several seconds. In the reverberation chamber are placed a loud speaker and a microphone. The loud speaker in the chamber is connected by suitable means to the microphone in the studio, and the microphone in the reverberation chamber is electrically connected to the sound-transmission channel. The output of this channel is then recorded or broadcast. In this way the acoustic liveness of the reverberation chamber will be added to the original sound picked up by the studio microphone. Such a reverberation chamber offers only a fixed amount of reverberation and is not capable of instantaneous variation or control.

The acoustic control of sound recording or broadcasting either through reverberation chambers or in the space where the

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**Acoustic Consultants, Inc., New York, N. Y.

original sound is created, depends upon the acoustic properties of the enclosure and the placement of the microphone relative to the sound-source. A correlation between microphone placement and acoustic characteristics of interiors has been worked out by Albersheim and Maxfield. If a sound is produced in a room, a short time elapses before the intensity of the sound reaches a maximum value. This time is called the growth time. If the sound-source suddenly ceases to emit energy, time elapses before the energy is completely absorbed or falls below the threshold of audibility. The reverberation time is defined as the time required for the sound to diminish to one-millionth of its maximum value.

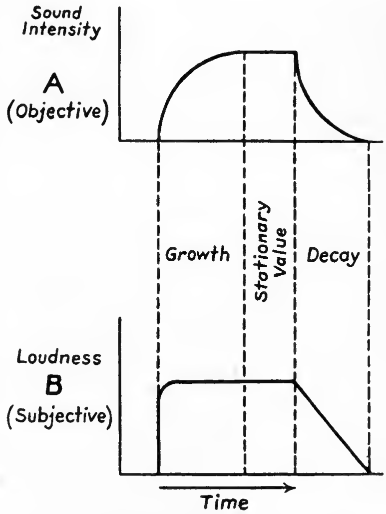

FIG. 1. Diagram illustrating growth and decay of sound in a room.

In Fig. 1 (*A*) is diagrammatically shown how the sound-energy in a room builds up to the stationary value and how it decreases to the threshold of audibility. The subjective impression upon the ear, which is logarithmic, is shown in Fig. 1 (*B*). The growth time of the sound is scarcely detected (curve *B*) because subjectively the sound seems to reach its peak value almost instantaneously, whereas the decay is more noticeable since it drops from a higher to a lower intensity proportionately with time.

Experience has shown that music and speech require different reverberation times and that different musical compositions require different rates of decay. Since it is always rather difficult to change the acoustic characteristic of a room at will there has been for many years a need for a practical method of artificially controlling reverberation for producing any desired rate of decay of the sound. Since the growth of the sound is scarcely discernible, such a reverberation machine need only control the decay rate. However, the growth of the sound may be artificially produced, if desired for any reason, by the same method.

The problem of artificial reverberation can also be expressed a little differently. If, by some artificial means, the intensity of a sound can be controlled or regulated so as to correspond to the natural change of intensity, the effect must be the same as the effect of natural reverberation.

A simple way of producing reverberation artificially is to record the sound and to have a number of time-displaced pick-up heads feed the energy, through adjustable volume controls, back into the transmission line to which the microphone is connected, through an amplifier of the desired gain and frequency characteristics.

The volume controls are so adjusted that the amounts of energy supplied to the transmission line, from one pick-up to the next, follows an exponential law. To approach theoretically the natural rate of

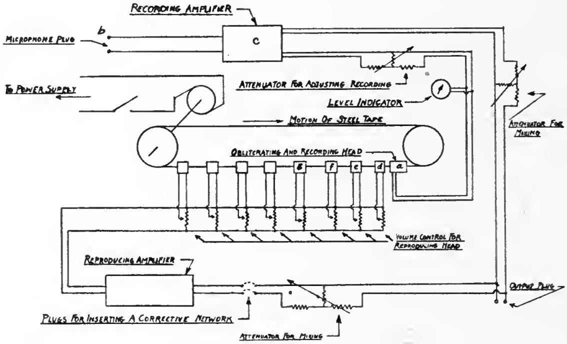

FIG. 2. Circuit diagram of reverberation unit.

decay, an infinite number of pick-up heads would be required. For most practical purposes, however, several reproducing heads are sufficient.

An artificial reverberation machine must meet the following requirements:

(*1*) Immediate playback.
(*2*) Low maintenance cost.
(*3*) Control of intensity and frequency response.
(*4*) Mechanically and electrically fool-proof.

Existing methods of sound recording can not fulfill these requirements. Film recording used in the sound motion picture industry requires processing before reproducing. Mechanical recording is too expensive because of the necessity of continuously using new recording material. There are other methods of recording that are a practical solution of the problem. One of the methods makes use of a tape coated with fluorescent material, which, when exposed to ultraviolet light controlled by a suitable light-valve, will fluoresce for a short while. This tape passes a number of photocells, which then pick up the sound and reproduce it. The exponential decay of the fluorescence has attracted experimenters to this means of creating artificial reverberation. After a certain time the emission ceases, particularly if the exposure was made to infrared light, and a new recording can take its place. In this method the background-noise remains constant as the signal-level diminishes; the signal-to-noise ratio therefore decreases. For long periods of reverberation the fluorescence decays too rapidly.

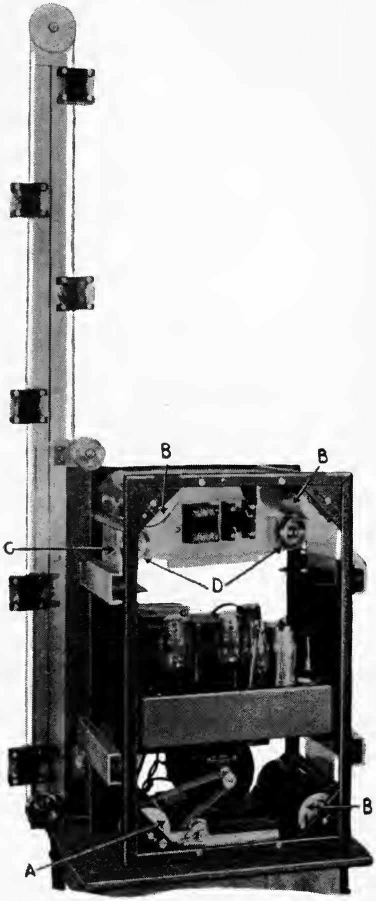

FIG. 3. Mechanism for driving the tape.

The author's method makes use of the principle of magnetic recording that has proved practicable. A magnetic record may be instantly reproduced and immediately obliterated. A complete description of the principle of magnetic recording has been published in the JOURNAL by S. J. Begun.[1] For artificial reverberation the tape may be used as shown in Fig. 2. The recording head *a* is supplied with energy from the microphone *b* and amplifier *c*. The pick-up heads (*d*, *e*, *f*, and *g*) and the recording amplifier are connected to a mixer amplifier, the output of which can either feed into a transmission line or a loud speaker. The mixer amplifier is provided with adjustable filters for the pick-up heads to make it possible to get any frequency-response desired in reproduction. Such adjustment of response is valuable since the reverberation time is not the same for all frequencies, and depends upon the absorption coefficient of the room for different frequencies. It is very important that the sound-carrier move without appreciable variation of speed, particularly since the machine is used most frequently for musical reproductions. Fig. 3 shows a mechanism for driving the tape. A motor drives, through a belt, one cylinder *a*, and additional cylinders *b* are driven by the endless tape loop *c*, the ends of which are joined over two cross-over rollers *d*. This endless loop can be made long enough for any desired reverberation time, and as many reproducing heads can be arranged as required. The machine is normally provided with eight reproducing heads logarithmically displaced in time; the first so located that it will pick up the record after 0.1 second, the second after 0.16 second, the third after 0.25 second, the fourth after 0.4, the fifth after 0.66, the sixth after 1 second, the seventh after 1.7 seconds, the eighth after 2.7 seconds. The arrangement of the complete unit for motion picture studio and broadcasting use is shown in Fig. 4. The equipment is rack mounted, enclosed in a cabinet, and supported on casters so that it can be easily moved from one studio to another.

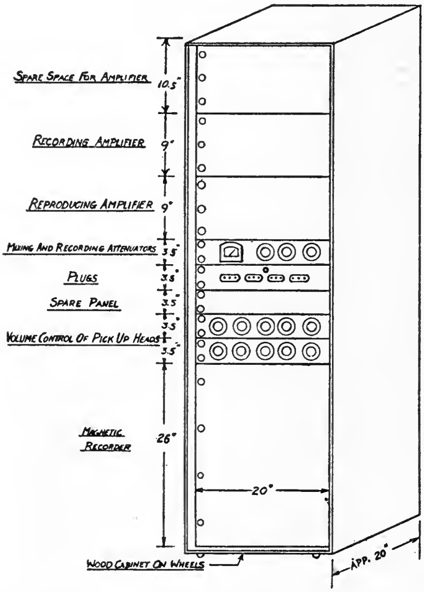

FIG. 4.—Arrangement of reverberation control unit.

Magnetic recording meets the quality requirements for synthetic reverberation: Its frequency responses, using adequate equalizers, are flat from 50 to 7500 cycles, and, if desirable, even higher. The signal-level is 40 db. above the background-noise. A sound-carrier of steel tape 0.1200 mil wide and 0.003 mil thick is used. This steel tape is particularly strong, and tests have shown its mechanical strength and electromagnetic properties to be entirely satisfactory. The machine requires little servicing and is simple to operate. The mechanism shown in Fig. 3 has been designed jointly by S. J. Begun, A. Stapler, and the author. The electrical and physical designs of the unit have been anticipated by A. N. Goldsmith[2] in his patent on synthetic reverberation under which this company is licensed.

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DISCUSSION

DR. GOLDSMITH: The method here described is obviously one of which we shall hear more as time goes on, because it is impossible that reverberation of all sorts and types will be produced merely by simulating the actual physical chamber or enclosure in which the original reverberation might take place. It is manifestly not economical in the long run to have a great number of empty rooms or pipe lines of different characteristics not flexibly controllable, when such an ingenious mechanism as Mr. Wolf has described can be conveniently and economically used for the purpose.

The versatility of that type of mechanism depends upon the work in connection with magnetic recording that was described. The problem of producing a reliable telegraphone is not so simple as it sounds, because if one takes a piece of steel wire and tries to run it around in a loop over and over again, he soon makes the interesting discovery that steel can be defined as a material that kinks and snaps itself automatically. The problem of producing telegraphones with wire elements is difficult if one requires reliable, continued operation, and it takes a clever arrangement, such as this steel-tape holder, to accomplish the results in heavy-duty service.

The flexibility of the circuits and arrangements that have been shown is perhaps greater than has been indicated. Thus, if one wants to simulate the acoustics of a room which has walls, floor, and ceiling of different characteristics, one can divide the reproducing pick-up heads into three major groups corresponding respectively to the horizontal right and left walls, the front and back walls, and the ceiling and floor, and then put into the circuits of the reproducing heads corrective networks corresponding in general to the frequency and also the phase-of-reflection characteristics of the walls in question; so that one can modify each of the three groups of major reflections more or less systematically as desired.

Other interesting possibilities exist. In the panel arrangement that was shown are a group of reproducer amplitude controls—that is, volume controls. It is possible to interconnect those by chains, levers, or other mechanical means, so as to have a master control. One can even move the recording heads along, changing the time of each delay; or vary their amplitude systematically, or both, so that by means of a simple knob one can go to extremes of flexible control, one can change the delays in each reproducer head relative to fundamental sounds and change the relative amplitudes and/or tone qualities from each. So one could conceivably have a knob with a pointer moving over a scale marked: "small room of wood," "larger room of stone," "scene under a bridge," "cathedral interior," and so on; and by merely turning the knob one could actually change the resulting acoustics over this wide series of conditions.

There are other interesting applications, as Mr. Wolf has pointed out, for this technic; but one of the main points that should be considered is that the acoustic output-to-ground-noise ratio of each of the echoes produced by the machine remains satisfactory.

There is another point of interest. It is believed telegraphone recording equipment is entirely adequate for the purpose mentioned, for two reasons, first, because its tonal quality is very high when it is properly built; and, second, because the role played by the very high frequencies is less in synthetic reverberation than in the original sound.

Finally, there is another point of interest. To the practical man carrying out recording in studios, this device offers the possibility of later sound editing on a large scale, because he can take an original record of sound in "dead" surroundings, and then he can add any desired type of reverberation at any time thereafter. This he can re-record in any desired fashion as often as desired, and experiment and produce different types of reverberation until he finally hits the one that gives him, for example, the effect of a man walking out of a room into a tunnel and into a larger room. That can be experimented with over and over again until the desired result is obtained, without injury to the original record.

Perhaps I should apologize for the length of this discussion, but I am greatly interested in the whole philosophy of producing sound effects by electrical means rather than by clumsy, large, and costly, mechanical means.

MR. KELLOGG: My first SMPE paper was read in 1928 under the title, "Some New Aspects of Reverberation," in which I indulged in the speculation that since we did not need reverberation to help intensity any more with our electrical apparatus, we could control things beautifully if we could only get rid of the natural reverberation and supply just what we wanted where we wanted it and when we wanted it by various electrical devices. It seemed that the remarkable flexibility and power our new electronic and acoustic tools were going to give us better control than we have ever had before.

Well, I have been waiting during the intervening ten years to see any of that really done. After all, I do not think that such mere speculation as I indulged in is a particular credit compared to really doing something about it.

There is one aspect in the production of reverberation by a recording sound system which is not necessarily an indication of its being faulty, but it is fundamentally different from what we will get with any normal natural reverberation. If the absorbent qualities of the walls are such as to cause, let us say, twice as much absorption at 5000 cycles as we have at 2000, the 2000-cycle tone would be audible for twice as long a time as the 5000-cycle tone. In the case of reverberation produced by recording the sound, if the rate of attenuation is determined by the gain settings of the several pick-ups, all the components will have the same reverberation time. Therefore, the only kind of room this will truly simulate is one which has exactly equal attenuation at all frequencies.

I am not saying that the kind of reverberation you may get by the recording method may not be even better, provided you keep the ground noises down, but it is essentially different.

There is one phase of the question that I feel deserves much consideration. It seems to me to be very desirable, if we have a ready means of producing artificial reverberation, to do it in the listening and not in the recording. I grant that by doing it in the recording you make it available for all theaters, but the ideal system which I hope ultimately to see in use is one in which the original sound recorded with very little reverberation, and in the reproduction the non-reverberant sound will come from a speaker directly in front of you, and echoes will come from speakers scattered around the room.

We tried some experiments a number of years ago in Camden to check out this idea, and it works according to theory very nicely. If we put all the echoes through one loud speaker in front of us we got the impression of sound coming down a long hallway. Although the tests were made in a small room we got quite a good illusion of being in a large room when we produced only the initial sound under a loud speaker directly in front, and the reverberation or echoes with scattered speakers around the room.

We did those experiments with a record and a series of pick-ups. The thing one would naturally be likely to do in arranging a series of pick-ups would be to space them uniformly. We did not get far enough to make any analysis of that, or to try many variations, but such uniform steps are obviously not what happens in the echoes we get in natural reverberation. Can Mr. Wolf tell us what he has found in the way of optimum arrangements?

MR. WOLF: I did not quite follow some of your reasoning as to why we could not simulate the reverberation condition. Theoretically, with the flexibility that we have, we believe that we can simulate or at least create the illusion of any desired reverberation condition.

The distribution of the reproducing heads is not very critical. We are now building a machine on which we can put as many as 40 or 50 heads, or even more if desirable. Preliminary experiments indicate that only a small number of heads are necessary and their positions are not very critical. They may be spaced logarithmically or uniformly, and still produce a very good illusion of reverberation with a small number of heads spaced almost at random.

DR. GOLDSMITH: There is another point of interest in this connection. It is possible, of course, to simulate effects in a room having different attenuation rates for the different frequencies by placing in each reproducer-head circuit a frequency-selective circuit, so that with the passage of time one cuts down the different frequencies to different extents. It is thus possible to simulate the desired effect.

MR. KELLOGG: I checked that, by increasing attenuation of certain frequencies on the pick-ups that are reached successively by the location.

THE EVOLUTION OF ARC BROADSIDE LIGHTING EQUIPMENT*

PETER MOLE**

Summary.—*From the earliest days of artificial lighting the broadside type of unit has been a fundamental lighting tool. Regardless of the light-source used in such lamps—whether mercury-vapor tubes, carbon arcs, or incandescent filament globes—the broadside is a lamp of the floodlight type, designed to emit a relatively wide flood of soft, moderately powerful illumination. It has withstood innumerable changes in lighting and photographic technic, including the introduction and acceptance of spotlighting, the change from orthochromatic to panchromatic film, the changes from silent to talking pictures and from arc to incandescent light-sources, and the present growing popularity of natural-color photography.*

The paper traces the evolution of arc broadsides only, and comment upon the design and performance of the early units. The evolution of the broadside is followed through successive improvements in silent-picture usage; its decline at the introduction of sound and Mazda lighting; through the relatively recent rebirth of arc lighting due to the requirements of modern natural-color photography; and the most recently introduced units of this type which are replacing equipment designed less than five years ago at the introduction of the three-color Technicolor process. Comparison is made between the early, intermediate, and modern units as regards color distribution, light distribution, steadiness and length of burning period, indicating that though less public attention has been given to these types than to the more familiar spotlighting units, the broadside has kept pace with advances in lighting and equipment design.

The first artificial light-sources used to illuminate motion pictures were of the "broadside" or floodlighting type. From that day down to this, the "broadside," regardless of the type of light-source it housed, has remained a fundamental tool of motion picture lighting.

So far as is known, the first installation of artificial lighting for motion picture production was made at the original Biograph studio on 14th Street, New York, N. Y., in 1905. The lamps used were primitive "banks" of mercury-vapor tubes, suspended above the sets under the glass roof, to supplement to daylight on dull days, and to replace it on dark ones.

Other pioneer producers and technicians were not long in appreci-

* Presented at the 1938 Fall Meeting at Detroit, Mich.; received October 31, 1938.

** Mole-Richardson, Inc., Hollywood, Calif.

ating the commercial advantages of artificial lighting, and in time virtually all the eastern studios equipped themselves with mercury-vapor lighting equipment. When the industry began its migration to California, the vapor-tubes followed, for in spite of the most enthusiastic claims, clouds do sometimes obscure the California sun, and artificial lighting remained a commercial asset.

As this development progressed, the mercury-vapor tubes were adapted to a variety of units, all of the floodlighting type. In addition to the original overhead units were "broadside" units of from six to eight tubes, mounted on wheeled stands to permit their use on the stage floor; "goose-neck" units which resembled the "broadside" banks but with the addition of a second bank, mounted above the first and directed at a downward angle; and in some instances—special low front-lighting units (usually of four tubes) mounted horizontally on a low, wheeled carriage and used to throw light upward against the faces of the players.

The first arc-light unit to appear seems to have been the Aristo, introduced not long after the introduction of the vapor tube. This unit, which was an adaptation of similar street-lighting units, was an overhead floodlight. It was a single arc, burning at about 28 amperes and 63 arc volts. It was commonly fitted with a simple conical reflector reminiscent of those on street lamps, and the arc was enclosed in a glass globe. With its small dimensions and relatively high power for those days, it became very popular for supplementing natural light on glass stages.

The introduction of true arc "broadsides"—that is, floodlighting units for floor use—appears to have taken place about 1912. According to cinematographers active at the time, the Wohl was one of the first, if not actually the first of these units used. It, like most of its successors for a decade or more, was an adaptation of units previously made for photoëngraving. These pioneer lamps were what might be called double-twin arcs, for they consisted of a pair of twin-arc units, each with a large, box-like reflector, mounted one above the other on a common stand. The stand consisted of three upright posts, arranged parallel to each other in a triangular formation; the lamps slid up and down between the two front posts, while a counterweight operated on the third post. The four arcs were wired in series-multiple. They burned at 30 amperes when all four arcs were connected in series across a 220-volt circuit, or at 60 amperes if each two arcs were burned independently in multiple on a 110-volt line.

The advantages of arc lighting became increasing pronounced as cinematographers drew away from the earliest flat lightings and began to experiment with the possibilities of creating effects of contour and separation of planes by contrasts in lighting. A considerable variety of arc "broadsides" were built during the next several years by a number of manufacturers. Among these might be mentioned one curious design in which a single arc of relatively high power (30–40 amperes) was mounted to burn horizontally in a semicylindrical reflector, and another in which the carbons were placed at right angles to each other. In general, however, the successful designs soon evolved to the form familiar to all who have had any experience with production prior to the early days of sound.

In general, these lamps were of the twin-arc type with the two arcs placed beside each other with the carbons vertical, and burning in series at about 30 amperes. The lamp was mounted on a pedestal quite similar to the types in general use today, with the necessary ballast resistance at the base of the pedestal.

These arcs were generally used in conjunction with the softer vapor tubes. Before the introduction of arc spotlighting equipment, they were the only sources of strongly directional "hard" light available. In some studios the way in which the "hard" and "soft" lighting was mixed was left to the cameraman. In others, a rigid studio policy dictated the lighting: in some such cases all the vapor lights might be used overhead, and all arcs on the floor; in others, vapor lights exclusively on the floor, and arcs overhead.

A common malady throughout all the days of the early arcs was the so-called "kleig eye," medically termed conjunctivitis. It was a painful inflammation of the eye and eyeball. The cause was simply ignorance of the spectral characteristics of arc lighting. Arc light has always radiated strongly in the injurious, short-wave ultraviolet region. At that time, the lamps were very generally used with no diffusion, or at best a simple scrim of silk or tracing-cloth which, of course, failed to impede the ultraviolet rays. Since the rebirth of arc lighting five or six years ago, modern knowledge of spectral radiation has virtually eliminated this malady. Ordinary lead glass absorbs all the injurious components of the ultraviolet radiation. Accordingly modern arcs are always used with some sort of a lead-glass window—clear, if no diffusion is wanted; translucent, if diffusion is desired. And "kleig eye" is known only to press agents seeking imaginary copy.

The performance of the early arcs left much to be desired. Of course, when motion pictures were the silent drama, it did not matter whether or not lighting equipment burned silently; but then, as now, a steady-burning light-source was important to good cinematography. Even the most enthusiastic booster of these early lamps could not deny that they flickered badly, and frequently went out at the most inopportune moments. It was probably fortunate that the film used in those days was of relatively limited sensitivity, for maintaining a mere exposure level of illumination usually required the use of so large a number of overlapping lamps that the effects of flickering by individual lamps were minimized.

In a certain measure this performance was due to the then relatively limited knowledge of carbon design and production. Fundamentally, however, the flickery performance of all types of pre-talkie "broadsides" must be laid to the crude methods of feeding the carbons. Some early lamps even used a simple, hand-operated gravity feed. The majority made use of some type of gravitational-magnetic feed, which fed both arcs simultaneously. The result, of course, was an exceedingly intermittent feed. The lamps would burn with less and less intensity and increasingly pronounced flicker as the arc-gap grew wider. Then the carbons would suddenly feed, after which the light would momentarily become abnormally brilliant, and then diminish slowly as before. The electricians of those days used to keep long poles available on the sets with which to beat or jolt the lamps at the start of each "take," in the hope that the jolt would cause the carbons to slip down and thus minimize flickering during the scene. Floor lamps were often shaken, and the main switch flipped rapidly on and off for the same reason. The percentage of otherwise good scenes spoiled by lamp flicker was high.

Fig. 1 shows a curve made by one of these lamps with a General Electric recording photometer. The lamp used was a typical twin-arc "broadside" of the later, pre-Vitaphone vintage. It is possible that when the lamp left its maker's hands some fifteen years ago its performance might have been considerably more creditable; but time unfortunately did not permit completely reconditioning the unit, and the test was made with the lamp in approximately the condition it would be in under normal studio usage of its period.

It will be observed that when first struck, the arc leaps to a relatively high intensity, reaching a peak after about 30 seconds, after which the intensity rapidly decreases, with frequent and strongly noticeable fluctuations; until, after approximately $3^1/_2$ minutes of burning, when the intensity has declined to approximately $^1/_3$ its original value, the lamp retrims itself, without, however, regaining more than $^2/_3$ of its initial intensity. Thereafter the cycle of decline and retrimming repeats itself.

Similar tests, covering a period of an hour's burning, were even more noteworthy. The short-period fluctuations already noted stood out prominently, and superimposed upon them was a pattern of longer-period fluctuations of still greater intensity. These occurred at approximately 5-minute intervals, and at the peaks the recording stylus was thrown completely off the scale. Immediately before these

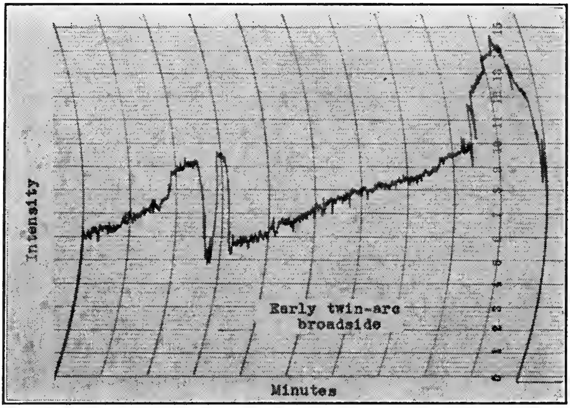

FIG. 1. Characteristic of early type of lamp, prior to 1926.

peaks, as the carbons in retrimming momentarily touched before striking what for all purposes was a new arc, the intensity dropped to zero.

It will be seen that there was a triple flicker in these lamps, phased as follows: first, minor variations in intensity at intervals of less than 2 seconds; second, fluctuations of 40 to 50 per cent at intervals of approximately 3 minutes; third, fluctuations of several hundred per cent at approximately 5-minute intervals. Thus while these lamps would actually burn for considerable periods, it will be obvious that for true photographic effectiveness it was seldom safe to burn them continuously for more than 3 minutes, or at most 5 minutes without extinguishing for adjustment. Even during this short burning period, they were only momentarily at their best performance.

The coming of sound and the introduction of panchromatic film, occurring a most simultaneously, spelled the doom of these early arcs. Even though it was in time found that arcs could be silenced quite effectively by the application of choke-coils, the much longer scenes general in talking pictures demanded the use of steady, flicker-free illuminants. At the same time, panchromatic film's stronger sensitivity in the yellow-red region made the early arcs, which were deficient in this range, inferior to the steadier and redder incandescents. High-intensity arc spotlights, of course, continued in occasional use, since no other illuminant could compete with their strong, intensely directional beams for certain dramatic lighting effects.

The arc was reborn about five years ago, with the introduction of the three-color Technicolor process. With any process of natural-color photography or cinematography the color of the light is of fundamental importance, both technically and commercially. The color control possible in the camera's separating filters, and in the multiple color-printing operations naturally make a certain degree of compensation possible. Natural daylight, however, is a fairly uniform blend of rays of all spectral colors. If the system is balanced for this standard, there is difficulty in using it with light which, like the incandescent, leans to the red end of the spectrum, or, like the earlier arcs, leans to the blue end. Printing color-control alone is seldom sufficient to compensate for such differences. The filter-balance of the camera can, of course, be altered to make such compensation. But this is not commercially feasible, for it would necessitate either readjusting the camera-filters, which are an integral part of its optical system, or the use of completely different cameras whenever a company went from an artificially lighted stage to naturally lighted exteriors. A further complication is found in the general practice of using "booster" lights to supplement natural light outdoors. To be useful, such artificial light must mix imperceptibly with daylight.

The logical requirement in lighting—the one that the Technicolor engineers set up as a basic standard—would be that the artificial light must have as nearly as possible the spectral distribution of natural light at mid-day.

Certain other requirements, almost equally important, also existed. The light-losses inevitable to distributing an image over three films, and absorbing color-components of each with selective filtering, necessitated, especially at the outset, illuminants of high intensity. The requirements of talking pictures naturally presupposed a silent lamp, while the length of scenes in such pictures made flicker undesirable. The high sensitivity of the Technicolor process definitely called for flicker-free lamps.

Arc lighting seemed inherently more nearly suited to these requirements. Arcs are the most intense illuminants thus far available for motion picture lighting. Experience had shown how they could be silenced satisfactorily. Their radiation, while not then ideally matched to the daylight standard, even then seemed more nearly suitable and appeared capable of being made more so. On the other hand, the arcs then available, especially the fundamental "broadside" types, flickered badly. Since much scientific knowledge had been amassed since the design of these early lamps, however, it appeared hopeful that flickering could be overcome, or at least minimized. Accordingly the Technicolor Motion Picture Corporation commissioned the Mole-Richardson engineers to develop arc equipment suited to modern production in the three-color Technicolor process.

Since the fundamental lighting tool was the "broadside" arc, and since the then-existing "broadsides" were perhaps the least adequate of any existing units, the first lamp to be developed for three-color Technicolor cinematography was the "Side Arc" (*MR* Type *29*). This unit has been thoroughly described in previous papers, and little need be said in detail about it at this time. While similar in appearance to previous arc "broadsides," in design and performance it was revolutionary.

This lamp, though it operated at 40 amperes, used carbons much smaller than any previously used in arc "broadsides," and of different composition. These carbons were specially developed for the purpose by the National Carbon Company, and were known as 8-mm. Motion Picture Studio Carbons. The light radiated was an almost perfect substitute for daylight. The intensity of the light of these lamps was approximately 250 per cent greater than that of previous "broadsides."

Like previous arcs of the same type, the twin arcs were burned in series, with a ballast resistance. Instead of feeding simultaneously, as did most previous "broadsides," each pair of carbons was fed and controlled independently, to maintain the required voltage across its arc-gap. This naturally did much to eliminate flicker.

Fig. 2 shows a record of a test made with one of these lamps. It will immediately be observed that the characteristic slow loss of intensity, and the longer-period fluctuations of the previous type arcs have been eliminated, although considerable minor variation still remains. However, judged by the "broadsides" then existing, and by the arc spotlights then used, the Side Arc was considered a flickerless lamp. For overhead use a companion design (*MR* Type *27*) was made, mechanically the same, but mounted for overhead use. It was known as the "Scoop."

During the ensuing five years new and greatly improved types of arc spotlighting equipment (*MR* Types *65*, *90*, and *170*) have been brought out, as detailed in previous papers. Their performance was

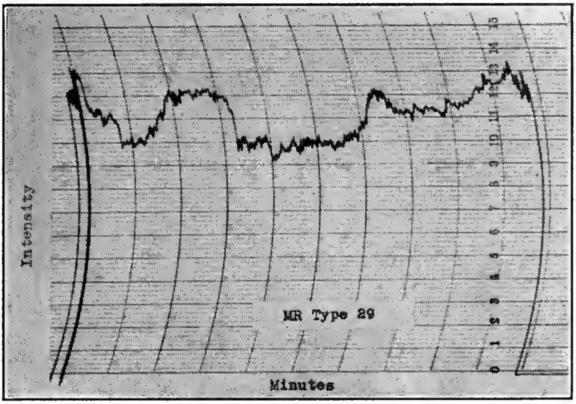

FIG. 2. Characteristic of side arc.

so improved that the imperfections of the Type *29* Side Arc became evident.

Two improvements in arc "broadsides" were deemed especially necessary: first, further reduction of flickering; second, longer burning periods without retrimming or other attention. The latter was of definite commercial importance, for much time was lost retrimming large batteries of arcs, especially the overhead Scoops, on large sets.

Those requirements have been met in a new unit, introduced only within the last two months. Known commercially as the "Duarc" (*MR* Type *40*), it embodies principles not hitherto employed in studio floodlighting arc equipment.

Research in connection with the design of high-intensity arc spotlights had indicated that in these rotary-carbon spotlights much of the flicker was eliminated by continuous feeding of the carbons. Therefore, in the Duarc the carbons are fed continuously. Each arc is, of course, fed and controlled individually.

Front and rear views of the Duarc are shown in Fig. 3, while the same lamp, without its covering, is shown in Fig. 4. It will be seen that each pair of carbons is fed by means of an endless chain; the carbon-holders are mounted on opposite sides of this loop in such a way that as one holder ascends the other descends. Each chain is

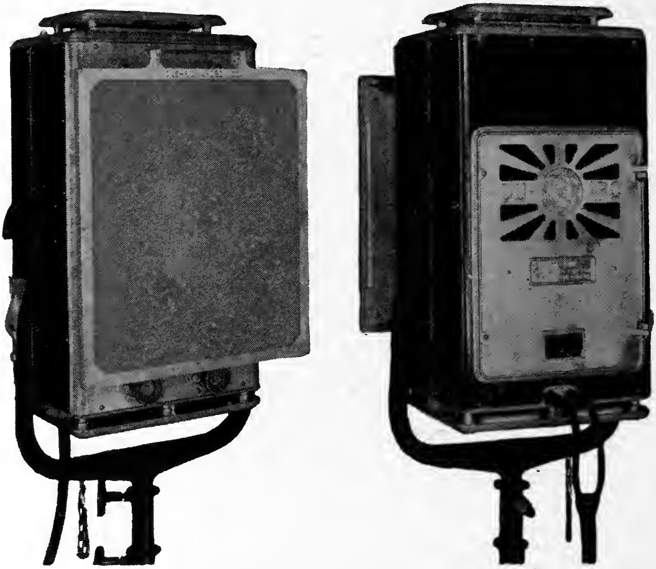

FIG. 3. Front and rear views of the Duarc.

driven by an independent, slow-speed electric motor, which requires only 600 revolutions to feed completely a trim of carbons. This requires over 2 hours.

The operation of these motors, and hence of the carbon feed, is controlled automatically by the resistance across each respective arc. This is done by an adaptation of the familiar Wheatstone bridge principle of balanced resistances.

The cycle of operation in the Duarc is as follows. When the master switch is thrown, current is fed into the motors, causing them to revolve sufficiently to bring the carbon electrodes into contact. As the current flows through these electrodes, the motors immediately and automatically reverse themselves, drawing the carbons apart to form the arc. When the carbons are so separated as to give the most satisfactory arc, the motors again reverse and drop to the very slow speed of 5 rpm.; then they feed the carbons continuously, at a rate in each case dictated by the resistance across the individual arc-gap, keeping the arc at its most favorable point until the carbons are consumed. Special 8-mm. positive and 7-mm. negative carbons have been developed for this lamp by the National Carbon Company.

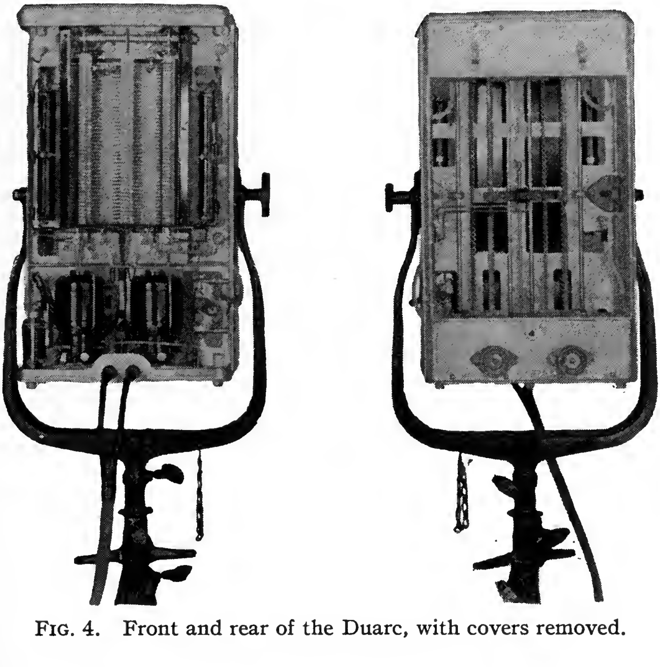

FIG. 4. Front and rear of the Duarc, with covers removed.

The practical result of these improvements is shown in Fig. 5. From this curve, made under conditions similar to those of the two previously shown for earlier types of "broadsides," it will be seen that while minor fluctuations still exist in the light-flux of the "Duarc," they average less than $^1/_6$ the magnitude of those of the Type *29* Side Arc, and less than $^1/_{25}$ the magnitude of the pre-talkie "broadside." They are scarcely evident, either visually or photographically. The several superimposed fluctuation patterns of greater magnitude and longer period, evident in the earlier lamps, have wholly disappeared. For all practical purposes it may be said that the long-sought goal of an absolutely flickerless arc "broadside" has at last been attained.

At this point may be mentioned one of the frequent instances where the performance concepts of the engineer and the practical comeraman do not agree. Measurements of the intensity of the light-flux radiated by the Duarc, made by Mole-Richardson and Technicolor engineers, indicate that there is very little difference between the intensities of the new Duarc and the older Type *29* Side Arc. This is as it should be,

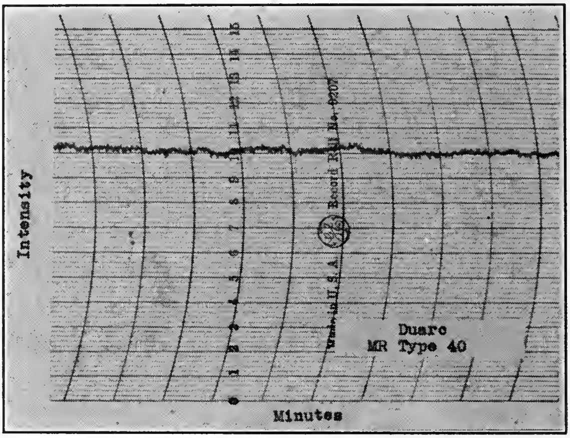

FIG. 5. Characteristic of the Duarc.

for increased uniformity of light-flux, rather than increased intensity, was the aim from the start.

Several cinematographers, on the other hand, after using the new lamp on production, have reported that they obtained better results with the new lamp, used 8 feet distant from the subject, than they did with the earlier Side Arc at half the distance.

A number of practical improvements in design have been possible by virtue of the radically different principles involved in the new unit. For one thing, earlier "broadsides" were generally fitted with a hinged cover over the upper part of the carbon-feed mechanism. This cover was almost invariably opened when the lamp was in use, for better ventilation. In the Duarc, asbestos insulation is applied behind the sheet-metal housing of the unit, and between the reflector and the mechanism. The latter, especially, insulates the mechanism from the heat of the burning carbon electrodes. More accurate knowledge of convection currents within such a lamp also dictated the design of ventilating ports and inner light-baffles. As a result, the operating mechanism of the Duarc is semipermanently sealed. In actual use there is no reason for opening this compartment save for rare major repairs which would, of course, never be made on the set.

The only manual operating controls are the main switch and two knobs which project from the front of the lamp, directly below the reflector. Each of these is connected to one of the two carbon-feed chains. Their purpose is to permit quick separation of the upper and lower carbon-holders when the lamp is to be retrimmed.

The carbon-holders are of the quick-release type, consisting of a split bushing compressed by a small coil-spring. The butt-ends of the carbons are simply inserted in these holders, after which the spring-loaded bushing holds them fast. No tools are needed for trimming or retrimming the lamp.

Another innovation is found in the diffusing screen and its mounting. Previously, because of the heat radiated from the arc, such diffusers had necessarily to be made of relatively narrow strips of glass, mounted in a frame that, for better ventilation, was simply hung rather loosely over the front of the lamp.

The diffuser used in the Duarc is constructed of a single sheet of translucent pyrex heat-resisting glass, mounted in a rigid cast-aluminum frame. This frame fits closely over the lamp opening. For trimming or inspection, the frame slides up and off a tongue-and-groove joint like a window-screen. Ventilation is cared for without the necessity of any opening between the lamp and the diffuser, while, of course, the use of pyrex virtually eliminates heat-breakage risks. The frame design prevents undesired "spilled light," including both visible and ultraviolet rays. The diffuser frame is hinged to open like a book, so that the diffusing screens may be replaced easily, while in the somewhat rare event that no diffusion is needed, a pane of clear pyrex may be used. Hooks are provided by which additional diffusing media, silks and the like, may be hung over the regular diffuser as desired by the cameraman.

The Duarc is a twin-purpose unit. Ordinarily it is mounted on a conventional three-lift pedestal for floor use, allowing a wide range of adjustment from very low to very high positions. Alternatively, special chain hangers are available by which the same units may be utilized either singly or in banks for suspended overhead units, replacing the older "scoops" previously referred to.

The fully automatic operation of the Duarc gives a very practical advantage for this latter use. Much time is ordinarily lost with "scoops" of conventional type when used on large sets, due to the relatively frequent need for retrimming. Such units are suspended from the roof-trusses of the stage, directly over the set. They are in most cases quite inaccessible. Retrimming means that the lamps must be lowered to the floor so that the electricians can get at them; in only rare instances it is possible to reach them by ladders. In any event, reaching and retrimming large batteries of such lamps is a serious interruption to shooting. In a modern production, where overhead costs may mount up at several hundred dollars an hour, such delays are not only inconvenient, but expensive.

The Duarc, however, has an unusually long burning period, as it burns both carbons down to stubs less than three inches long. Under both tests and practical operating conditions, these lamps have burned without attention for periods in excess of 2 hours, on a single trim.

In practice, this means that with only reasonable care to turn the lamps off during nonproductive periods between takes, the Duarcs, used as overhead lamps, may be used without retrimming for not less than half a day. Under some conditions, where production for other reasons is slow, the lamps may well operate for a full day on one trim. In any event, no shooting time need be lost, as the lamps can be retrimmed at the noonday halt, and need no other attention during the day.

Since the lamps automatically strike their arcs whenever the current is switched on, they may be operated either singly or in banks by remote-control switches. An interesting fact revealed in recent tests of these lamps is that by the use of a conventional dimming rheostat it is possible to fade these lamps in and out with no appreciable flicker—a valuable asset in certain types of dramatic effect-lightings. Since the Duarc strikes its arc almost noiselessly, and settles down immediately to steady burning with no initial period of abnormal strength, these lamps may also be switched on or off as required in the middle of a scene.

It is evident that in the approximately 26 years since the introduction of the industry's first arc "broadsides," the design, performance, and operation of these fundamental units have made genuine progress. Yet during much of the period, "broadside" design remained actually almost static, as the more spectacular spotlighting units were introduced and developed. The original principles of "broadside" design, borrowed from other fields, had seemed good enough. Only when more scientific methods of design were applied, together with a willingness to cast aside previously conventional practices and develop lamps wholly intended for motion picture use, was radical progress made. The same has been true of spotlighting equipment—as witness the advances made when previously conventional ideas were supplanted by the modern Fresnel-lens spotlight designs, originated solely for motion picture lighting—and the same must be true of virtually every other phase of equipment design for motion picture apparatus. Having attained the status of a major scientific industry, the motion picture should no longer be satisfied to borrow and adapt, but can strike out for itself, designing and using equipment planned exclusively for the special requirements for making better motion pictures.

DISCUSSION

DR. GOLDSMITH: How close can you bring a broadside like that to an actually recording microphone without the microphone picking up anything from the motors during automatic feeding?

MR. MOLE: We have placed this new lamp within six feet of the microphone and have found it very satisfactory. It depends entirely on the particular dramatic effect that you are trying to accomplish in recording.

A short time ago, in a picture in which Shirley Temple was the principal artist, these broadsides were used and we were confronted with a problem of recording the scene in a very low key. Nevertheless, we were able to use these lamps within about six feet of the microphone with satisfactory results.

MR. FINN: What is used for the mat surface diffuser?

MR. MOLE: The diffuser, which is placed in front of the lamp, is pebbled and sandblasted glass. It gives a soft, diffused light on the subject. The reflector is chromium.

DR. GOLDSMITH: So you get your efficiency of reflection from the chromium-plated reflector and depend on the diffusers for the quality of the light, that is, the softness or diffusion?

MR. MOLE: Yes.

DR. GOLDSMITH: Have you ever tried to any extent successfully using a hard spot with a diffuser on it, when you have to place the lights quite a way off from a set, and yet desire controlled diffusion?

MR. MOLE: Sometimes they use a 150-ampere Sun arc, with a diffusing glass in front of it, to give a large diffused surface.

SOME STUDIES ON THE USE OF COLOR COUPLING DEVELOPERS FOR TONING PROCESSES*

K. FAMULENER**

Summary.—*Some experiments on the toning of motion picture positive film by the methods of direct dye coupling color development, which have heretofore been applied principally to natural color processes, are described.*

Also methods of obtaining a wide range of colors and of controlling contrast are discussed.

During the past year there has been a revival of interest in the toning of motion picture positive film. Several productions have appeared that were toned throughout and others in which certain sequences were colored. The tendency in the application of these tones has been to obtain a subtle coloring of the image rather than the blatant results that in previous years were associated with toning processes.[1] In fact, the recent productions have used browns and blues to obtain blue-black or warm black tones rather than definite blues and browns.

Essentially the process of toning motion picture film consists of converting the silver image to, or replacing it with, a colored compound. In this respect toning differs from tinting since only the image is colored, the highlights remaining clear. There are many methods available for obtaining these toned images but the majority fall into a few general classes.

(*1*) *Metallic Toning*.—(*a*) The conversion of the metallic silver to a colored silver compound. The common method of obtaining a sepia by sulfide toning is an example of this.

(*b*) Replacement of the silver image with a colored metallic compound, frequently a ferrocyanide. Iron and uranium toning are the outstanding examples; iron producing the familiar blue ferriferrocyanide while uranium yields the reddish-brown uranium ferrocyanide. Recently, toning with uranium has been a more popular method of obtaining warm blacks than has the older sulfide method.

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* Presented at the 1938 Spring Meeting at Washington, D. C.; received May 26, 1938.

** Agfa Ansco Corp., Binghamton, N. Y.

(2) *Dye Toning.*—(*a*) The conversion of the silver image to a salt that will mordant basic dyes. This method is well known and has been used for some time. The image is generally converted to either silver iodide or uranium ferrocyanide. Both these compounds have strong mordanting characteristics. The difficulty with this method has been to obtain an image in which the dye tone is not contaminated with the color of the mordanting salt and, secondly, to obtain basic dyes with sufficient color range and stability.

(3) *Differential Hardening Methods.*—(*a*) The silver image is treated with a bleach and the products of the reaction between this bleach and the silver hardens the adjacent gelatin so that dyes will be differentially absorbed. This has had comparatively slight application to monochrome toning but has found some application in natural color processes.

(*b*) The silver image is treated with a bleach, the products of the reaction hardening or tanning the adjacent gelatin. The unhardened gelatin is then washed away with warm water and the remainder dyed. This is used in the production of matrices for polychrome imbibition work but has found little application as a monochrome method.

(*c*) The silver image is treated with a bleach and the product of the reaction dissolves the adjacent gelatin which is washed away and the remainder dyed. This process has found little application and is of interest merely because it complements the tanning processes. In this case a positive dye image will be obtained from a negative silver image.

(4) *Color Development.*—(*a*) Color development with color formers. Here, the oxidation product of the developing agent is an insoluble dye which is coprecipitated with the developed silver image. Examples are leuco indigo and leuco thioindigo.

(*b*) Coupling color development in which the oxidation products of the developing agent couple with a compound that may be present either in the developer or in the emulsion to give a comparatively insoluble dye. These dyes are frequently, but not necessarily, of the indophenol or indamine class.

In the previously outlined methods, excepting color development the film must first be developed to a black-and-white image before it can be colored. In most cases where direct toning baths of the ferrocyanide type are used, the film is developed, fixed, washed, and dried normally, that is, as a black-and-white print and then later toned, washed, and dried.

While the outline given above does not touch all of the available methods for producing a colored photographic image, most of the processes in actual use are variations of the above systems. The methods described under the heading of color development have in the past been applied almost exclusively to two or three color processes. However, they offer several advantages for the production of toned monochrome images as well and it is the latter of these methods, the dye-coupling method, that is to be discussed. The obvious saving through such a system is the elimination of the multiplicity of operations generally associated with toning. Here it is only necessary to develop the film, fix it, wash it, and dry it. This, of course, yields an image consisting of metallic silver and a relatively insoluble dye. In most natural-color processes where color development is used, the final result is a pure dye image, the silver being removed with a bleach such as Farmer's reducer after color development. However, in the case of monochrome color development the silver is left in the film. This does not greatly detract from the color values since the silver contributes most to the high densities where colors normally are not brilliant.

In 1912 Fischer patented[2] and in 1914 Fischer and Siegrist published[3] the process of producing colored photographic images by the use of dye-coupling development. In his patent Fischer outlined the chemistry of the process and covered quite broadly the type of compounds that could be used. The developing agent was a paraphenylenediamine or paraaminophenol; the specific compound mentioned in his example being diethylparaphenylenediamine, otherwise paradiethylaminoaniline. The coupling agents used were phenols such as alpha napthol, amines, or in fact compounds having an active methine group such as acetoacetic ester, benzyl cyanide, and phenylmethylpyrazolone. An excellent review of their work as well as that done more recently by the Schinzel brothers[4] has been given by Friedman.[5]

When the problem of dye-coupling development of cine positive was undertaken diethylparaphenylenediamine was used as the developing agent and alphanaphthol as the coupler to produce a blue image; acetoacetanilide, and later dichloracetoacetanilide to produce a yellow image, and phenylmethylpyrazolone to produce a magenta image.

Certain characteristics of the process became apparent immediately. One was that a developing time approximately double that used for normal black-and-white positive work is necessary to obtain a contrast and density approaching that of black-and-white positive development. Another was that the usual hypo, acetic acid, sulfite, alum hardening, and fixing bath could not be used without bleaching the dye image. This was most noticeable with the yellow image and to a less extent with the blue and the red. It was found that a special hardening bath had to be used. This consisted of hypo, sulfite, and alkaline formaldehyde. It was necessary to use the formaldehyde in in order to harden the film sufficiently to withstand machine processing.

Two problems had to be overcome before this process could be said to have any value. First, methods of blending the colors to obtain intermediate tones had to be worked out, and, second, the contrast of the process had to be increased before it could be applied to motion picture positive work.

Several methods of blending colors have been arrived at. It was found that various coupling agents could be combined in the same bath and intermediate tones would result. However, the ratio of the concentration of the various coupling agents present did not bear any direct relation to the color that would be formed. For instance, in producing a green far more dichloracetoacetanilide than alpha napthol had to be used.

While the combining of coupling agents produced fairly good results, another and more flexible method was worked out. This consisted of using three independent color-forming developer solutions: a magenta, a blue-green, and a yellow. By developing the film in these solutions, almost any color desired could be obtained. The film could be either completely developed in one of these solutions or started in one and completed in a second; or even started in one, carried on in a second, and completed in a third. Then, by varying the time of development in each of the solutions used, the color tone of the final positive could be controlled to make a long range of colors available under reproducible processing conditions. This method of obtaining a range of colors seems particularly desirable when applied to machine processing, since with three solutions in the developing line a change-over from any color to any other color is possible without compounding new formulae. In a machine thus adapted to color development it is only necessary to vary the number of strands immersed in each color developer. As an example a green image is formed by developing the positive for $2^1/_2$ minutes in the blue-green color developer and then continuing in the yellow developer for $4^1/_2$ minutes. It is interesting to note that equal times of development in two developers did not produce the same hue when the order of development was changed. For instance, by developing for $3^1/_2$ minutes in a blue developer and then an equal time in a magenta developer, a redder image was obtained than if development was started in the magenta developer and completed in the blue developer. This effect was to be expected since we know that when a film is placed in a developing solution there is a certain inertia period before the image begins to become visible. Since this inertia has to be overcome in the first solution and not in the second solution, we would expect the tone of the second solution to predominate and this has been found to be true.

Either of the methods outlined above, that is, the combination of two or more color-forming compounds in the same solution or sequential development in three color developers producing subtractive primaries can be used and have been used to produce a variety of tones.

The remaining problem was to obtain sufficient contrast for positive work. This was attacked in three ways. First, the inclusion of a high-

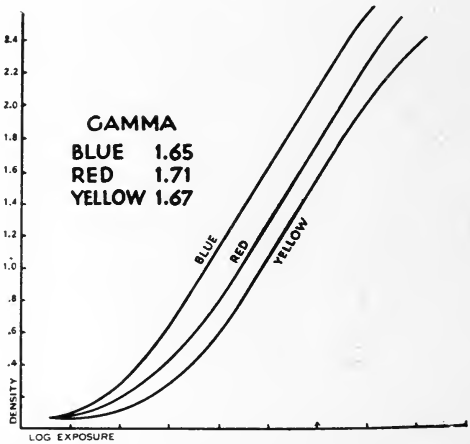

FIG. 1. Two-bath color-coupling development.

contrast developing agent in the coupling developer solution was tried. Hydroquinone proved quite satisfactory for this purpose and did not interfere greatly with the color formation since its action was to build up the heavy densities which, even normally, did not show brilliant colors. The use of hydroquinone was applied in two ways. The first consisted merely in adding hydroquinone to the single solution developer containing both a developing and a coupling agent. This yielded quite satisfactory results.

The second method made use of a two-solution developer in which the first solution consisted of hydroquinone, diethylparaphenylenediamine, a weak alkali, and bromide; and the second consisted of the coupling agent together with a strong alkali and bromide. It was felt that this two-solution system offered several advantages. The keeping qualities of the two solutions were very good and uniform results could be obtained merely by replenishing the first solution. Also, a two-solution system did not unnecessarily complicate the development process since, for the production of different colors, the same first solution was used followed by the appropriate second solution. Moreover, with a two-solution system an accurate control of the time in each solution is not nearly as important as it is when a single developer is being used. In most cases the reaction goes to completion and the time-gamma curve flattens out, resulting in a considerable processing latitude. In Fig. 1 are shown sensitometric curves obtained by developing Agfa Cine positive film in three different color-forming developers containing hydroquinone. For all these curves the developing time in the first solution is three minutes and in the second, five. The temperature of the solutions is held constant at 70°F.

A third method that has been used to control the contrast and one that is more of experimental interest than practical value follows: The positive was developed to a normal black-and-white silver image, fixed, and washed as usual. It was then bleached in a solution that converts the image to a silver salt and flashed with white light. The film was then re-developed in the color-forming developer. This gave excellent results but was, of course, a long process quite similar to dye toning and other common toning procedures. As such, it offers but slight advantage over the commoner methods. Of course, it has the general advantage of all these color development methods in that a wide range of tones is possible. Also, the contrast presented no difficulty since the reaction goes to completion in the second development and the contrast obtained through the first, *i. e.*, black-and-white development, was maintained throughout the rest of the process.

Following the presentation of the paper a demonstration reel made up of scenic material color developed to appropriate tones was shown, to demonstrate the result of direct color-coupling development. Five different solutions were used to obtain the five tones shown. Alpha naphthol, dichloracetoacetanilide, and phenylmethylpyrazolone were the couplers. For the red and red-brown tones phenylmethylpyrazolone and dichloracetoacetanilide were combined; different proportions being used to obtain the two colors.

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[4] SCHINTZEL, K. AND L.: "Dreischicht-Farbenphotographie durch gleichzeitige Dreifarbenentwicklung," *Das Lichtbild*, **12** (1936), p. 919.

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DISCUSSION

MR. CRABTREE: When mixed couplers are used in the single developers does not the hue change with exhaustion?

MR. FAMULENER: We did not run any direct exhaustion tests. It is possible that that would take place, but the problem can generally be handled by raising the concentration of the coupling compounds beyond the exhaustion limit one would normally expect, allowing the developing agent rather than the coupling agent to regulate the exhaustion.

MR. CRABTREE: Another difficulty, of course, is in being sure that the projection contrast is correct by the time you have got the hue that you want.

MR. FAMULENER: This problem is handled as in black-and-white work, by the proper formulation of the developer and the determination with light-test strips of the correct printing exposure.

MR. CRABTREE: And assuming that you are replenishing correctly.

MR. FAMULENER: In the course of the work we did make some sensitometric studies, but we felt sensitometry would tell us little because the psychological effects of the color on the screen are more important to the observer than the theoretically desirable contrast obtained on a sensitometric strip.

MR. PRESGRAVE: Is it possible to do double-toning in this way, by a combination of developing black-and-white first?

MR. FAMULENER: We did no work on that. Undoubtedly it could be worked out, but I do not care to give an answer without doing further experimental work.

MR. TOWNSLEY: Have you done any work on the negatives?

MR. FAMULENER: Are you thinking of using it for fine-grain development? We did not run any exhaustive tests, and I do not believe there is any reason to believe that you would get any finer grain with dye-coupling than by using an ordinary paraphenylenediamine developer. If you bleach out the silver and use only the dye as the image the contrast drops so low it is difficult to get a printable negative.

MR. TOWNSLEY: I will have to disagree with you. I have done some work along that line, and have had surprisingly good results.

MR. FAMULENER: We tried it and had difficulty getting a high enough contrast to get a printable negative.

MR. CRABTREE: I think that if there is any diminution in graininess it is obtained at the expense of loss in definition, due to wandering of the dye.

MR. FAMULENER: That is generally true, particularly when the couplers that we mentioned are used, because they are slightly alkali soluble, and will wander.

MR. TOWNSLEY: It is perfectly possible to get less graininess but as you say, it is at the expense of contrast. Less graininess does not necessarily mean an increase in resolving power.

THE METRO-GOLDWYN-MAYER SEMI-AUTOMATIC FOLLOW-FOCUS DEVICE*

J. ARNOLD**

***Summary.**—During recent years an important problem in major-studio cinematography has been that of following focus. Due to the shallow depth of field in modern lenses when used at maximum apertures, it is necessary to alter the focus frequently during the filming of a scene. In moving-camera shots, which are being used with increasing frequency, this problem is naturally aggravated, since both camera and players may move. The use of "blimped" cameras for sound pictures also aggravates the cameraman's problems, as finder parallax is greatly increased by placing the finder outside the camera "bungalow."*

At the Metro-Goldwyn-Mayer Studio these problems have been simplified by the use of the semi-automatic follow-focus device. This consists of a finder which is both focused and pivoted to correct for parallax as the lens is focused. Individual cams coordinate the finder movement with the characteristics of any given lens.

During recent years the twin problems of following focus and of finder parallax have assumed major importance in studio camerawork. Whereas only a few years ago the camera was usually stationary, and the movements of the actors circumscribed to the plane of best focus, today both camera and actors move freely around and through the set, often in conflicting directions and with little apparent consideration of the focal limitations of yesterday. It is no exaggeration to state that present-day camera crews, with standard production sound camera equipment, are daily called upon to make "follow shots" that less than a decade ago would have been considered the province of the Akeley camera specialist.

The difficulty of making these shots has, of course, been increased by the restrictions imposed by the use of sound. Where previously the finder was mounted close to the photographing lens, today the camera must be encased in a sound-proof "blimp." With a blimped camera, two courses are possible, neither of which is wholly satisfactory. If the finder is mounted in its usual place, directly on the

* Presented at the 1938 Fall Meeting at Detroit, Mich.; received October 26, 1938.

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

camera, it must be enclosed within the blimp, and is accordingly difficult to view accurately. If the finder is mounted more conveniently outside the blimp, its separation from the camera lens is nearly doubled, and parallax becomes a serious problem.

Several years ago these related problems came under practical consideration at the Metro-Goldwyn-Mayer Studio Camera Department. It was determined that if they could be solved the necessary research would pay concrete dividends in speedier, more efficient production and in fewer retakes.

Since no great progress appeared likely in the realization of a genuinely silent camera, it was recognized that sound-proof blimps must be considered as a permanent factor. For maximum production convenience, it was decided that finders should be mounted accessibly outside the blimps.

The problem thus became one of coördinating the focal adjustments of the camera and finder lenses, and at the same time pivoting the finder automatically so that at all settings the fields covered by the two lenses should coördinate, notwithstanding that they must be over 9 inches apart. Automatic, virtually fool-proof operation, and durability were necessarily aimed at, despite the inevitably precise nature of the mechanism and adjustments involved.

These aims have to a great extent been realized in the Metro-Goldwyn-Mayer semiautomatic follow-focus finder, which has been fitted to all of the studio's forty-odd production cameras, and in daily use for the last two years (Fig. 1). The device is not yet fully automatic, but involves the use of removable cams matched to the characteristics of each lens used; but within this limitation the device has proved so accurate that the operative cameraman can depend on the focus and position of his finder image to indicate corresponding properties in the photographed image.

The foundation of the device is an erect-image optical finder of essentially conventional type. The optical system and prisms used in this finder have, however, been designed and ground by the studio's engineers, and provide a finder image of considerably greater brilliance and clarity than usual.

Obviously, if the finder image is to be sufficiently accurate to serve as a precise visual monitor for the camera image, the focusing movement of the finder lens must be straight in and out, rather than rotating. This is provided by interposing a tubular slip-joint between the finder lens and the finder proper. This joint carries no load, however.

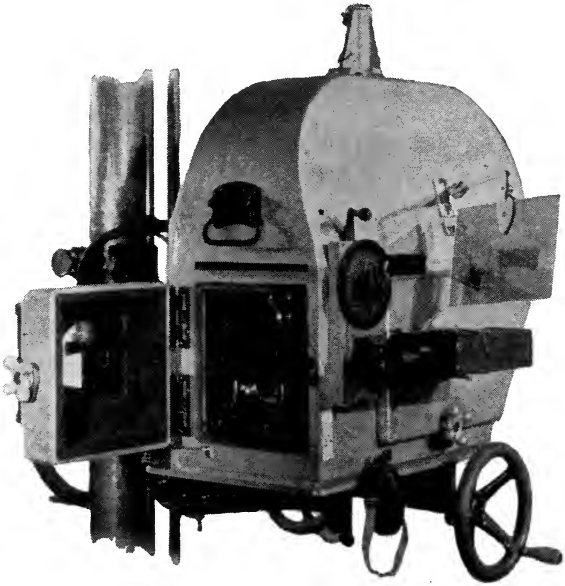

FIG. 1. Camera "blimp" with Metro-Goldwyn-Mayer Semi-Automatic Follow-Focus Finder attached. Focus is controlled from calibrated dial above Finder.

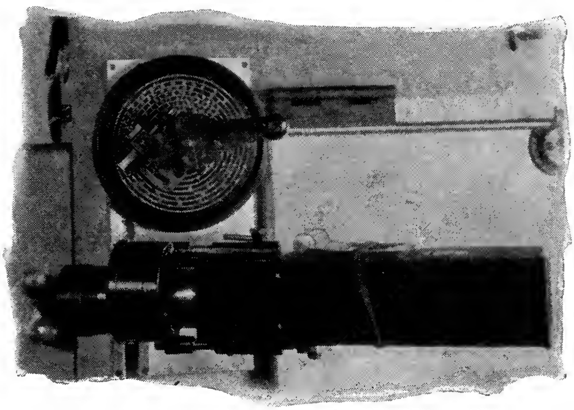

FIG. 2. Closer view of Metro-Goldwyn-Mayer Semi-Automatic Follow-Focus Finder. Note manner in which finder-lens moves straight in and out to focus, and dial calibrated for all commonly used lenses.

The load is taken up by two rods attached to the lens-mount of the finder, and sliding in long friction bearings on the top and bottom of the finder housing.

The camera lenses are conventionally mounted. Following the usual practice, the lens-mounts are fitted with precision gear-teeth which mesh with a train of gears connected to the focusing control outside the blimp. In the lenses used on Metro-Goldwyn-Mayer cameras, the teeth of the gear-rings on the lens mounts are cut with special precision, to eliminate backlash.

The gear-train with which these gears mesh leads to a vertical shaft, the upper end of which is connected to the focusing control on the outside of the blimp, while the lower end actuates the pivoting and focusing of the finder.

These latter movements are coördinated with the focusing of the lens by means of a roller-tipped lever working against a cam. The cams are made of hardened tool steel, and ground to the precise curvature that matches the characteristics of the individual lens with which the cam is to be used. The cam is in the form of an approximately triangular piece of flat metal, and is held rigidly in place on hardened dowel-pins by spring-loaded fasteners. Each cam is matched to an individual lens, and is considered as a permanent accessory of that lens. Since the other parts of the device are standardized and built to the highest precision standards, however, any lens and cam may be used with equal accuracy on any camera equipped for this system.

It will be evident that since modern studio camerawork makes use of lenses of many focal lengths ranging from 24 mm. to $4^1/_2$ inches, which if conventionally mounted would require different amounts of rotation to cover the full range of focal adjustments, the finder-synchronizing cams for some lenses might attain impractically large proportions. This has been eliminated by using lens-mounts carrying focusing threads of differing pitches for the various lenses. The 24-mm., 35-mm., and 40-mm. lenses use a 6-pitch thread; the 50-mm. and 75-mm., a 4-pitch thread; and the 4-inch and $4^1/_2$-inch a $2^1/_2$-pitch thread. Thus over a range of focal settings between infinity and 2 feet, a 24-mm. lens requires less than half a revolution of the controlling handle, while for a similar range a $4^1/_2$-inch lens requires more than a full revolution of the handle. This has proved a convenience for the assistant cameraman, who usually operates the device when following focus.

The scales for all commonly used lenses are engraved on a single focusing dial mounted on the left-hand side of the blimp directly above the finders (Fig. 2). A movable indicator on the control handle obscures all calibrations except those for the lens being used, minimizing the risk of errors. A duplicate dial and control are placed on the right side of the blimp for use in cramped quarters, when the assistant can not conveniently operate the control from the left side.

Whenever lenses are removed from the camera, or placed thereon, lens, focusing control, and finder mechanisms must all be brought to a marked neutral point—infinity focus for all lenses—before the lens can be removed or inserted. The lever working against the synchronizing cam is spring-loaded, and automatically bears against the cam. As there is no other mechanical connection between the finder mechanism and the camera-focusing mechanism, the finder may be removed from the camera whenever the director or cinematographer may wish it for use in lining up the next shot. Immediately the finder is put in place on the blimp, however, lens, focus-control, and finder form a single mechanical unit, and operate in exact synchronism. Probably no mechanism of moving parts can ever be constructed or maintained with such perfection as to be wholly without play; but in this device the play is reduced to proportions that are too minute to introduce appreciable error into the result on the screen. In no portion of the mechanism do the tolerances exceed 0.001 inch, while in some components, such as lens-mounts and gearing, tolerances as close as 0.0005 inch are maintained.

In practice this makes it possible for the cameraman to depend upon the indications of the finder as to focus and scene alignment without the necessity of opening his blimp, racking over the camera and studying the camera image on the ground-glass. The assurance this gives to the camera crew will be obvious. The operative cameraman, simply from what he has seen through his finder during the making of the scene, is able to state with confidence whether or not the focus and framing of even the most intricate follow-focus or moving-camera shot was correct. Being able to discover such errors immediately on the set, rather than in the projection room the following day, has increased production efficiency and has in several instances resulted in notable economies.

INDEPENDENT CAMERA DRIVE FOR THE A-C. INTERLOCK MOTOR SYSTEM*

F. G. ALBIN**

Summary.—*The a-c. interlock motor system used to drive cameras, recording, re-recording, and projection machines in synchronism has special advantages in such applications as driving projector and camera for projection background process. The system is generally started from a central point, such as the recording room, and the cameraman does not have means for running his camera independently as is so often required for photographing slates, exposure tests, and silent scenes.*

An addition has been made to the system to give it the advantages of the synchronous motor system: namely, the facilities enabling the cameraman to operate his camera at will at regular speed. The addition consists of a set of relays with control circuits, and a frequency-changer and field-exciter set. Normally, the camera motors are connected to the common interlock system through the relays. If, however, the button provided at the camera is depressed, the pilot relay operates the main relays which transfer the camera motor circuit to the bus of the frequency-changer and field-exciter set. The camera motor is operated as a true synchronous motor. One phase of the rotor is short-circuited, and the remainder is excited with direct current and serves as the field. The three-phase stator is supplied with three-phase power of a frequency that will cause the motor to run at the required speed, the same speed as when driven with the interlock system.

The power developed by the a-c. interlock camera motor when operated as a synchronous motor is approximately the same as under normal operating conditions. The acceleration is typical of small synchronous motors when the power supply is suddenly connected. The pull-in torque is superior to the slotted-rotor type of as-synchronous motor. The operation of the system is smooth, simple, and efficient, and has, after several years of use, proved its value.

In the production of motion pictures, several types of motor systems for driving the cameras, recording machines, and sound or picture projection machines in synchronism are in general use. Among these types are the following with a brief description of their characteristics.

(*1*) *The a-c. interlock or selsyn system, wherein the primary and secondary winding of each motor is connected in multiple with the re-*

* Presented at the 1938 Fall Meeting at Detroit, Mich.; received October 17, 1938.

** United Artists Studio, Hollywood, Calif.

spective windings of all the other motors of the system, and the primaries are excited by alternating current.

The secondaries of all motors are thereby electrically interlocked, and mechanically driving one motor of the system, called a distributor, will cause all of the others to rotate at the same (electrical) speed.

The interlocking torque decreases with increase of speed, diminishing to zero at synchronous speed for the frequency of the excitation potential. The usual operating speed is approximately $^2/_3$ of synchronous speed.

The merit of this system is that all motors will remain interlocked at all operating speeds, including zero or standstill.

However, any motor depends upon the distributor, and thereby can not be operated independently at will. The inertia of the system is large in comparison with that of the motor required for the camera, and the acceleration is lower than desired for operating a camera alone. A small motor, such as a camera motor, may be connected suddenly to the distributor or system already running at full speed without damage, except for introducing a surge in the system speed. The camera motor then runs as an induction motor with torque toward the synchronous speed. At interlock speed it should fall into step with the system, which it often fails to do, but runs with a fluctuating speed greater than interlock speed. Thus, operation on and off a running distributor is not reliable or completely satisfactory.

FIG. 1. Non-synchronous distributor.

(2) *The synchronous motor system wherein by proper choice of frequency of power supply and gearing ratio or both, the load may be driven at the exact speed desired.*

Two or more motors on the same power-supply line run in synchronism after arriving at the speed synchronous with the line frequency. Thereby the cameras, recorders, *etc.*, may be run in synchronism, and the system is highly satisfactory when it is not important to be interlocked from zero speed or standstill position.

(*3*) *Direct-current motors with a-c. interlocking potential obtained from the armatures* via *slip-rings and brushes, as commonly used for portable systems.*

The frequency of the interlocking potential is the product of the speed and the number of poles. At standstill position, therefore,

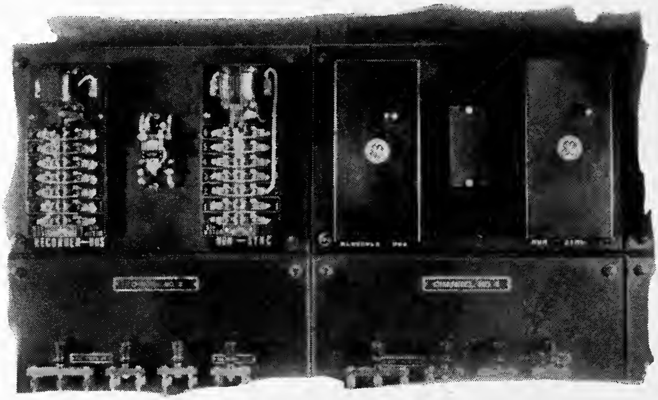

FIG. 2. Relays for transferring stage motor leads from normal recording motor system to non-synchronous distributor bus.

there is no interlock torque, and in this respect, this motor system is similar to the synchronous motor system.

For certain purposes, such as for re-recording, photographing of projected background, *etc.*, the a-c. interlock system is indispensable. The ability to set the several machines such as camera, projector, or playback on start marks at standstill and run them exactly in synchronism from the start, is invaluable, and possible only with the a-c. interlock system.

To minimize the variety of motors in use, involve only one system for all types of photography and sound recording, except trick work, and for general economic reasons, the a-c. interlock system, together with a means for driving the camera independently at will, is the conception of an ideal motor system.

Alternating-current interlock motors have a 3-phase winding on each stator and rotor, constituting the primary and secondary of a transformer. The turn-ratio is approximately unity, so that either may be used as primary. If one winding is excited by a 3-phase supply and the other connected through external circuits, the speed will approach the synchronous speed of any typical induction motor:

$$S = \frac{f \times 60}{P}$$

where S = Speed in rpm.
f = Frequency of 3-phase power-supply, in cps.
P = Pairs of poles.

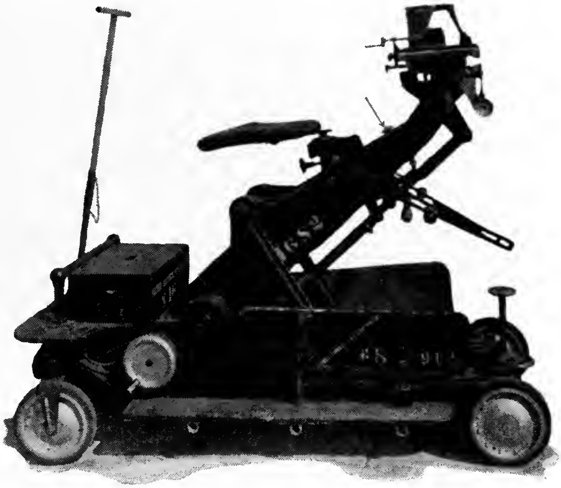

FIG. 3. Showing location of switch with respect to the camera (arrow indicates switch).

As pointed out in a previous description of the a-c. interlock system, the motors are operated at approximately $^2/_3$ synchronous speed, and so geared as to drive the camera normally. By operating the motor synchronously with a frequency $^2/_3$ as great as that used for the interlock system, the same speed is attained as previously.

To convert the motor into a synchronous motor, one phase of the leads to the secondary is short-circuited, and from this common tie a large condenser is connected to the third lead. Thus a low-impedance path for a-c. secondary current is provided in all phases, and the motor has torque as a closed secondary induction motor.

A d-c. potential is applied across the condenser terminals sufficient to pass an exciting current through the secondary windings equal to the normal rms. value of the secondary current. The field thus formed is the resultant of the currents through the windings of two phases.

Fig. 1 is an illustration of a machine, called a non-synchronous distributor, designed to supply the required 3-phase power at the reduced frequency, and the d-c. excitation power. The capacity of this machine is sufficient to supply the entire lot, or six production companies. It consists of a geared slotted-rotor motor driving a frequency-changer at a speed which reduces 60 cps. to 40 cps. Connected

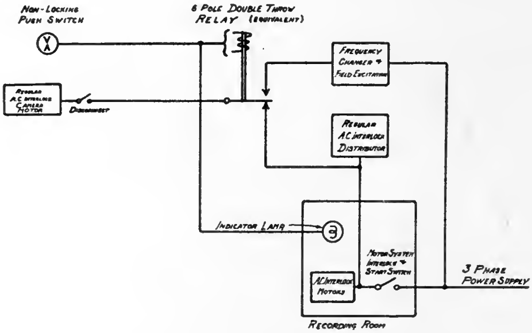

FIG. 4. Diagram of independent camera motor drive.

to the high-speed shaft of the motor is a small compound-wound d-c. generator, producing 30 volts.

Not illustrated, is a box containing the condensers and a step-up transformer. It has been found beneficial to increase the potential of the 40 cps. supply to the same value as usual for 60 cps. with a corresponding large current. However, when the field is proportionately increased so as to restore the power-factor of the current to unity, the current is well within safe limits, especially in view of the intermittent duty of the motor. The torque of the motor under this condition is about equal to the maximum provided when operating as an a-c. interlock.

Fig. 2 shows the relays used to transfer the stage motor leads from the normal recording motor system to the bus supplied by the non-synchronous distributor. The small relay is a pilot operated by a non-locking switch at the camera. Fig. 3 illustrates the position of this switch with respect to the camera.

One large relay connects the load to the recording motor system, and the other to the non-synchronous distributor. These two relays are electrically interlocked so as to insure against simultaneous closure of both relays. The pilot relay selects the relay for the circuit desired. Fig. 4 is a schematic diagram of the entire system.

For silent shooting, when no sound recording or other equipment is involved, the output of the non-synchronous distributor is trunked directly to the stage without relays, and the a-c. interlock motor is used on the camera, replacing the "wild" motor and providing superior speed regulation, quieter operation, and general simplification of operations.

After several years of use of this motor system, it has proved completely satisfactory, highly efficient, and superior to any other system for general requirements of the several types of shooting used in producing motion pictures in a studio.

SILENT WIND-MACHINE*

F. G. ALBIN**

Summary.—*The machines generally used on the motion picture production sets to create wind for pictorial effects are large motor-driven propeller fans mounted on floor stands. The noise-level at high velocities is so high that satisfactory sound recording of the scene is practically impossible. The size and shape require that the machines be placed at such distance that the directivity is not readily controllable. The additional hazard to sound recording of causing wind around the microphone always exists and, commonly, the desirable microphone placement is sacrificed in order to avoid the wind.*

A new wind-machine has been adopted and use for several years with a great improvement realized. It is a centrifugal blower, such as is commonly used in ventilating systems. The air is conducted by canvas ducts to the set where the scene is being enacted. The ducts are equipped with variously shaped fittings and nozzles so that the air stream may be directed as desired.

It has been found expedient to locate the blower outside the stage building and enter the duct through a special portal. Thereby the greatest noise source, the blower, is remotely located and insulated from the scene by the walls of the stage building. Furthermore, it incidentally serves as a ventilator, supplying fresh air to the scene. Measurements of noise-level for various wind velocities indicate improvements up to 70 decibels in noise reduction. Thus sound recordings of scenes requiring wind are made possible where heretofore it was necessary to photograph the scene without sound and provide synchronized sound subsequently.

Many scenes in the production of present-day motion pictures call for the creation of artificial wind for pictorial effects by the use of wind-machines. The popular types of machine are similar to those illustrated in Figs. 1 and 2. These are propellers driven by motors mounted on floor stands. Fig. 1 is an airplane type of propeller with two blades. Its diameter is about 4 feet, and it operates at speeds up to 1200 rpm. Fig. 2 is an improved 3-blade screw type propeller. Its diameter is also about 4 feet, and it operates at speeds up to 600 rpm.

Wind-machines, in general, have long been obnoxious to the sound recorders; first, because of the noise of the machines, and, second, be-

* Presented at the 1938 Fall Meeting at Detroit, Mich.; received October 17, 1938.

** United Artists Studio, Hollywood, Calif.

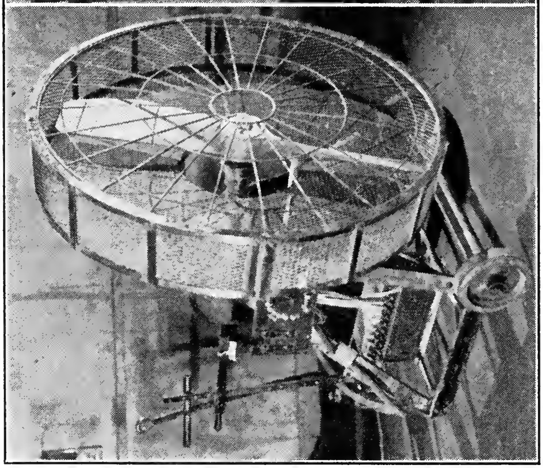

FIG. 1. Airplane type of propeller, with two blades.

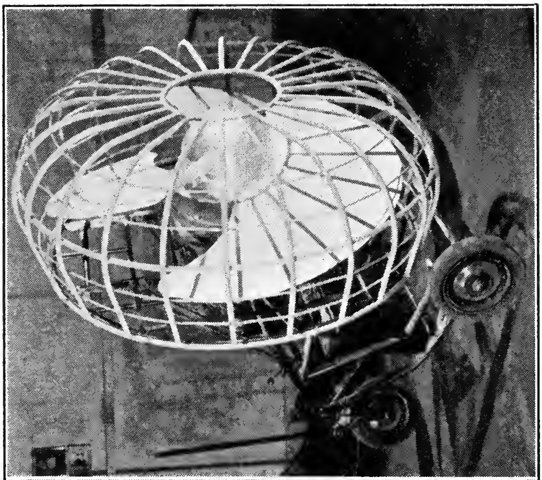

FIG. 2. Improved 3-blade screw type propeller.

cause of the noise effect of the wind produced above the scene in the vicinity of the microphone or striking the microphone. Wind "gags" on the microphone minimize the second trouble; but in the event of

FIG. 3. Doorway used for machine, when more convenient than special portals.

the first, sound must be disregarded, making necessary subsequent synchronization of dialog and sound-effects for the scene. This post-synchronized recording seldom equals the original, at best. Furthermore, a noisy device is distracting to actors, even when recording is not involved.

A new type of wind-machine consisting of a conventional centrifugal ventilation-system blower has been adopted. This machine is comparatively large, but by virtue of its greater pressure enabling it to force the air through ducts, the machine may be situated remotely from the scene, and the noise of the machine is no problem. Once the installation for a particular set is made, the direction of the wind may be maneuvered with the nozzles more easily than is usually practicable with the propeller machines.

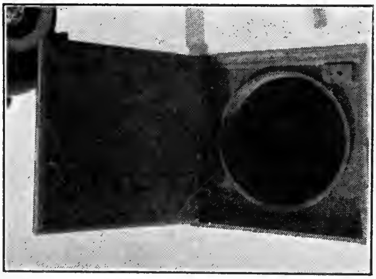

FIG. 4. One of the special portals.

The machine is usually situated outside the stage building, and the duct enters by way of a portal, as illustrated in Figs. 3 and 4, respectively. Fig. 3 illustrates a doorway, which is used when more convenient than one of the special portals.

The loss of insulation occasioned by cutting the entrance through the stage wall has not been found serious. Added insulation against

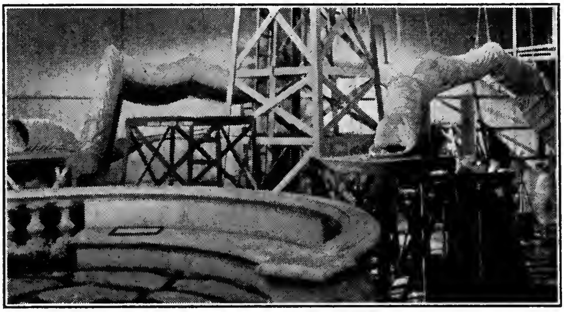

FIG. 5. Typical installation of branch ducts on a stage.

noises in the vicinity of the blower is provided, when necessary, by blankets around the duct, inside or outside the stage, or both. Insulating blankets around the blower protect the stage from noises entering through the blower and ducts.

FIG. 6. Reducers, couplings, and nozzles used with the wind-machine.

Fig. 5 shows a typical installation of branch ducts within a stage. Various fittings such as reducers, couplings, and nozzles are provided, a few of which are illustrated in Fig. 6.

A comparison of maximum velocities obtainable from the several types of wind-machines is illustrated by the contour diagram of

Fig. 7. The conditions for each of the various instances is indicated. In all cases, the motors were operated at practically full speed. The velocities were measured by means of a double Pitot tube connected with an inclined draft water-gauge. The double Pitot tube automatically corrects for static pressure, leaving an indication proportional to velocity pressure, which readings are converted into velocity in feet per minute, as illustrated in the figure. The values indicated for velocities on the axis are fairly accurate, but due to turbulence, the other values represent occasional peak values rather than average

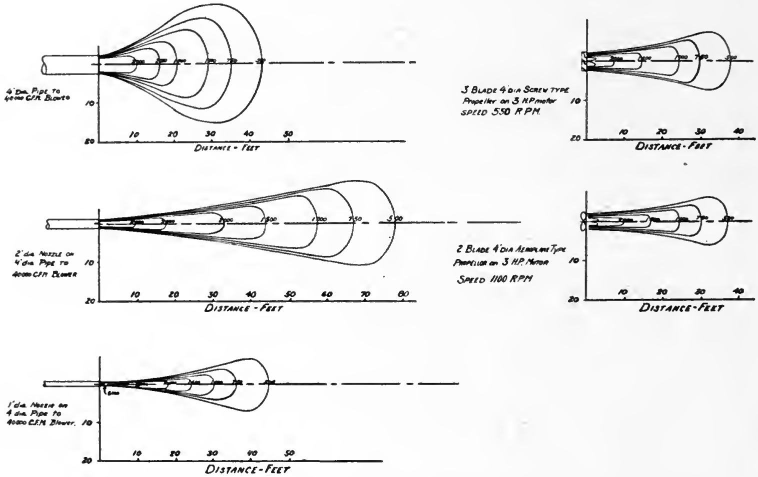

FIG. 7. Velocity contours of wind from several types of wind-machines.

values. As a check of these readings, data were also taken with an anemometer.

It is evident from Fig. 7 that the velocities attainable with the blower are considerably greater than with the propellers. When a large nozzle is used, the area covered is much greater than possible with the propeller.

The measured noise-level for the various types is the indication of the excellence of the blower as a wind-machine. A sound-level meter using 10^{-16} watt per sq. cm. as reference level and indicating in terms of decibels with this reference, and incorporating a weighting network for 70 db. loudness was used. The measured sound-levels with maximum speeds were as follows:

	Decibels
2-blade propeller	+76
3-blade propeller	+70
4-inch pipe on blower	+53
2-inch pipe on blower	+54
1-inch pipe on blower	+60
2-inch pipe on blower (Reduced speed)	+45

To reduce the blower performance down to the level of the propeller, the motor was slowed down, resulting in a lowered noise-level and a field-velocity pattern much the same as for one of the propellers. The noise-level was then approximately 30 db. lower. The chief source of noise is the turbulence within the canvas ducts due to corrugations of the duct surface. Additional care in installing these ducts, keeping them taut, serves to minimize the noise.

Small blowers used in this manner have been used with great success when the volume requirements are not as great. Several years of use in the production of many pictures have proved the value of the blower type of wind-machine.

Acknowledgment is given to Paul Widliska, of United Artist Property Shop, and to the Carrier Engineering Corporation for their assistance in preparation of the material in this paper.

NEW MOTION PICTURE APPARATUS

During the Conventions of the Society, symposiums on new motion picture apparatus are held in which various manufacturers of equipment describe and demonstrate their new products and developments. Some of this equipment is described in the following pages; the remainder will be published in subsequent issues of the Journal.

CHARACTERISTICS OF SUPREME PANCHROMATIC NEGATIVE*

A. W. COOK**

In a previous paper[1] Superpan negative film has been discussed. Since the properties of that product are well known, the characteristics of Supreme negative will be compared with them, in order that the properties of the newer material can be conveniently interpreted in relation to practical experience of the cinematographer or photographic technician.

The introduction of a film having such a radical increase in sensitivity combined with fine-grain size might be expected to arouse speculation concerning the possibility that hypersensitizing might have been employed during manufacture. It would appear that such speculation was still furthered because the makers of Supreme negative film had announced a method of "dry hypersensitization" with mercury vapor.[2] For this reason it must be emphatically stated that the increased sensitivity of Supreme negative is not attained by hypersensitizing or by using the old Superpan type of emulsion "pepped up" or pushed to limits. This would only endanger other desirable qualities, especially the fine-grain characteristics, for the sake of more speed. On the contrary, Supreme negative has an entirely new type of emulsion which incorporates the practical application of several new discoveries and developments in the technic of emulsion making.

In physical characteristics Supreme negative and Superpan negative are identical, with a double coating of emulsion on one side of the base, over a gray antihalation layer. The back of the cellulose-nitrate base is chemically treated to inhibit any tendency toward the generation of static electricity under certain conditions of use.

In expressing the sensitometric relationship between Supreme negative and Superpan negative, the usual D-Log E curves are used, plotted from strips exposed in a Type IIB sensitometer employing the standard negative filter provided with the instrument. Steps indicated on the Log E axis of the curves represent an exposure increment of 100 per cent, and all curves have been corrected for fog

* Presented at the 1938 Spring Meeting at Washington, D. C.; received April 18, 1938.

** Agfa Ansco Corp., Binghamton, N. Y.

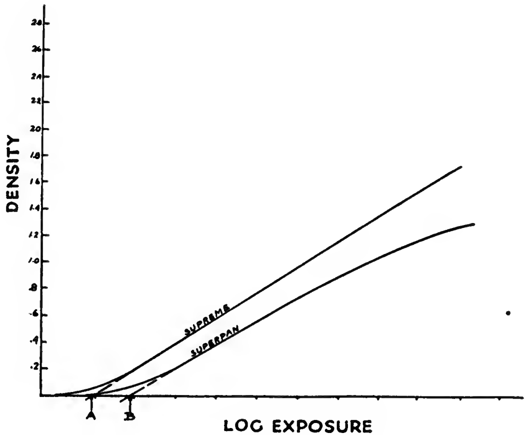

FIG. 1. Agfa Supreme and Superpan negative. Type II*b* sensitometric curves showing inertia speed ratio at *A* and *B*.
Exposure step increment 100 per cent; developed in Agfa borax to equal gamma values.

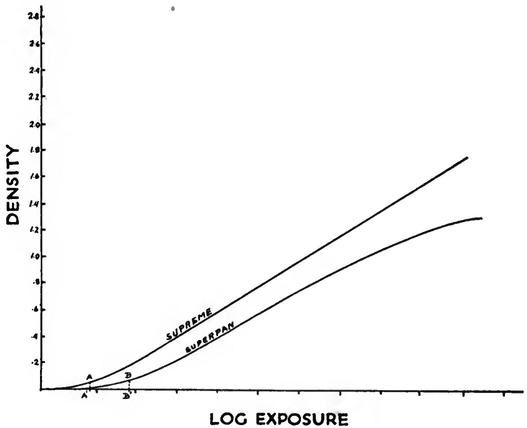

FIG. 2. Agfa Supreme and Superpan negative. Type II*b* sensitometric curves showing speed relation (*A′* and *B′*) at gradient values of 0.3 (*A* and *B*).
Exposure step increment 100 per cent. Developed in Agfa borax to equal gamma values.

and optical density of the gray base. It should be understood that the curves under consideration illustrate *relative* values only and are not of *individual* quantitative import.

The relative inertia speeds of Supreme negative and Superpan negative are compared in Fig. 1. The inertia values at A and B are one exposure step apart, and from their relative positions it may be seen that the speed of Supreme negative, as determined by inertia, is 100 per cent greater than that of Superpan negative.

In the curves shown in Fig. 2 the points A and B, respectively, indicate gradient values of 0.3, arbitrarily selected for the present discussion as a value approximating the minimum useful gradient. The exposure values opposite points A and B, as indicated by A' and B', are likewise one step apart, and it may be

FIG. 3. (*Left*) Agfa Supreme Panchromatic negative exposed at $f/4.5$, 1/40 sec.; (*right*) Agfa Superpan negative exposed at $f/3.2$, 1/40 sec. (Developed to same gamma.)

seen that the speed of Supreme negative determined by the minimum useful gradient is 100 per cent greater than that of Superpan negative, and in agreement with the relative sensitivity determined from inertia.

A further comparison of Supreme negative and Superpan negative, by means of camera exposures, shows that comparable photographs of the same subjects can be made with Supreme negative exposed at $f/4.5$, and with Superpan negative exposed at $f/3.2$, using the same shutter opening and camera speed in both cases (Fig. 3). The pictorial results from such tests verify the conclusions drawn from sensitometric tests, and readily demonstrate that under conditions of actual practice Supreme negative requires only half the exposure necessary for Superpan negative.

In practical cinematography the unusual light sensitivity of Supreme negative is most advantageous, since, with the same level of illumination required by older supersensitive films, it permits the use of smaller lens-stops with materially increased depths of focus. If the use of a smaller lens-stop is not desirable, the higher speed of Supreme negative permits a reduction of approximately 50 per cent in the set lighting, assuming that all other conditions of exposure remain the same.

Supreme negative has a gradation inherently steeper than that of Superpan negative, and, when developed to a gamma between 0.60 and 0.70, Supreme requires about 15 to 20 per cent less developing time. Fig. 4 shows time-gamma and time-fog curves for the two films, machine developed in Agfa *17* borax developer at 65°F. Because of the steeper gradation of Supreme negative, development can not be based upon the results of developer tests made with earlier types of film. This is particularly important if all the advantages of improved film quality are to be fully realized. However, if the film is over-developed through error or miscalculation, the unusually long scale and high shoulder minimize the tone

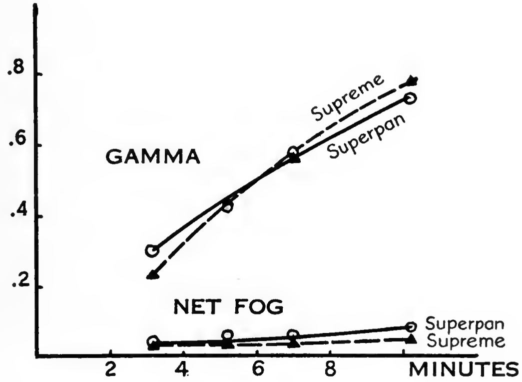

FIG. 4. Time-gamma curves: Agfa Supreme and Superpan negatives. Developed in Agfa No. *17* borax developer at 65°F.

distortion that might be expected. Referring again to Fig. 2, the unusual latitude is graphically indicated by the long straight-line portion of the characteristic curve. In practice, this is manifested by more faithful reproduction of highlight or shadow tone values, thus lending greater brilliance to the finished print.

A survey made among a number of the major laboratories has shown that it is rather common practice to base processing technic on the overall-gamma method of tone reproduction.[3] Under such a system negatives and positives are developed to predetermined gammas, the product of which is the overall gamma selected as the value that most nearly reproduces the tonal values of the original subject under normal conditions of projection. Since the overall-gamma theory is entirely valid only when dealing with the straight-line portions of characteristic curves, processing control based upon this theory is the more effective in proportion to any extension of the straight-line response of the negative and positive materials in use. With this in mind, the advantages accruing from the use of Supreme negative may be readily appreciated.

Fig. 5 shows spectograms of both Supreme negative and Superpan negative films exposed with tungsten light, and it will be seen that the relative color sensitivities are almost identical. The higher speed of Supreme negative extends through the full range of spectral sensitivity, and no alteration is required in the make-up normally employed with the older supersensitive films. Factors for some of the more commonly used filters are listed in Table I.

TABLE I

Exposure Multiplying Factors for Wratten Filters in Normal Daylight

Filter Used	Ultra Speed	Superpan	Supreme
Aero No. *1*	1.5	1.5	1.5
Aero No. *2*	2.0	2.0	2.0
3N5	4.0	4.0	4.0
5N5	6.0	5.0	6.0
K-1	1.8	1.6	1.8
K-$1^1/_2$	2.0	1.8	2.0
K-2	2.0	1.9	2.0
Minus blue	2.5	2.5	2.5
G	2.5	3.0	3.0
23-*A*	3.5	4.0	4.0
25-A	5.0	5.5	6.0
B	9.0	7.0	9.0
C-4	10.0	7.0	8.0
C-5	6.0	6.0	5.5
F	7.0	7.0	8.0
N.D. 0.25	1.8	1.8	1.8
N.D. 0.50	3.1	3.1	3.1
N.D. 0.75	5.6	5.6	5.6
N.D. 1.00	10.0	10.0	10.0
72	20.0	20.0	30.0

The obvious advantage in speed of Supreme negative over Superpan negative has been effected without sacrificing any other essential characteristic. This fact is singular when one considers that higher speed has usually been synonymous with coarser grain, higher fog, poorer keeping quality, and, in some cases, flatter gradation. In fact, from a manufacturing standpoint, the limiting factors in speed have been determined by the minimum requirements for each of these other important characteristics. In the production of this film, not only have these other characteristics been unimpared, but in some cases refined to a degree never before realized in super speed films.

In Fig. 6 are shown enlargements made from single frames of each film. The subject photographed was the same in each case and the negatives were developed to the same gamma. Some comparison of the grain of the two films can be seen from these prints, although it must be acknowledged that in general such a comparison does not necessarily depict the effect as it would appear upon the screen. The practical difference as seen in motion projection is in this case, however, of the same order as shown here.

This fine grain coupled with unusual sensitivity makes Supreme negative an excellent film for the photography of projected background scenes. It allows

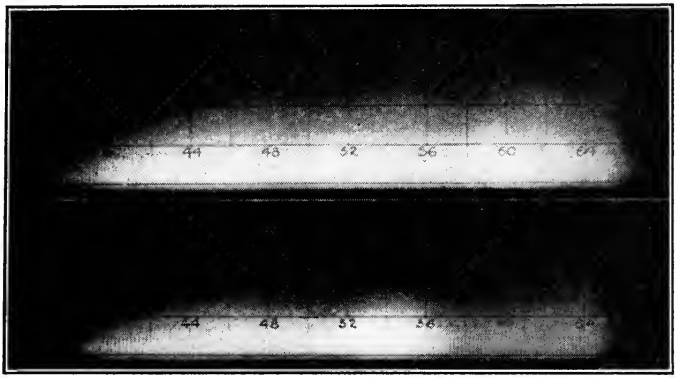

FIG. 5. Mazda wedge spectrograms: (*Above*) Agfa Supreme Panchromatic negative; (*below*) Agfa Superpan negative.

larger screens of diminished brightness to be photographed with adequate exposure, or with screens of normal size and undiminished brightness the combination shot may be made with a smaller lens-stop, thus increasing the depth of focus

FIG. 6. Agfa Supreme and Superpan grain comparisons, 20*X* normal.

and obviating the necessity for the players to remain inconveniently close to the background. Since the film used to photograph projection background shots is actually being used as a duplicate negative, it may be seen that the unusually fine grain of Supreme negative makes it additionally valuable for this type of work.

In perfecting the Supreme negative emulsion, not the least consideration was given to its aging characteristics. Before the first regular production was coated, several months were spent in studying the aging characteristics of the final experimental coatings. These tests were conducted on accelerated and normally aged material. It was not until the stability of the film had been proved fully equal to that of Superpan negative that it was adopted for production.

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NEW BACKGROUND PROJECTOR FOR PROCESS CINEMATOGRAPHY*

G. H. WORRALL**

A new type of background projection apparatus has been developed using the Mitchell sound or eccentric movement identical with the one used in the latest cameras, except for some minor details (Fig. 1).

The principal objectives in designing this equipment were freedom from maintenance and elimination of excessive noise. Freedom from maintenance is accomplished by elimination of heating of the mechanism and by use of the eccentric movement which has relatively little wear. The noise is reduced by the eccentric movement since the accelerations are low, due to the use of eccentrics instead of cams.

It has been found from experience that it is necessary, in order to have steady background projection, to have pilot-pins that give positive registration using the same holes for projection as used in exposing the original film. Thus the present projectors in most studios in Hollywood today are built around a camera movement having pilot-pins. The film in this movement is guided through a narrow channel composed of very light steel plates which reciprocate in a direction parallel to the lens axis in order to push the film on and off the pilot-pins. In order to reduce the inertia it is necessary to make the plates as light as possible; consequently the spill light that strikes the plates causes them to warp and, in time, to require considerable maintenance. The new projector using the eccentric

* Presented at the 1938 Spring Meeting at Washington, D. C.; received April 18, 1938.

** Mitchell Camera Corp., West Hollywood, Calif.

movement similar to the Mitchell camera movement has a fixed film-race, with the pull-down claws and pilot-pins entering the film in this fixed race and moving it in the direction of travel only, so that a heavier and more rigid construction may be used around the aperture. The movement has also been modified to accommodate a very large angle of light. The regular pilot-pin bearings have been offset downward so that they do not interrupt any of the beam of light, and, at the same time, the bearings themselves are removed from the heat so that the pins will not freeze, due to oil evaporating from the bearings if subjected to excessive heat.

The present method of illuminating the aperture in order to get a reasonably uniform light on the film is to cover an area of several inches in diameter on the

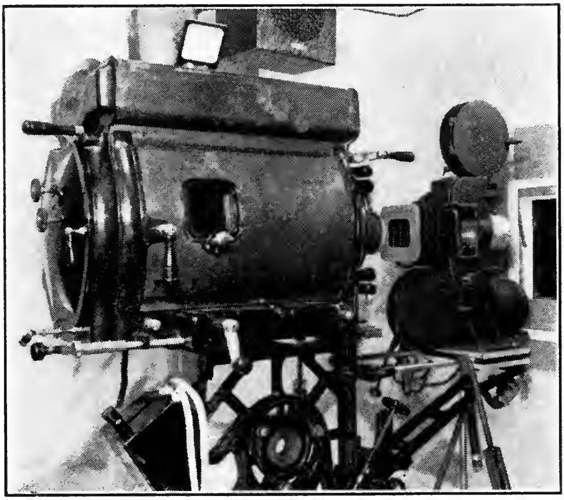

FIG. 1. Background projector.

front of the projector and to use only the center portion of this area. This method necessarily throws considerable heat on the projector with a corresponding rise in temperature, sufficient at times to cause the mechanism to freeze. To overcome this difficulty a radiator consisting of a series of fins extending from the edge of the usable light-beam, outward in all directions for approximately $1^1/_2$ inches, was placed between the lamp and the main body of the projector. This radiator defines the light that falls upon the aperture and prevents any spill light from falling upon the main body of the projector. The radiator is insulated from the main body of the projector by means of a thin disk of relatively poor conducting material so that a rather steep gradient is maintained between the radiator and projector. The difference of temperature is of the order of 100°F across approximately $^1/_8$ inch of non-conducting material. Thus the difficulties caused by excessive heating of the mechanism are removed.

The projector is equipped with an interlock motor and synchronizing device for setting the shutter in phase with the camera shutter after interlock has been established.

Probably the most interesting question in connection with a projector of this type is: "Is the picture steady?" In answering this it can be pointed out that the projector has been tested in several of the major studios both visually and photographically, and has proved itself capable of projecting extremely steady pictures. The machine is at present being used by the Technicolor Motion Picture Corporation in some experimental work to demonstrate the possibility of process work in connection with their system of color photography, and has proved quite satisfactory for such use.

BOOK REVIEWS

Photographic Chemicals and Solutions: J. I. Crabtree and G. E. Matthews, *American Photographic Publishing Co.*, Boston, Mass. (1939), 366 pp., $4.00.

This is a book that can be recommended unreservedly as filling a need too long neglected by photographic writers. While a large portion of the material has necessarily been taken from papers published in the SMPE JOURNAL and other publications, many original items have been incorporated to form a thorough and extremely useful text and reference book.

An excellent introduction discusses the differences between the British and American systems of measurement and the many advantages of the metric system, but recommends that both American and metric equivalents be given for all formulas for the benefit of those who prefer not to change their present methods.

Next follows an effective discussion of "photographic" arithmetic, illustrated by many examples of conversion of formulas and related topics.

The chapter on apparatus not only covers numerous types of units but includes many useful hints as to the most effective use of these units. Then follows a comprehensive chapter on materials used in the construction of photographic apparatus of all kinds.

After these preliminaries and chapters on the importance of temperature control and water purity, follows a chapter on the mixing and using of photographic solutions. The thoroughness of the treatment of this topic may be gathered from the fact that there are 63 pages of concise and accurate information furnished.

Following chapters on solutions at high temperatures, storage of solutions, and substitution of chemicals, is an authoritative discussion of stains and their cause and treatment. This is succeeded, logically, by a discussion of the proper cleaning of photographic apparatus and general suggestions and precautions.

The book closes with an extensive formulary, list of solubilities, a valuable list of manufacturers of suitable materials, and an index. The book is well printed on high-grade paper and should be on every photographers bookshelf.

R. F. MITCHELL

Moderne Mehrgitter Elektronenroehren ("Modern Multigrid Electron Tubes"); M. J. O. Strutt, Eindhoven, Holland. Second volume: **Electro-Physical Foundations,** *Julius Springer*, Berlin (1938), 144 pp.

The first volume of *Modern Multigrid Electron Tubes*, published in 1937 dealt with their construction, operation, and properties. Its reception by the professional world encouraged Dr. Strutt to prepare this second volume, which deals with the electrical and physical fundamentals of electron tubes.

The first part of this second volume, starting from the laws of electrodynamics, derives the characteristics of the tubes from their constructional data. The second part deals with the highly complex electron movement in multigrid tubes. Not only are screen-grid and pentode tubes, discussed but also hexodes, heptodes, and octodes. The second portion contains also detailed descriptions of the apparatus and methods developed in the Research Laboratory of the Philips A. G. for determining the characteristics of these multigrid tubes particularly in their relation to short-wave work.

Some appreciation of the completeness of this text can be gained from the table of contents: (*1*) Basic equations, mechanical analogies, and units, (*2*) Electron movement in a diode, with and without initial velocity, (*3*) Electron movement in a diode with constant cathode emission temperature, (*4*) Electron movement in a triode, (*5*) Static tube capacities, (*6*) The screen grid-plate spacing of an ideal tetrode, (*7*) Applications of the screen grid-plate spacing in high-frequency amplifier tubes, high-frequency, mixing, and power-amplifier tubes, (*8*) Dynamic tube capacities, (*9*) The characteristic tube admittances in the short-wave region, (*10*) The electron time of travel effect in amplifier tubes, (*11*) Dynamic measurements of the electron movement in hexodes and heptodes, (*12*) Electron movement in an alternating current field, (*13*) Dynamic measurements of the electron movement in an octode, (*14*) Tubes with a curved electron track, secondary emission tubes, (*15*) Ground-noise and the construction of low-noise-level tubes, (*16*) Comments on electrode temperatures, (*17*) Appendix, supplementing some computations in the text.

The author's very concise and clear representation of the abundant material is supported by numerous graphical and pictorial illustrations.

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.

Acoustical Society of America, Journal

10 (Jan., 1939), No. 3

Departure of Overtones of a Vibrating Wire from a True Harmonic Series (pp. 161–166) — R. S. SHANKLAND AND J. W. COLTMAN

Resonance in Certain Non-Uniform Tubes (pp. 167–172) — A. T. JONES

Effect of Physical Size on the Directional Response Characteristics of Unidirectional and Pressure Gradient Microphones (pp. 173–179) — F. MASSA

Indoor and Outdoor Response of an Exponential Horn (pp. 180–183) — C. P. BONER, H. W. JONES, AND W. J. CUNNINGHAM

Exploration of Pressure Field Around the Human Head During Speech (pp. 184–199) — H. K. DUNN AND D. W. FARNSWORTH

Moving Coil Pistonphone for Measurement of Sound Field Pressure (pp. 200–202) — R. P. GLOVER AND B. BAUMZWEIGER

Effect of the Consonant on the Vowel (pp. 203–205) — J. W. BLACK

Tubular Directional Microphone (pp. 206–215) — W. P. MASON AND R. N. MARSHALL

Investigation of Room Acoustics by Steady-State Transmission Measurements. I. (pp. 216–227) — F. V. HUNT

Frequency Distribution of Eigentones in a Three-Dimensional Continuum (pp. 228–234) — R. H. BOLT

Distribution of Eigentones in a Rectangular Chamber at Low Frequency Range (pp. 235–238) — DAH-YOU MAA

Apparatus for Acoustic and Audio-Measurements (pp. 239–245) — H. A. CHINN AND V. N. JAMES

American Cinematographer

19 (Dec., 1938), No. 12

Three New Eastman Negative Emulsions: Background X, Plus X, and Super XX (pp. 487–490, 525) — E. HUSE AND G. A. CHAMBERS

Howard Greene Awarded Photographic Honors for October (pp. 494)

20 (Jan., 1939), No. 1

Securing Uniform Results with Meters on Interiors (pp. 6–7) — D. B. CLARK

Technical Progress in the Past Year (pp. 8–10, 46) — W. STULL

New Tests Coördinate Make-Up (pp. 11–12) — G. GAUDIO

Stills from 8-Mm. Film (pp. 21–22, 45) — R. W. TEOREY

Telco Begins Production (pp. 31–32) — I. B. HOKE

Art Reeves Offers First Independent Re-Recorder (p. 33)

20 (Feb., 1939), No. 2

Make-Up and Set Painting Aid New Film (pp. 54–56, 85) — J. VALENTINE

Gadgets for the Moviemaker (pp. 57–58, 87) — R. W. TEOREY

Metal Film Steadily Progresses (pp. 59–60) — R. W. CARTER

Lighting the New Fast Films (pp. 69–70)

Photophone Soundheads Provide Studio Presence (pp. 76–77)

British Journal of Photography

85 (Nov., 25, 1938), No. 4099

Progress in Colour (pp. 744–746), Pt. I

85 (Dec. 9, 1938), No. 4101

Progress in Colour (pp. 773–774), Pt. II

85 (Dec. 23, 1938), No. 4103

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British Kinematograph Society, Journal

2 (Jan., 1939), No. 1

Demonstrations of New Apparatus (pp. 47–53)

Cinematographie Française

21 (Nov. 25, 1938), No. 1047

L'Ultra-Cinema a fait de nouveaux progres (High Speed Motion Pictures Progress, 3000–4000 Frames per Second) (pp. II–IV, VII)

Communications

18 (Dec., 1938), No. 12

A Bibliography on Recording (pp. 22, 27) — J. G. SPARLING

Electronics

11 (Dec., 1938), No. 12

A Laboratory Television Receiver—VI (pp. 17–19) — D. G. FINK

Thermionic Emission in Transmitting Tubes (pp. 22–25, 32) — C. P. MARSDEN, JR.

Spherical Tank U H F Oscillator (pp. 26–28) — H. E. HOLLMAN

Characteristics of Phosphors for Cathode Ray Tubes (p. 31)

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International Photographer

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Future of Television (pp. 9–11) — E. HUSE AND

New Eastman Emulsions (pp. 23–35, 27) — G. A. CHAMBERS

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Color Progress Dominates 1939 Technical Horizon (pp. 9–10) — E. GIBBONS

Telco Bids for Color Recognition (pp. 10–13)

Why Modern Lamps Are Better (pp. 21–23) — P. MOLE

Projection Symposium (pp. 24–25, 27) — W. S. THOMPSON

International Projectionist

13 (Dec., 1938), No. 12

P. A. Units Increasingly Important in Daily Projection Routine (pp. 7–11, 29–30) — A. NADELL

Studio Projection: Routine, Methods and Equipment (pp. 12–16) — M. CHAMBERLIN

The Projectionist's Part in Efficient Economical Sound System Installation (pp. 19–21). — A. GOODMAN

14 (Jan., 1939), No. 1

Matching Various Units of Theatre Public Address Equipments (pp. 7–8, 10) — A. NADELL

Technical Data on New RCA Sound Systems (pp. 20–21)

Kinematograph Weekly

262 (Dec. 1, 1938), No. 1650

A Revolutionary Projector (p. 31)

262 (Dec. 22, 1938), No. 1653

Microphones and Their Employment (pp. 23, 28) — R. H. CRICKS

263 (Jan. 12, 1939), No. 1656

Technical Developments During 1938 (pp. 143, 149) — R. H. CRICKS

263 (Jan. 19, 1939), No. 1657

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20 (Nov., 1938), No. 11

Die Bildwandhelligkeit in Filmtheatern (Screen Brightness in Motion Picture Theatres) (pp. 285–291) — H. JOACHIM

Die Moglichkeiten des Schmaltonfilms (Possibilities of Substandard Sound Films) (pp. 292–296) — W. PISTOR

Methoden zur Messung des photographischen Gleichrichtereffektes (Methods of Measuring the Photographic Rectifying Effect IV) (pp. 296–299) — A. NARATH AND W. VOX

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Ein Zweipackverfahren für subtraktive Dreifarbenkinematographie Agfa Pantachrom-Verfahren (Bipack Method for Subtractive Three Color Motion Picture Photography, Agfa Pantachrom Method) (p. 323)	J. EGGERT AND G. HEYMAR
Synchronlauf von Bild und Ton, insbesondere mittels Drehrichter (Synchronization of Picture and Image, Particularly by Means of a Synchronizer) (pp. 324–327)	K. SCHWARZ
Die Aufnahme und Wiedergabe von Reihenbildern mittels Linsenrasterschichttrager (Taking and Reproducing a Series of Pictures by Means of Lenticular Screen Films) (pp. 327–328)	O. BENDER

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Grossbilderzeugung beim Fernsehen (Large Pictures by Television) (pp. 1–5)	R. MOLLER
Physikalische Problems der Fernaufnahme (Physical Problems Encountered in Telephotography (pp. 6–9)	H. I. GRAMATZKI
Mechanische Filterung Bei Tonfilmmaschinen (Mechanical Filtering in Sound Film Apparatus) (pp. 9–14)	H. MULLER
Plastischer Film (Stereoscopic Film) (p. 15)	R. THUN
Der elektrische Belichtungsmesser für die Berufskinematographie und seine Problems (An Electric Exposure Meter for Professional Motion Picture Photography and Its Problems) (pp. 16–18)	H. C. OPFERMANN

Optical Society of America, Journal

29 (Jan., 1939), No. 1

A Note on the Color Temperature-Candlepower Characteristic of Tungsten Lamps (pp. 16–19)	K. S. WEAVER AND H. E. HUSSONG
A Simple Photox Photometer Head (pp. 35–36)	E. D. WILSON

Philips Technical Review

3 (Oct., 1938), No. 10

Television with Nipkow Disc and Interlaced Scanning (pp. 285–291)	H. RINIA
The Diffraction of Light by Sound Film (pp. 298–305)	J. F. SCHOUTEN

Photographic Journal

78 (Dec., 1938)

Exhibition of Kinematography (pp. 715–716)	
The Technique of Sound Recording (pp. 727–731)	T. S. LYNDON-HAYNES

Die Photographische Industrie

36 (Dec. 28, 1938), No. 52

Grossere Lichtausbeute durch Kondensoren mit Zylinderwirkung (Greater Light Yield by Use of Condensors that Produce a Cylindrical Effect) (pp. 1441–1443)

37 (Jan. 25, 1939), No. 4

Zur Tonaufzeichnung mit ultraviolettem Licht (Sound Recording with Ultraviolet Light) (pp. 81–84) A. NARATH

Television

11 (Dec., 1938), No. 130

Television Picture Faults and Their Remedies, I (pp. 717–20) S. WEST

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How the Picture Is Synchronised, II (pp. 741–742)

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1939 SPRING CONVENTION

SOCIETY OF MOTION PICTURE ENGINEERS

HOLLYWOOD-ROOSEVELT HOTEL
HOLLYWOOD, CALIFORNIA
APRIL 17th–21st, INCLUSIVE

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Headquarters

Headquarters of the Convention will be the Hollywood Roosevelt Hotel, where excellent accommodations are assured. A reception suite will be provided for the Ladies' Committee, and an excellent program of entertainment will be arranged for the ladies who attend the Convention.

Special hotel rates, guaranteed to SMPE delegates, European plan, will be as follows:

One person, room and bath	$ 3.50
Two persons, double bed and bath	5.00
Two persons, twin beds and bath	6.00
Parlor suite and bath, 1 person	8.00
Parlor suite and bath, 2 persons	12.00

Indoor and outdoor garage facilities adjacent to the Hotel will be available to those who motor to the Convention.

Members and guests of the Society will be expected to register immediately upon arriving at the Hotel. Convention badges and identification cards will be supplied which will be required for admittance to the various sessions, the studios, and several Hollywood motion picture theaters.

Railroad Fares

The following table lists the railroad fares and Pullman charges:

City	Railroad Fare (round trip)	Pullman (one way)
Washington	$132.20	$22.35
Chicago	90.30	16.55
Boston	147.50	23.65
Detroit	106.75	19.20
New York	139.75	22.85
Rochester	124.05	20.50
Cleveland	110.00	19.20
Philadelphia	135.50	22.35
Pittsburgh	117.40	19.70

The railroad fares given above are for round trips, sixty-day limits. Arrangements may be made with the railroads to take different routes going and coming, if so desired, but once the choice is made it must be adhered to, as changes in the itinerary may be effected only with considerable difficulty and formality. Delegates should consult their local passenger agents as to schedules, rates, and stop-over privileges.

San Francisco Fair

On February 18, 1939, the Golden Gate Exposition opened at San Francisco, an overnight trip from Hollywood. The exposition will last throughout the summer so that opportunity will be afforded the eastern members of the Society to take in this attraction on their Convention trip. Special arrangements have been made with the Hotel Empire at San Francisco for Convention delegates visiting the Fair, at the following daily rates:

One person, room and bath	$3.50
Two persons, double bed and bath	5.00
Two persons, twin beds and bath	6.00
Suites:	
Parlor and bedroom for two persons	8.00 and up
Two large bedrooms, each with private bath and a living room; for four persons	16.00

Reservations can be made either by writing directly to the Hotel Empire or by addressing Mr. W. C. Kunzmann, *Convention Vice-President*, Box 6087, Cleveland, Ohio.

Technical Sessions

The Hollywood meeting always offers our membership an opportunity to become better acquainted with the studio technicians and production problems, and arrangements will be made to visit several of the studios. The Local Papers Committee under the chairmanship of Mr. L. A. Aicholtz is collaborating closely with the General Papers Committee in arranging the details of the program.

Studio Visits

On the afternoon of Tuesday, April 18th, Paramount Pictures, Inc., will act as hosts of the Convention at their Hollywood Studio. The program will be in charge of Messrs. L. L. Ryder and H. G. Tasker. On the afternoon of Thursday, April 20th, the delegates of the Convention will be entertained at the studio of Warner Brothers First National, Inc., at Burbank. The program of the afternoon will be under the supervision of Mr. N. Levinson.

Semi-Annual Banquet and Dance

The Semi-Annual Banquet of the Society will be held at the Hotel on Thursday, April 20th. Addresses will be delivered by prominent members of the industry, followed by dancing and entertainment. Tables reserved for 8, 10, or 12 persons; tickets obtainable at the registration desk.

New Equipment Exhibit

An exhibit of newly developed motion picture equipment will be held in the *Bombay and Singapore* Rooms of the Hotel, on the mezzanine. Those who wish to enter their equipment in this exhibit should communicate as early as possible with the general office of the Society at the Hotel Pennsylvania, New York, N. Y.

Motion Pictures

At the time of registering, passes will be issued to the delegates to the Convention, admitting them to the following motion picture theaters in Hollywood, by courtesy of the companies named: Grauman's *Chinese* and *Egyptian* Theaters (Fox West Coast Theaters Corp.), Warner's *Hollywood* Theater (Warner Brothers Theaters, Inc.), Pantages *Hollywood* Theater (Rodney Pantages, Inc.). These passes will be valid for the duration of the Convention.

Ladies' Program

An especially attractive program for the ladies attending the Convention is being arranged by Mrs. N. Levinson, *hostess*, and the Ladies' Committee. A suite will be provided in the Hotel, where the ladies will register and meet for the various events upon their program.

Points of Interest

En route: Boulder Dam, Las Vegas, Nevada; and the various National Parks. *Hollywood and vicinity:* Beautiful Catalina Island; Zeiss Planetarium; Mt

Wilson Observatory; Lookout Point, on Lookout Mountain; Huntington Library and Art Gallery (by appointment only); Palm Springs, Calif.; beaches at Ocean Park and Venice, Calif.; famous old Spanish missions; Los Angeles Museum (housing the SMPE motion picture exhibit); Mexican village and street, Los Angeles.

In addition, numerous interesting side trips may be made to various points throughout the West, both by railroad and bus. Among the bus trips available are those to Santa Barbara, Death Valley, Agua Caliente, Laguna, Pasadena, and Palm Springs, and special tours may be made throughout the Hollywood area, visiting the motion picture and radio studios.

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.

SMPE Standards.—The revised edition of the *SMPE Standards and Recommended Practice* was published in the March, 1938, issue of the JOURNAL, copies of which may be obtained for one dollar each.

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

Lapel Buttons.—The insignia of the Society, gold filled, with safety screw back. One dollar each.

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

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

ABSTRACTS OF PAPERS OF THE SPRING CONVENTION

AT

HOLLYWOOD, CALIF.

APRIL 17–21, 1939

The Papers Committee submits for the consideration of the membership the following abstracts of papers to be presented at the Spring Convention. It is hoped that the publication of these abstracts will encourage attendance at the meeting and facilitate discussion. The papers presented at Conventions constitute the bulk of the material published in the Journal. The abstracts may therefore be used as convenient reference until the papers are published.

J. I. CRABTREE, *Editorial Vice-President*
S. HARRIS, *Chairman, Papers Committee*
L. A. AICHOLTZ, *Chairman, West Coast Papers Committee*

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O. O. CECCARINI	G. E. MATTHEWS	H. G. TASKER
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A. A. COOK	W. A. MUELLER	I. D. WRATTEN
L. J. J. DIDIEE	F. A. RICHARDSON	C. K. WILSON

Report of the Progress Committee; J. G. Frayne, *Chairman.*
A summary of advances made during the past year in the various technologic phases of the motion picture art.

"Brief Review of Foreign Film Markets during 1938;" Nathan D. Golden, *Motion Picture Division, U. S. Bureau of Foreign and Domestic Commerce.*
American motion pictures continued to enjoy widespread popularity throughout the world during 1938, although the intensification of difficulties abroad has resulted in a drop of 70 to 65 per cent in America's domination of the world's motion picture screens. The obstacles encountered have been of diverse character, including legislative restrictions, quota systems, high taxes, foreign-exchange controls, occasional excessive censorship, so-called "racial" theories, fervent efforts to build up local film industries, active hostilities in the Far East and Spain, transfers of territories, and such intangible factors as uncertainty and apprehension.

Various significant legislative enactments occurred during the year in Europe. Great Britain imposed a new quota system, to last for 10 years. Commencing

January 1, 1939. Italy placed the distribution of all films under Government monopoly, and because of the severe terms of this decree American picture firms have ceased doing business in Italy. In Switzerland was a new decree making the importation of motion pictures subject to an import permit from the Interior Department. Denmark created a Government agency, the Film Central, to distribute all Danish films not distributed by the producer himself or by independent Danish distributors. Notwithstanding the erection of new barriers, American films have continued to enjoy a substantial European market.

The ban on the, importation of American motion pictures into Japan was lifted in October, 1938 for a limited number of American films. New South Wales established a new Theater and Films Commission and set up new provisions of the Quota Act

Difficulties loomed in Argentina through the introduction of a bill to give definite powers of regulation and control to the local Cinematographic Institute; Argentina has also imposed a ban on the importation of advertising matter. In Guatemala a new tax was levied against American distributors. Cuba attempted to put through an exhibitor's quota, but the bill failed of passage, being wholly impracticable in its provisions.

The Latin American market at present appears to afford a promising opportunity to offset the restriction of our picture markets in other parts of the world. With 5239 potential theater outlets in that area today, and with new theater construction increasing every year, American companies are coming to realize that Latin America is a region that should be intensively cultivated. This, it is believed, may best be done by producing in Hollywood Spanish-dialog films employing stage favorites brought from Latin America and placed in Hollywood settings, with the use of reconstructed sets and our proficient American technic.

During 1938, foreign motion picture production totaled 1706 feature films, against 1809 in 1937. The countries of the Far and Near East led in production, with 967 features, as compared with 959 in 1937. Production in Europe fell off sharply, the total for all Europe being only 609 features. Latin American feature-film production increased by 40 films to a 1938 total of 130, Mexico being the largest producer, with 60 features.

Spanish-dialog films have scored notable box-office successes in nearly every Latin American country in which they have been shown, locally produced pictures having often exerted a powerful appeal during the past year, because they have portrayed familiar aspects of life, in a language understood by the audiences. On the other hand, a wealth of recent evidence demonstrates the grave defects and difficulties of the motion picture production attempted in certain countries abroad on wholly insufficient foundations.

"Television Lighting;" William C. Eddy, *National Broadcasting Co.*, New York, N. Y.

Lighting a television production presents many problems peculiar to this new field of public entertainment. These problems have necessitated the redesign of lighting equipment and the establishment of a simplified technic for handling the equipment that differs radically from moving picture practice.

To cope properly with the lighting requirements of the continuous action sequences, characterizing television productions, a system employing inside silvered incandescent lamps in a standardized unit was developed by NBC engineers. Based on multiple standardized groups of $1^1/_2$ kw. each, these units are used in both the foundation light and modeling equipment of the television studios in Radio City, thus insuring quantitative as well as qualitative control of lighting by the personnel.

With cameras generally in motion and an average duration of pick-up from one camera a matter of seconds, the problem of modeling in the sets becomes acute. This appears to be satisfactorily solved by the technic now in use wherein the major interest is centered around the close-up camera. Even this solution, however, required new and ingenious equipment to maintain light in the sets and still give floor precedence to the cameras and sound equipment.

While NBC at the present time has appeared to have standardized on the inside silvered lamp, exhaustive tests were carried out in an attempt to utilize more orthodox equipment. Actual tests under production conditions proved, however, that certain requirements of space, weight, and flexibility could not be had without a serious sacrifice of foot-candles on the set, resulting in the present set-up of equipment and personnel that are handling the television lighting assignment in the East.

Under these circumstances, our producers—relying on their scientific skill, the richness of their facilities and resources, and the variety and range of talent available to them in every field—will, it would seem, be well advised to stress most strongly in the foreign markets the factor of the *superior quality* of American films. We should export only pictures of unquestioned excellence. High quality will continue to retain for American motion pictures an exceedingly worth-while place in the markets of the world.

"The Time Telescope;" C. R. Veber, *Department of Biophotography, Rutgers University,* New Brunswick, N. J.

The Veber time telescope or combination time-lapse and photoelectric exposure control machine speeds up imperceptible motion. It is the antithesis of the Edgerton time microscope, which covers the other end of the time spectrum.

This optico-electric robot has both constant and variable (integrated) exposure time. The variable-exposure control with exposure modulator gives either a gradual change in density, or equal average frame densities regardless of spectral or intensity changes in subject lighting. It corrects for failure of film to follow the reciprocity law. Photoelectrically regulated, it is the first known camera control mechanism that automatically exposes the subject properly regardless of changes in color density, area, and average light intensity during or between exposures. Long periods of time between exposures make possible the use of a small fixed diaphragm ($f/256$), one advantage of the photoelectrically controlled exposure time. A photoelectrically variable diaphragm is not good here due to low exposure range, constantly changing the depth of field.

Norman McClintock, of Rutgers, in 1933 assigned the author to develop time-lapse machines that would eliminate curtains and permit time-lapse photography in field and greenhouse as well as in laboratory. Grants by the Chilean Nitrate Educational Bureau and Rutgers University made possible the construction of a number of machines including the one described here. Fifteen thousand feet of time-lapse material has been made in 2 years—40,000 machine hours of operation, the first time-lapse pictures made under natural conditions, and the longest continuous run six months.

Other uses, besides plant growth studies, include time lapse studies of erosion, disintegration and rotting, plastic flow, temperature and other changes, corrosion, wear, and pitting.

"Analysis and Measurement of Distortion in Variable-Density Recording;" J. G. Frayne and R. R. Scoville, *Electrical Research Products, Inc.*, Hollywood, Calif.

Types of non-linear distortion in variable-density recording are discussed and methods of measurement outlined. The frequency intermodulation method is described and applied to film processing for determination of optimal negative and positive density and overall gamma. Variance of these parameters from classic sensitometric values are traced chiefly to halation effects in film. Use of yellow dye in emulsion and fine grain emulsions tend to bridge the gap between intermodulation and sensitometric control values.

"Microphones for Sound Recording;" F. L. Hopper, *Electrical Research Products, Inc.*, Hollywood, Calif.

Factors influencing the choice of a microphone for sound recording are considered. The characteristics of a new miniature condenser transmitter and amplifier, as well as a number of other types of microphones now in use, are included.

"A Lightweight Sound-Recording System;" F. L. Hopper, E. C. Manderfeld, and R. R. Scoville, *Electrical Research Products, Inc.*, Hollywood, Calif.

A portable system for production recording, consisting of two main units, is described. A mixer, recording amplifier, monitoring facilities, and noise-reduction unit are contained in one compact unit weighing 42 pounds. A film recording machine weighing 100 pounds completes the system, and contains all modulator, lamp, and motor controls, as well as film speed indicator and footage counter. The power supply may be secured from batteries or a-c. operated rectifiers.

Report of the Projection Practice Committee, H. Rubin, *Chairman.*

A report of the work of the Committee since the last Convention. Work on the proposed revision of the NFPA *Regulations for Handling Nitrocellulose Motion Picture Film* has been completed and the revision will be placed before the NFPA at the Chicago meeting in May. The present report discusses also the Committee's search for practicable and inexpensive light-measuring instruments for use in theaters, in addition to other subjects engaging the attention of the several sub-committees.

Report of the Exchange Practice Committee; A. L. Schwalberg, *Chairman.*

A brief account of the work of the Committee during the past year, including handling of shipping cases, direction of rewinding film returned from theaters, disposition of scrap film, use of lacquer in splicing, etc.

"A Direct-Reading Photoelectric Densitometer;" D. R. White, *Dupont Film Mfg. Co.*, Parlin, N. J.

A photoelectric densitometer has been built which shows the density of the area being measured on a direct-reading scale visible at a reading window. A density range from 0 to 3.0 is covered with a reproducibility of approximately ±0.005. A motor-driven circular neutral wedge is used as the balancing means, and the density scale marked on the wedge is read by a stroboscopic flashing light controlled through a special amplifier system.

"An Instrument for the Absolute Measurement of the Graininess of Photographic Emulsions;" A. Goetz, W. O. Gould, A. Dember, *California Institute of Technology*, Pasadena, Calif.

The objective determination of graininess is based upon the evaluation of a graininess coefficient G defined by the distribution function of the relative transparency fluctuations $\left(x = \frac{\Delta T}{T_m}\right)$: $\pi(x) = \frac{C}{G} \cdot e^{-(x/G)^2}$. The instrument consists of a microphotometric recorder and a photoelectric integrator. In the former unit the x-fluctuations of a uniformly exposed section of an emulsion are recorded with high resolving power and magnification (300X) by means of a photocell. The amplified photocurrent is traced with a high-frequency galvanometer on 35-mm. film analogous to a large-scale variable-area record. Thus, a true representation of shape and frequency of the x-fluctuations in the scanned emulsion area (width: 30 microns, length: 10 mm.) is obtained in black and white.

The distribution function of the fluctuations as well as the value of G is obtained by placing the record on a revolving drum and scanning it by an illuminated slit. The light transmitted by the record falls upon the photocell, the current of which is thus representative of the average occurrence of x-fluctuations for a deviation (ΔT) from the mean transparency (T_m) determined by the position of the slit on the record. Hence, the change of the photocurrent represents the distribution function while the slit is moved across the revolving record. The scale on which the photocurrent is measured consists of a family of distribution curves (probability integral $\int \pi(x)$), each being characteristic for a certain G-value. The mechanical arrangement is such that a light-beam indicating the photocurrent selects and follows a particular curve while the slit is moved, thus determining whether or not, and if so to what extent, the x-fluctuations follow the above distribution function. Furthermore, it indicates the graininess coefficient in terms of the above function. The taking of a graininess record of an emulsion (capable of up to 10^5 fluctuations) takes 3 min., its analysis 2 min.

"A Multiduty Motor System;" A. L. Holcomb, *Electrical Research Products, Inc.*, Hollywood, Calif.

Various features of motor drive systems now in use by motion picture studios are described and the requirements for an ideal system defined. A recently developed system is described that will operate efficiently on alternating current for stage use or on direct current for location work. Many operating facilities are included which a survey has indicated should become a part of any ideal motor drive system.

"Acoustic Condition Factors;" M. Rettinger, *RCA Manufacturing Co.*, Hollywood, Calif.

The term "acoustic condition factor" in this paper is used as a general term descriptive of the acoustic environs of a point in an enclosure. Relationships expressed as ratios are given for several quantities, such as "useful" and "harmful" sound, direct, and generally reflected sound energy and sound intensity. Curves are shown representing loci for partial anti-nodes produced by interference between direct and first as well as second reflections in a rectangular room in which the sound source is located symmetrically. Equations are given expressing the minimal distance between source of sound and microphone for the probable avoidance of recording absolute nodes.

"Recording and Reproducing Characteristics;" K. F. Morgan and D. P. Loye, *Electrical Research Products, Inc.*, Hollywood, Calif.

In the improvement of sound motion pictures, the trend has been to make the response of all parts of the recording and reproducing circuits as nearly "flat" as possible. In some cases, however, this has resulted in unnatural sound, and therefore certain empirical practices have been adopted in the studios and theaters to make pictures sound best.

The results of a study are described, the purpose of which has been to evaluate the factors affecting the quality of speech as recorded and reproduced, from the vocal cords of the actor on the sound stage to the brain of the listener in the theater. The characteristics of the various factors have been determined and combined with dialog, voice effort, and other equalizers designed to produce an overall characteristic "subjectively flat" at the brain of the theater patron. These factors, as well as others now in the process of being studied further, are presented.

One of the most important characteristics studied is that of the change in voice quality with a change in effort on the part of the speaker, which is described in detail. The stage and set acoustic characteristics, microphone characteristic, and dialog equalization to compensate principally for the hearing characteristic of the average theater listener, are among the factors discussed.

"The Polyrhetor, a 150-Channel Film Reproducer;" G. T. Stanton, *Electrica Research Products, Inc.*, New York, N. Y., F. R. Marion and D. V. Waters, *Western Electric Co.*, New York, N. Y.

The creation of a modern Babel might appear to be the purpose of the Polyrhetor, or 150-channel film reproducer, recently completed for the World's Fair in New York. Actually, 150 versions of a fifteen-minute story are carefully sorted to bring each to only four persons seated in comfortable chairs on a moving conveyor.

A verbal description of a diorama along the edge of which the conveyor progresses, carefully synchronized with the motion of this conveyor, is given each group of persons and is repeated to each succeeding group with approximately a six-minute lag. In telling the fifteen-minute story, approximately 150 versions are being repeated simultaneously, each version differing only in its starting time.

In considering possible ways of meeting the elaborate and unheard of requirements established for this sound system, various combinations of disk, film, and steel-tape reproducing apparatus were considered, a novel form of film reproducer being selected primarily on the basis of proved operating reliability over long periods of time.

The apparatus is a twenty-ton magnification of the call announcer, the first model of which is satisfactorily operating in telephone plants after nine years of continuous service. The Polyrhetor consists essentially of a rotating steel drum eight feet in diameter, machined to watch-like precision, capable of carrying 24 continuous film loops past 168 optical scanners and associated amplifiers mounted on seven posts equally spaced about the drum. A multiple system of sectionalized trolleys conveys the sound through sliding contactors to small speakers in the cars, around which sufficient acoustical partitioning is provided to avoid program interference from car to car.

This project presented many problems unique in sound equipment design and their step-by-step solution is briefly discussed.

"Simplifying and Controlling Film Travel through a Developing Machine;" J. F. Van Leuven, *Fonda Machinery Co.*, Los Angeles, Calif.

A developing machine is described in which the drive of the film is frictional and the film-carrying rollers are driven on the slack of the film. The first driving roller is slightly smaller in diameter than all succeeding driving rollers, thereby setting up a tension on the film throughout the machine.

The upper shaft of film-carrying rollers is held in peripheral engagement with the driving rollers by adjustable springs which have a mounting that is yieldable downward so that any excess tension on the film draws the film-carrying rollers away from the driving rollers until the excess tension has been relieved, which allows the film-carrying rollers to be drawn upward by the springs to contact the driving rollers again.

The driving rollers are directly over the upper film-carrying rollers. The driving mechanism is completely above the tanks and solutions, and all film-carrying rollers in the wet end are mounted individually free and, in turn, are all mounted on free-turning tubing or shafting.

Film-carrying rollers in the dry box, in addition to being mounted on Arguto bushings and individually free, are mounted on tubing which in turn is mounted with grease-seal ball-bearings on shafting, the entire unit being free to rotate or to slide laterally on the shaft, thus becoming self aligning.

To meet the high initial and maintenance cost of ball-bearings found in film-carrying spools, $7^1/_4$-inch film-carrying rollers are used throughout.

Film enters machine in a steady, constant flow. Tension can be altered by the operator and, when regulated by adjustment of springs, remains virtually constant throughout the machine. The steady flow makes great speed possible and yet retains a high factor of safety. The machine has the following attributes: great simplicity; entire freedom from precision maintenance; film is always under even adjusted control and does not slip on rollers; breakage from mechanical causes is practically eliminated.

"A Reel-and-Tray Developing Machine;" R. S. Leonard, *Municipal Light and Power System*, Seattle, Wash.

A reel-and-tray film-processing system of 7 to 200-ft. capacity, designed to overcome deficiencies in existing small-scale film-processing equipment, is described. Some of the difficulties encountered in its construction are related, and a summary given of the results in practice. Advantages listed are, one-man operation; cleanliness; economy of solution, because only enough is used to develop the film and is then discarded; uniformity of development with any quantity of film from 7 to 200 feet; no film damage; no undue aerial or chemical fog; clean energetic development with straight H&D curves; and flexibility in use or extension to future developments.

"A New Mobile-Film Recording System;" B. Kreuzer, *RCA Manufacturing Co.*, Hollywood, Calif., and C. L. Lootens, *Republic Productions, Inc.*, North Hollywood, Calif.

The design requirements for this type unit and how these requirements were met in the selection of truck, body design, equipment layout, *etc.*, are discussed. The recording equipment utilized together with the power equipment and other special features of the unit are described. This type of unit has been in successful operation without revision.

"An Introduction to Television Production;" H. R. Lubcke, *Don Lee Broadcasting System*, Hollywood, Calif.

The current television technical facilities of the Don Lee Broadcasting System in Los Angeles are briefly described. A mosaic type camera and accompanying Don Lee control equipment are used. A coaxial cable conveys the signal therefrom to the *W6XAO* sight-sound television transmitters, operating on daily schedule on 45 and 49.75 megacycles, respectively.

The routine of production of a dramatic comedy serial entitled, *Vine Street*, in its thirty-second biweekly episode at this writing, is utilized as an example. A total time of twenty hours of one or more members of the dramatic unit is required to prepare and present one fifteen-minute episode.

The sequence of production is as follows: preparation of script; construction or modification of props and scenery; cast memorization of lines; cast rehearsals; camera-sound, sound-effects, light rehearsal with production staff; make-up; the performance itself, including visual-aural introduction of the act; the performance proper with overall supervision of lighting, microphone, and television adjustments by a television-producer at a distant receiver; closing announcement; written and verbal report of errors or advances in technic made during the performance.

Specifications for the physical instrumentalities and the current television technic are covered for each of the above factors of production.

Report of the Television Committee; A. N. Goldsmith, *Chairman.*

Partial reports by the two sub-committees: (*A*) on Television Production and Reproduction Technic, O. B. Hanson, *Chairman*, and (*B*) Film Properties and Laboratory Practice, O. Sandvik, *Chairman*. The scopes of activity of the sub-committees are described, and their program for the coming year. Among the items covered by these scopes are (*1*) glossary, (*2*) bibliography, (*3*) tutorial material, (*4*) dimensional practices, (*5*) normal equipment and procedure, (*6*) special problems such as inter-industry coördination, future equipment needs and specifications, *etc.*

"A Continuous Type Television Film Scanner;" Peter C. Goldmark, *Columbia Broadcasting System*, New York, N. Y.

A motion picture film scanner, the first of the continuous type to be used for television transmissions, is described. The apparatus was put into operation in New York City in the summer of 1937 and has been in use since. In its preferred form the scanner projects the image of a continuously moving film onto the cathode of a dissector tube. Five images, representing different portions of the film in the gate, produced by five stationary lenses, are superimposed one on top of the other, while a rotating shutter with concentric slots permits only one lens at a time to produce an image. The scanning is accomplished partly by the uniform motion of the film and partly by the magnetic scanning of the electron image in the opposite direction. The pictures thus obtained are completely free from shading, cover a great range of contrast, are free from flicker, and are steady. The construction of the scanner is simple and inexpensive.

"Safekeeping the Picture Industry;" K. W. Keene, *Underwriters Laboratories, Inc.*, San Francisco, Calif.

The purpose of the paper is to deal with a very specialized phase of the motion picture industry; that is, its hazards of fire and consequent accident, as due not solely but chiefly to the prevalent use of nitrocellulose film. Consideration will be given to the causes of hazards and an attempt made to show that they are real and what is being done about them.

The many organizations and groups concerned with and supporting the cause of fire prevention and protection in the industry are first described briefly as to their basic organization and methods, and are then correlated.

The publications by these organizations—standards, recommended regulations, *etc.*—as they bear on the picture industry with respect to the storage, handling and use of nitrocellulose film and the equipment associated therewith, are works not of one man or even of one group of men, but instead reflect the best opinions obtainable from a cross-section of all the industries and groups who are interested. The rules, so to speak, are formulated democratically.

All the many forces pitted against the common enemy, fire, are sincere, and it should be cause for pride that our American institutions—manufacturer, utility, insurance, government, education, association, *etc.*—support this cause unhesitantly and generously in time and money.

As distinguished from the recommended Regulations of the National Board of Fire Underwriters and the National Fire Protection Association, which in general specify the safe methods of installation and use of and needed safeguards for apparatus and equipment in the field, the Standards of Underwriters' Laboratories specify the safe construction and performance of apparatus and equipment and are applied and "policed" in the producing factory.

The paper concludes with a discussion of some of the underlying considerations affecting the Standards of Underwriters' Laboratories as applied to projectors, rewind machines, sound amplifiers, speakers, *etc.*

"RCA Aluminate Developers;" J. R. Alburger, *RCA Manufacturing Co.*, Camden, N. J.

A fundamentally new principle in design of photographic developers has been investigated and found to afford many worthwhile characteristics, chief of which is the effective self-replenishing property of the developer solutions. Application of the new principle to developer solution makes it possible to develop about eight times the quantity of film as would be possible under ordinary conditions. The principle may be applied to any developer.

"Push-Pull Class A-B Sound Track;" C. H. Cartwright, *Mass. Inst. of Tech.*, and W. S. Thompson, *RCA Manufacturing Company, Inc.*, Hollywood, Calif.

After an explanation of the term Class *A-B* and a brief specification of such a recording system, the general requirements for the operation of any Class *A-B* system are given and illustrated.

Differences between the operation of push-pull photocells and push-pull vacuum tubes are pointed out and explained, and a discussion of the relative advantages of Class *A*, Class *A-B*, and Class *B* push-pull tracks is given.

"A High-Intensity Arc for 16-Mm. Projection;" H. H. Strong, *Strong Electric Co.*, Toledo, Ohio.

A short description of a high-intensity reflector type projection arc lamp and associated rectifier equipment, designed as a light-source for 16-mm. projectors.

"The Status of Lens Making in America;" W. B. Rayton, *Bausch & Lomb Optical Mfg. Co.*, Rochester, N. Y.

When the modern optical industry was born, this country was predominantly agricultural. Its principal industrial developments related to transportation. It was natural, therefore, that Europe should have gained great prestige in the field of optics in the final quarter of the nineteenth century.

With the turn of the century, however, agricultural developments had about reached their limit and industrial activity began to occupy a larger place in American life. Along with others the optical industry felt the incentive to greater activity and the first fifteen years of this century saw a rapid advance in the magnitude of the industry and improvement in the quality of its product.

We were still, however, completely dependent on European sources of supply for our optical glass and for some of the small-demand class of laboratory instruments. Then came the war that not only cut off all aid from Europe but ultimately led Europe to our doors with appeals for optical munitions.

The war only hastened what would have been inevitable anyway, *viz.*, the complete independence of America in optical matters.

The American optical industry has now reached a point where its raw materials (optical glass) and its technical skill recognize no superiors. It can make any practical optical element or instrument for which quantitative specifications can be written.

"Notes on French 16-Mm. Equipment;" D. R. Canady, *Canady Sound Appliance Co.*, Cleveland, Ohio.

A brief résumé of French substandard projection equipment of unusual design including a general description of a practical application of the new water-cooled mercury-vapor lamp to 16-mm. projectors. Mention is made of an interesting projector that employs no sprockets, automatically adjusts the size of the loops, and reduces film wear to a minimum.

"New 16-Mm. Recording Equipment;" D. R. Canady, *Canady Sound Appliance Co.*, Cleveland, Ohio.

A description of new 16-mm. equipment, including recorder, film-phonograph, and a new 35-mm. to 16-mm. reduction printer.

"The Present Technical Status of 16-Mm. Sound-on-Film;" J. A. Maurer, *Berndt-Maurer Corp.*, New York, N. Y.

Improvements in the technic of recording and printing during the past few years have made possible the production of 16-mm. sound-films, either by optical reduction or by direct recording, having considerably better quality than is being obtained in general commercial practice. By the use of a moderate degree of equalization in recording, it is practicable to obtain from 16-mm. negative prints giving a flat frequency response to 6000 cycles, with useful response to 7500 cycles, when reproduced through a flat amplifying system. Harmonic and envelope distortion and speed variations can be kept within acceptable limits for high-quality reproduction. The principal remaining defect is background noise. Some general agreement upon commercial 16-mm. reproducing system characteristics is needed, however, before this improved quality can be made generally available.

"The Preservation of History in the Crypt of Civilization;" T. K. Peters, *Oglethorpe University*, Ga.

The problems confronting the scientist who inaugurates the unique task of preserving in film for the people of the 80th century a complete picture of our life in America today; the problem of the life of film and of its relationship to ancient papyrus that has come down to us over sixty centuries; the method of preserving it; the microfilming and preparation of the records; the making of a duplicate film on metal; and the entire scope of the project is set forth and discussed.

"New Frontiers for the Documentary Films;" A. A. Mercey, *United States Film Service, National Emergency Council*, Washington, D. C.

The motion picture today is the legacy of experimentation of the past. The ancient Egyptians indicated movement in their processional hieroglyphics; the Greeks suggested movement in the magnificent friezes on the Parthenon.

Muybridge's famed experiment with twelve cameras to catch the movements of a horse was antedated by experimentation of centuries before. Kircher with his magic lantern in 1640, Peter Mark Roget, Sir John Herschel, von Stampfer, Sellers, Heyl, the great Faraday, Daguerre, and Niepce—these and others worked and contributed to establish in practicality the law of persistence of vision with regard to moving objects.

From the still camera to the movie camera, man moved into new realms of record and drama. Thus was evolved the fade-out, the close-up, special lighting, dissolves, and process shots. We had the Melies, the Lumières, the Griffiths, and the deMilles contributing to early production technics.

The documentary is one of our oldest movie forms, for it means factual photography with the impact of drama. The documentalist takes real people in real places. The 15 years from Flaherty's *Nanook of the North* to Lorentz's *The River* represent years of advance in engineering; but those working in the medium recognize many unsolved problems of sight and sound.

The problems of modern life open exciting possibilities for both the producer and the engineer—problems that will mean new developments in the science of the motion picture. We have great frontiers ahead in the production of documentaries on housing, recreation, the business of food distribution, the problem of raising and obtaining food, communications, the conservation of natural resources, the backgrounds and rumors of war—all these offer a challenge to both the engineer and the producer, for in working together they will contribute much to a great art and a great science—the modern motion picture.

"A New Magnetic Recorder and Its Adaptations;" S. J. Begun, *Brush Development Co.*, Cleveland, Ohio.

A magnetic recording machine is now commercially available, using an endless steel tape loop as a recording vehicle. Such an endless loop makes it possible to record and reproduce without reversing the direction of rotation of the mechanism. Neither is it necessary to manipulate the recording and pick-up heads.

The simple operation of the unit makes it not only ideal for educational purposes, but also makes it very adaptable where a signal is to be repeated to a great number of times, or where reproduction is required shortly after recording, and where only the one reproduction is required. The same machine, with simple modifications, adapts itself to a great number of uses.

Exhaustive tests have been conducted to determine the life and the durability of the machine, under very severe conditions, and when operated by a layman. The results of such tests have been in every degree satisfactory.

"Lamps and Optical Systems for Sound Reproduction;" F. E. Carlson, *General Electric Co.*, Cleveland, Ohio.

Sound reproduction systems are designed on the premise that the sound-track will be illuminated by a scanning-beam of substantially uniform flux density. This paper presents results of extensive studies of the actual beam characteristics for all types of optical systems and lamps employed in the reproduction of sound from film. They were made possible by a unique microphotometer, designed by the author, with which the scanning beam can be analyzed in minute elements.

The studies cover: Relative levels of scanning beam illumination; effect of source displacement from design position on total flux at the sound-track; microphotometer recordings of distribution of flux density across the beam as affected by optical systems and source forms and by displacements of the source.

Report of the Studio Lighting Committee; C. W. Handley, *Chairman*.

An explanation is given of lighting problems from the viewpoint of the cinematographer. Certain advances in equipment and working tools remain in obscurity for a long period before they find their rightful places in motion picture set lighting because they seem to interfere with dramatic effect. If they possess merit, however, they are gradually adapted to general use. A typical example is the light-meter, which is now going through the final stages of assimilation to studio lighting technic. New fast films have been brought into use and the resulting changes in lighting technic are now in the process of perfection. Recent changes in lighting equipment are described. Three new higher-speed negative films for the Technicolor process are being used. The effect of the new films on Technicolor set lighting is explained.

"Further Improvements in Light Record Reproducers and Theoretical Considerations Entering into Their Design;" A. L. Williams, *Brush Development Co.*, Cleveland, Ohio.

Direct recording is becoming commercially more and more important. Acetate blanks are used for high-quality recordings, but these materials are essentially softer than pressed records, and therefore make necessary new considerations in the design of a high quality pick-up to be used with them.

It is shown that a dynamic stylus pressure of approximately 25 grams is the maximum force that acetate can tolerate without permanent deformation of the modulated grooves, even when due consideration is given to the proper matching of stiffness and inertia of the vibratory system of the pickup. A simple formula is given for the most suitable condition of the matching of inertia and stiffness for a complex wave-form.

Other factors that interfere with the construction of a light pick-up, such as uneven record and turntable surfaces, are explained, and suggestions are made for the reduction of these effects. The advantages of "constant amplitude" as a method of recording and reproduction, are shown, and a constant amplitude system is demonstrated.

"Application of Motion Picture Film to Television;" E. W. Engstrom and G. L. Beers, *RCA Manufacturing Co.*, Camden, N. J.

Motion picture film will form an important part of programs for television broadcasting. Film projectors for this use are required to meet a number of conditions peculiar to television. Methods for projecting and utilizing motion picture film are outlined. A specific film projector and associated television channel are described in some detail.

In establishing a technic for producing films most suitable for television, equipment is needed to interpret properly the final results. Apparatus that will be used by broadcasting stations is described. A simpler system has been designed that may be useful for the specialized service of gauging the merit of films for television. This is described and its operation indicated.

Some very preliminary observations are included on the characteristics of films that have given good results in experimental work and in field tests.

"Television Studio Technic;" A. Protzman, *National Broadcasting System*, New York, N. Y.

The studio operating technic as practiced in the NBC television studios today are discussed and comparisons are made, where possible, to motion picture technic. Preliminary investigations conducted to derive a television operating technic revealed that both the theater and the motion picture could contribute certain practices.

The problems of lighting, scenic design, background projection, and make-up are discussed, with special emphasis on the difficulties and differences that make television studio practice unique.

An explanation is given of the functioning of a special circuit used in television sound pick-up to aids in the creation of the illusion of close-up and long-shot sound perspective without impracticable amount of microphone movement. The paper concludes with a typical television production routine showing the coördination and timing of personnel and equipment required in producing a television program.

"Methods of Using and Coördinating Photoelectric Exposure-Meters at the 20th Century-Fox Studios;" D. B. Clark, *Twentieth Century-Fox Studios*, Hollywood, Calif.

Consistency in negative printing values is one of the most desirable single factors in modern cinematography. Photoelectric light-measuring devices can help the cinematographer maintain such consistency to a far greater degree than is possible otherwise. Not only tests, but actual production have shown that with the proper use of these instruments, the entire output of the studio's camera staff can be so coördinated that, almost without regard to the photographic conditions prevailing on the set, all negative will print correctly within a range of three or four printer-light adjustments.

To make this coördination possible, several requirements must be recognized. Among these are a dominant, and by no means completely fulfilled demand for photocell meters of unfailing consistency; *i. e.*, meters that are not subject to error from photocell fatigue, changes in humidity or temperature, and the like, and are sufficiently uniform that all the studio's meters may be expected to give uniform readings under any given conditions.

While these requirements are not wholly met in existing meters, it has been found possible to use such meters to advantage. Coördination is effected by use of a special, portable testing unit of the photometer type. In this a standard light-source is used in circuit with a battery and milliammeter, and controlled by a rheostat. When the light is brought to known intensities by the application of known currents, the photocell meter being tested must, if accurate, give predetermined readings.

Further logical developments, predictable on the basis of existing knowledge or equipment, should include complete acceptance of strict time-and-temperature methods of negative development and some form of automatic, photoelectric-cell-controlled print-timing. This would remove all variables, including human fallibility, from the processing problem, and leave the responsibility for results solely in the hands of the cinematographer, who would in turn be guided by his meter in keeping within the tolerances imposed by film and processing, and in his efforts to turn out consistently ideally exposed negative.

"20th Century Silent Camera;" G. Laube, *Twentieth Century-Fox Film Corp.*, Hollywood, Calif.

The camera operates without any sound-proofing box or blimp, weighs sixty pounds and is the first instrument of its kind to function without the incumbrance of sound-proofing enclosures.

A microscope viewing finder is built into the camera and is brought into position back of the photographing lens by rotating the camera case, which is mounted in a yoke.

The monitor view-finder is rigidly secured to the side of the camera and does not pivot or swing. However, the image produced by it truly conforms to the image being photographed on the film. This feature enables the operator to work with the complete assurance of seeing exactly what is being recorded on the film and without having to guess or make allowances for such errors that arise from parallax and change of focus.

The camera derives its driving power from a motor mounted on the back of the yoke member and drives direct to the shutter. Either synchronous or a-c. interlock motors may be used and driven at shutter speed. This type of drive assures an even and undisturbed rotating motion of the shutter.

The film-moving mechanism, or the so-called camera movement, embodies elements of absolute precision and locates each frame of the picture with registering pins that remain stationary during the exposure. The film is moved from frame to frame at a slower speed than with former cameras and with uniform acceleration, overcoming film damage and loop slap.

The dwell time, or the period when the film is standing still and receiving the exposure, is long and allows for exposure with a 200-degree shutter. These features provide a means for producing pictures showing a superb quality of definition and freedom from defects.

Many features of convenience are apparent. The camera may be synchronized with projection process by looking through a special aperture and turning a knob at the back. The camera conveniently loads when on a low or high set-up. The operator has an unobstructed view of the set when lining up, and may look directly over the camera. All parts are completely sealed from the action of sand, dirt, and water. The camera turret mounts four lenses and provides a quick change from one to another. The freehead is a new hydraulic type, with adjustable drag on both pan and tilt members.

SOCIETY ANNOUNCEMENTS

ATLANTIC COAST SECTION

At a meeting held at the Hotel Pennsylvania on March 8th, W. B. Rayton, of Bausch & Lomb Optical Company, Rochester, N. Y., presented a talk on a new series of projection lenses now in the course of design. The talk included a discussion of various factors involved in projecting light from the arc to the screen and the necessary relations between the size of the illuminant, the reflector, and the lens elements. The meeting was well attended and an interesting discussion followed the lecture.

The next meeting of the Section will be held at the Eastern Service Studios, Long Island City, N. Y., on April 6th, under the direction of R. O. Strock.

MID-WEST SECTION

On February 28th, at a meeting held at the Western Society of Engineers, Chicago, Ill., A. Shapiro, of the Ampro Corporation, Chicago, presented an illustrated talk on the subject of "Motion Pictures in Education." Briefly tracing the history of educational pictures, the educational advantages resulting from the addition of sound were analyzed. The paper was illustrated by typical classroom pictures entitled *Sound Waves and Their Sources* and *The Plow Breaks the Plains.*

ADMISSIONS COMMITTEE

At a recent meeting of the Admissions Committee at the General Office of the Society, the following applicants for membership were admitted to the Associate grade:

Alter, W. D.
717 Hazlett St.,
Brackenridge, Penna.

Bailey, G. C.
Kodak Mexicans Ltd.,
San Jeronimo 24, Apartado 7440,
Mexico, D. F.

Bantau, A. F.
902 W. 47th St.,
Los Angeles, Calif.

Freeman, L. C.
556 Westfield Ave.,
Westfield, N. J.

Hoover, G.
7635 Grand River Ave.,
Detroit, Mich.

Gray, G. F.
Box 600,
South Norwalk, Conn.

Javor, F. A.
232 Montgomery St.,
Jersey City, N. J.

K. M. Logue,
1245—20th Ave.,
Longview, Wash.

NADEL, L.
Zlota 65,
Warsaw, Poland

NORTON, J. S.
1922 N. Taft Ave.,
Hollywood, Calif.

NUNAN, J. K.
8612 Third Ave.,
Inglewood, Calif.

PERKINS, C. S.
1371 Walnut St.,
Newton Highlands, Mass.

SHORER, R. W.
18 West Court,
Sausuito, Calif.

WESSON, R.
203 Brunswick St.,
Rochester, N. Y.

WILSON, W. H.
National Carbon Co.,
30 East 42nd St.,
New York, N. Y.

WRIGHT, J. H.
412 W. Fifth St.,
Jamestown, N. Y.

ZOCHLING, L.
847 Lothrop Ave.,
Detroit, Mich.

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 400 feet long.

Price $25.00 each.

JOURNAL
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A CONSIDERATION OF THE SCREEN BRIGHTNESS PROBLEM*

O. REEB**

Summary.—The great interest that the problem of optimal screen brightness holds in motion picture engineering is proved by the numerous researches on the subject in recent years. Besides the very interesting American papers published in this Journal, some recent German works are worthy of consideration.

In 1936 Zimmermann determined the dependence of the visual effect upon the screen brightness and found that a maximum value is attained at about 14 foot-lamberts. He investigated also the influence of light distribution, and temporary brightness changes. Finally he pointed out that the time the eye needs to see all recognizable contrasts varies, according to the brightness level, between $^1/_3$ and $^1/_{10}$ second.

In 1936 Rieck verified, under conditions similar to those in cinema theaters, the character of the contrast-sensibility relation that Brodhun and König had found in their classical research.

Very recently H. Frieser and W. Münch reported results obtained by projecting a detail test-object. They determined the contrast threshold function under conditions very similar to those of actual projection. They did not find a material increase in the number of distinguishable contrast steps for picture brightnesses exceeding 10 foot-lamberts.

It is to be hoped that the consideration of the results of all these investigations will form a basis for early temporary screen brightness standardization.

The numerous investigations, reports, and discussions on the problem of screen brightness that have been published in the JOURNAL within recent years indicate the great interest which the study of this question has aroused in America.

Since the differences of screen brightness in the various theaters are large and the average brightness level is comparatively small, it is difficult for the industry to make prints suitable for all theaters. For that reason there is also in Germany a desire to arrive at a screen brightness standard that would make for the best possible uniformity of screen illumination. During recent years, three important investigations have been made in Germany to clear up these questions.

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* Presented at the 1938 Spring Meeting at Washington, D. C.; received April 14, 1938.

** Osram G. m. b. H., Berlin, Germany.

In 1936 K. F. Zimmermann[1] published the results of an investigation which had been carried out in the Illuminating Engineering Laboratory of the Osram Company. In this investigation he determined experimentally the contrast sensitivity of the eye under conditions very similar to those found in motion picture projection. In order to be able to determine the contrast sensitivity not only for contrast thresholds but also for the greater contrasts which are observed more frequently when pictures are projected on a screen, he chose as a criterion the time of observation necessary to recognize a certain contrast. Fig. 1 shows a projection field of the same kind as used in his experiments. The field is divided into four equal parts. Near the center a small circular test-contrast area was projected alternately into one of the four quadrants, the time of exposure being changed each time. The observer was required to indicate whether he had seen the test circle, and if so, in which quadrant. The brightness of the adaptation field was varied between approximately 0.5 and 14 foot-lamberts,* while the brightness of the small contrast field projected upon the adaptation field was varied between about 5 and 33 foot-lamberts. The sizes** of the screens used were 13, 19, or 26 degrees and the size of the contrast field was 11 minutes.

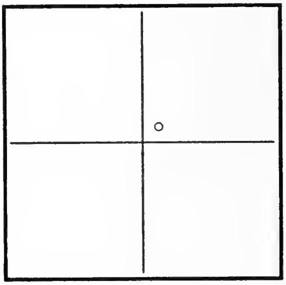

FIG. 1. Test-field used by Zimmermann.

Of the results of this work only the most important will be described here:

(*1*) If the ratio of the brightness being projected in the small test-field in relation to the brightness of the total area is designated as contrast, it is shown that the product of contrast and required time of observation remains constant with constant adaptation brightness. In other words, at a certain adaptation brightness, the stimulus time necessary to recognize a certain contrast is in inverse proportion to

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* Brightness values are here given in foot-lamberts. In the German reports the unit *apostilb* (abbr. *asb.*) is used. 10 asb. = 1 millilambert = 0.93 foot-lambert.

The question of which unit would be most suitable for use in international standardization is not discussed here, as neither the foot-lambert nor the apostilb is accepted as an international unit.

** *I. e.*, the angle of the projected beam (*Ed.*).

the test contrast. Zimmermann defines the reciprocal value of this product as *Sehleistung,* an expression which may be translated as "visual effect." Hence, the larger the visual effect, the shorter the time required for the eye to recognize a certain contrast, and the smaller the contrasts recognized within a certain time. Furthermore, the visual effect is constant for a definite adaptation brightness.

(*2*) The dependence of the visual effect upon the adaptation brightness as found by Zimmermann is shown in Fig. 2. Curves *1, 2,* and *3* correspond to three different screen sizes (13°, 19°, and 26°). Accordingly, the visual effect increases very rapidly in the lower adaptation brightness ranges, and at the higher brightness ranges, the

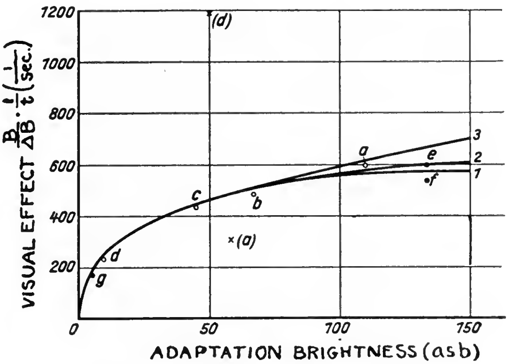

FIG. 2. Dependence of visual effect upon adaptation brightness. Image size: (*1*) 26°, (*2*) 19°, (*3*) 13°.

increase is very slow. At a screen size of 26°, a maximum visual effect is reached with a picture brightness of 14 foot-lamberts. At brightnesses of over approximately 7.5 foot-lamberts, no considerable increase of visual effect is reached with larger areas.

(*3*) In some experiments, in order to examine the influence of brightness distribution in the screen area, Zimmermann replaced the uniformly lighted screen with a checkered field (Fig. 3) and varied the brightness of the central field and of the checkered field in different combinations. All these experiments proved clearly that for the attained visual effect only the central brightness of the screen is important.

(*4*) In a further series of experiments Zimmermann investigated the influence of a temporary change of the adaptation brightness as it occurs with the change from a light scene to a dark one and *vice versa*. A temporary brightness contrast of 1:2.6 did not influence the measured visual effect, while temporary contrasts of 1:20 or 23:1 resulted in a decrease of the visual effect of about 11 per cent.

(*5*) An investigation to determine whether, at the same brightness, screen areas of different sizes would cause different brightness impressions on the eye of the observer, did not give any definite proof of such an effect at screen sizes of 8° and 26°.

(*6*) From the constancy of the product contrast × stimulus time it was concluded that, at the adaptation brightness concerned, the greatest stimulus time belongs to the smallest contrast perceivable,

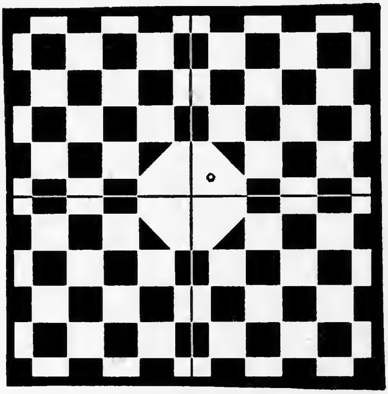

FIG. 3. Checkered test-field used by Zimmermann.

i. e., the threshold contrast. This maximum stimulus time is consequently the time needed by the eye for the perception of all contrasts recognizable at all with the special adaptation brightness used in this case. The dependence of this maximum stimulus time upon the adaptation brightness is shown in Fig. 4. This maximum stimulus time has a value of about 0.1 second at high brightnesses (10 to 14 foot-lamberts); while maximum stimulus times of about 0.2 to 0.3 second are necessary at lower brightnesses which correspond to shadow details in the picture. Incidentally, Zimmermann's results are based upon 42,000 observations gathered from eleven observers.

The classical researches of König-Brodhun on the contrast sensitivity of the eye in relation to the adaptation brightness were completed in 1936 with an investigation by Rieck[2] in the Beleuchtungstechnisches Institut der Technischen Hochschule Berlin. Rieck determined the contrast threshold up to a field brightness of about 185

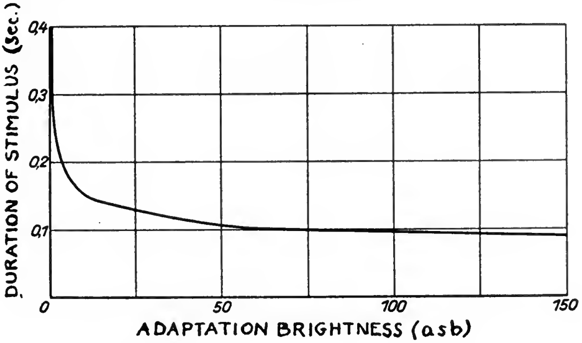

FIG. 4. Dependence of maximum stimulus time upon adaptation brightness.

foot-lamberts for a screen of 20° and a test-field of 2°. The systematic course of his curves (Fig. 5) agrees with the values of König-Brodhun obtained with an adaptation field of 6° and a test-field of 3°.

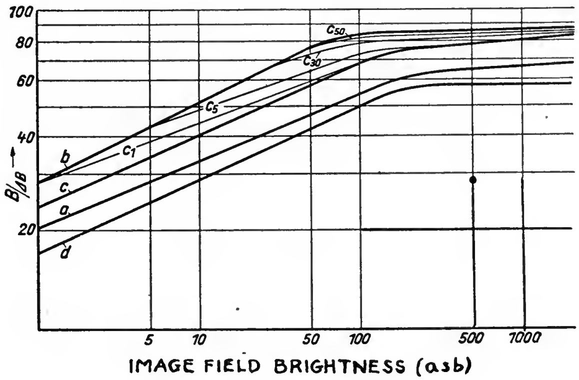

FIG. 5. Dependence of contrast threshold upon adaptation brightness. Surrounding field brightness (*a*) = 0; (*b*) = image field brightness; (*c*) = image field brightness; (*d*) = sensitivity difference according to König-Brodhun. Curves *a*, *b*, and *c* from measurements by Rieck.

The absolute values are a little higher with the larger area used in Rieck's investigations. A change in the brightness of the surrounding field results, according to Rieck's investigations, in an increase of the contrast sensitivity, until the brightness of the surrounding field is equal to the brightness of the screen area.

This statement, that the best contrast sensitivity is to be attained with a very bright surrounding field, seems to be in opposition to the work of O'Brien and Tuttle, who demonstrated that only very low brightnesses of the surrounding field are considered as not being disturbing to the spectator. However, comparison of these two results is very difficult, because it is not known which average brightness of the projected picture of O'Brien and Tuttle's experiments should be compared with Rieck's adaptation brightness values.

Fig. 6. Detail-plate used by Frieser and Münch.

Frieser and Münch[3] investigated the visual conditions in a projected picture, thus approaching more closely to the conditions found in actual practice than did former experimenters. These investigations were carried out in the Wissenschaftlich-Photographisches Institut of the Dresden Technische Hochschule and have been published only very recently. For their purpose Frieser and Münch used a so-called detail-plate, following the example of Goldberg and Luther. This in effect consisted of two crossed neutral gray wedges. One gray wedge extending uniformly over the whole field was combined with a plate provided with detailed stripes, its gradation of brightness being at right angles to that of the gray wedge. This forms the complete detail-plate shown in Fig. 6. Such a detail-plate makes it possible to determine, in a single screen area, the dependence of the contrast threshold upon the adaptation brightness which is variable between wide limits by means of the gray wedge. A detail-plate was projected by Frieser and Münch into a normally projected picture, as shown in Fig. 7. The different observers explored the picture to determine the just-recognizable contrasts. The results were recorded on a sheet of paper by an automatic device. Fig. 8 shows curves obtained by one observer.

Fig. 9 shows the dependence of the contrast sensitivity upon the brightness for different maximum brightnesses of the projected picture. Every curve corresponds to a special maximum brightness of the picture and of the detail-plate. It is evident that at lower maximal brightnesses there is a greater contrast sensitivity for lower brightness details than at higher maximum brightnesses. At higher brightness this proportion reverses, probably due to glare.

Further investigations of the authors refer to the dependence of the curves obtained of the contrast sensitivity upon the character, the brightness, and the size of the projected picture, and upon the influence of the change of adaptation when entering the projection room. From these results will be pointed out only the fact that no

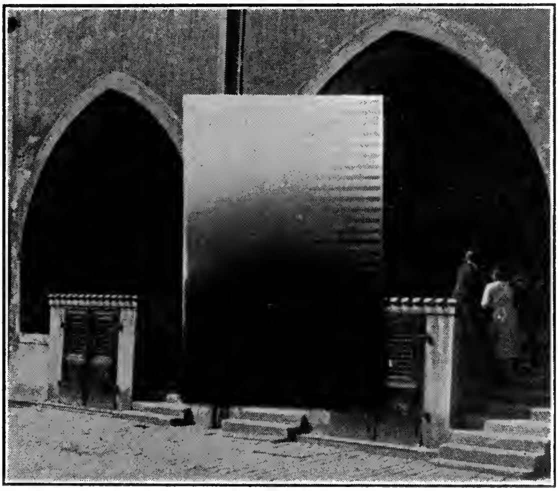

FIG. 7. Example of test-picture used by Frieser and Münch.

influence of the contrast sensitivity was noticed with a change in the screen size from 23° to 63°.

Finally (Fig. 10), the number of brightness steps distinguishable in a picture and the course of the visual acuity, as charted, is dependent upon the maximum brightness. It can be seen, as observed by Luckiesh, that the maximum value of the visual acuity is already attained with very low brightnesses. Also, the number of recognizable brightness thresholds increases very quickly at first, but there is no considerable increase with brightnesses of more than about 10 foot-lamberts.

A comparison of the results given by these three investigations shows the following:

Zimmermann's measurements of the visual effect and Rieck's values of the contrast threshold agree very well, although the methods used are very different. They both found that an optimum value of

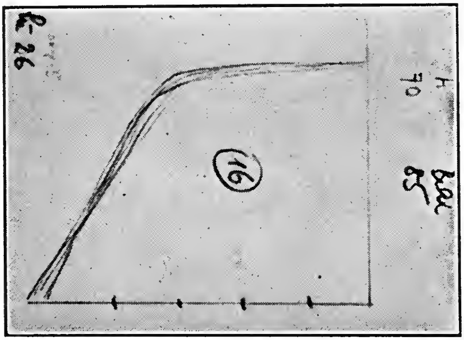

FIG. 8. Example of test-sheet obtained by one observer in Frieser and Münch's investigation.

visual conditions is attained with about 14 foot-lamberts, and that the visual effect corresponding to 8 foot-lamberts is not essentially surpassed by a further increase of the adaptation brightness. In these

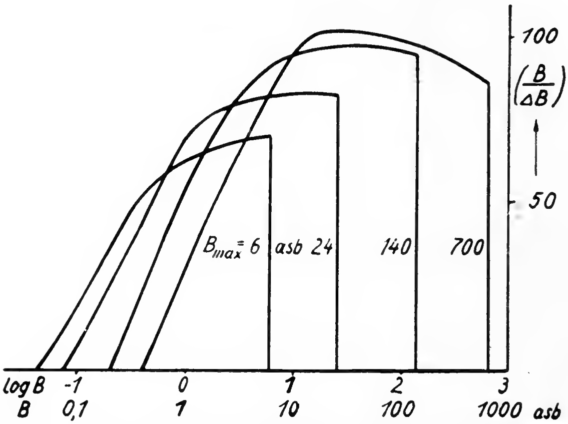

FIG. 9. Dependence of contrast sensitivity upon brightness.

researches the question is not answered as to which brightness value of various brightnesses existing in a really projected picture corresponds to the "adaptation brightness" of these experiments. This problem is solved to a large degree by the investigations of Frieser and Münch. These authors found a curve showing the relation between the number of recognizable contrast thresholds and *maximum* picture brightness, whose character is very similar to those of Zimmermann's and Rieck's curves. Thus, Frieser and Münch conclude, also, that a minimum brightness of about 8 foot-lamberts with running shutter and no film in the gate is sufficient to guarantee good picture projection. Although they found a slight increase of picture quality with still higher brightness levels, they believe that values of more than 8 foot-lamberts in the lightest parts of the picture, which

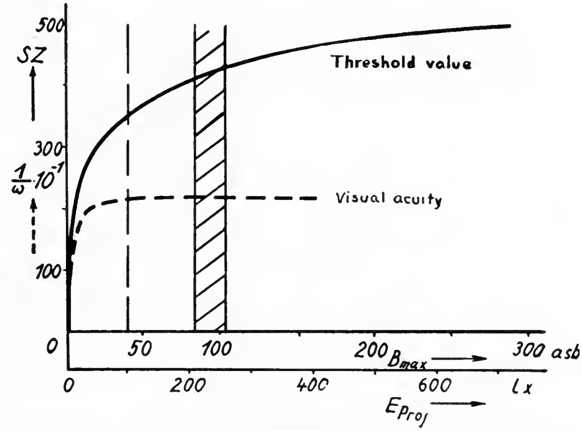

FIG. 10. Number of brightness steps and visual acuity as dependent upon maximum brightness.

corresponds to about 16 foot-lamberts without film, would not be so satisfactory on account of the possibility of flicker.

Between the results of the reported German researches and those of the SMPE Projection Screen Brightness Committee there is a large degree of similarity. This agreement seems surprisingly good with regard to the very different methods and conditions used by Lowry, O'Brien and Tuttle, Wolf, Luckiesh and Moss, and other American investigators.

A discussion of the German researches by the experts of the "Deutsche Kinotechnische Gesellschaft" showed that there is a possibility of arriving at a standard of screen brightness in the not too distant future. The German experts believe it best to recommend a brightness value that can be attained in all theaters, even the largest.

This is the reason why the difference from 7 foot-lamberts for the low value to 14 foot-lamberts for the high value seems too great. We in Germany would prefer a brightness standard of 8 foot-lamberts, which could be followed by all theaters, instead of a higher standard, which would furnish only a slightly better visual effect and would not be attainable by all theaters.

Moreover, screen brightness standardization should be completed by a recommendation limiting the brightness losses that occur both at the border of the screen and by viewing the screen under the largest observation angle possible in the individual theater. This latter limit is necessary in regard to the screens of the directional type. A brightness loss of 25 per cent measured horizontally from the center to the screen border and a loss of 50 per cent for viewing at the most unfavorable angle to the screen seem to be admissible.

We feel that it would be very desirable to make brightness measurements, as promptly as possible, in a number of motion picture theaters, under different conditions at the center of the screen, at the border, and with different viewing angles. We intend to start such measurements in Germany in the near future, and feel that it would be another step toward the desired goal of standardization if also in America more such data could be obtained. A survey of such data would provide a very good basis for discussion at next year's meeting of the International Commission on Illumination. There we might aspire to international agreement, which is requisite for uniformly good projection of the films in the various countries. I am exceedingly glad to have had the opportunity of speaking here on these problems, especially since the preparation of the screen brightness discussion for the 1939 ICI meeting lies in the hands of the American secretariat.

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[2] RIECK: *Das Licht* (Dec., 1936), p. 246.

[3] FRIESER AND MÜNCH: *Die Kinotechnik* (April, 1938).

A NEW 16-MM. FILM DEVELOPING MACHINE*

J. M. BLANEY**

Summary.—*A 16-mm. developing machine designed for installation in loft buildings without disturbing overhead ducts and piping is described. The machine is rated at 150 feet per minute. A detailed description is given of the constructional features of the equipment and its control.*

The 16-mm. developing machine described here is designed for installation in loft buildings without disturbing overhead ducts and piping. It is 20 feet long by 28 inches wide, and stands 74 inches high, exclusive of air ducts which may enter from either the top or the bottom of the dryer (Fig. 1).

The machine is rated at 150 feet per minute and, at that speed, development is effected in $3^1/_2$ minutes, fixing in $3^1/_2$ minutes, and washing in 7 minutes. The minimum drying period is 16 minutes, thus providing for low-temperature drying and, consequently, improvement in sound and picture quality.

There are two main drive shafts without couplings mounted in tandem on a structural steel frame which is normalized and accurately machined. These shafts are coupled through a gear box to a jack shaft which connects through a Dayton drive to a 5:1 variable-speed transmission. Both the motor and speed variations are remote-controlled electrically from the operator's station.

The motor control is provided with a device which assures an automatic slow start even when the machine has been stopped at the 150 feet per minute setting.

The dry elevator is built into the structural support for the wet drive frame and the film is protected effectively from light during storage. The four dryer compartments are similarly built into a unit structure which supports the dryer drive frame and gear box (Fig. 2). Spanning these two structures is the wet drive frame beneath which

* Presented at the 1938 Fall Meeting at Detroit, Mich.; received October 28, 1938.

** Cinaudagraph Corp., Stamford, Conn.

are five hard-rubber lined steel tanks which are supported independently of the drive structures.

The dry elevator has the conventional floating bottom shaft with a special device which increases the weight when elevated but is inoperative when in the running position. The elevator tows a feed-reel of 1200-ft. capacity and the film loops over a stop roller which automatically sets the elevator in operation as soon as a reel empties.

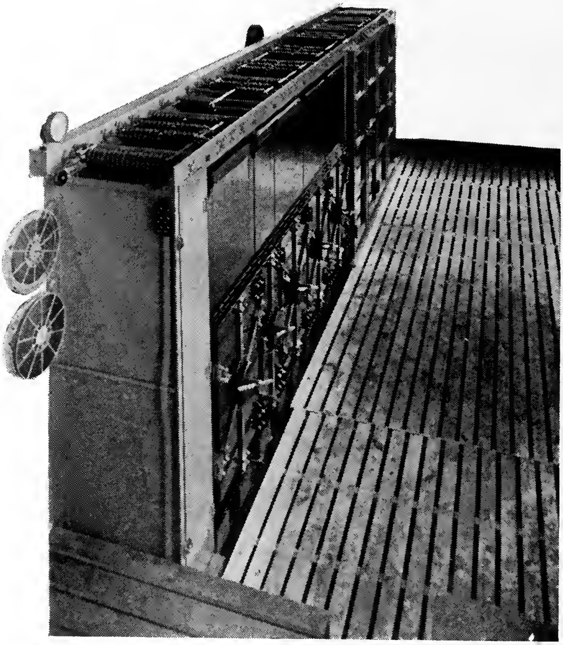

FIG. 1. Assembly with dryer ducts removed.

A special splicing block makes possible the joining of film in 20 seconds, in accurate register even in total darkness. A tachometer at the operator's station indicates film feet per minute.

While the machine is of the sprocket type, both the sprockets and the method of drive are radical departures from previous practice.

The developer section is described in detail since it is typical of the wet process drive although differing from that of the dryer. Three corrosion-resistant shafts extend across the drive frame and directly over the developer tank. These shafts are coupled to the main drive shaft through spiral miter gears.

On each of these three shafts are mounted in turn a sprocket, fifteen film rollers having an effective diameter about 140 per cent greater than that of the sprocket, and finally a film roller with a diameter equal to that of the sprocket. All the film rollers idle on the shaft except two rollers located midway which idle on a large hub fixed to the shaft. Three bottom shafts are supported in cone bearings by a unit frame which is affixed to pedestals in the bottom of the

FIG. 2. View from dryer end.

hard-rubber lined steel tank (Fig. 3). On each bottom shaft are fourteen idle rollers and one fixed roller with an idle spacer. Each section is provided with a device which we term a "compensator," since one of its functions is an expansion and contraction adjustment, but it serves other purposes later described in detail. The compensator consists of a weight, weight rod, and yoke between the jaws of which is mounted a film roller on cone bearings.

The threading of a single wet-process section is described in order to make more apparent the functions of the parts, the order of description being that of the film travel. The film is passed over a sprocket and is threaded in seven loops between as many top and bottom rollers, all of which are in fixed axial relation but capable of independent rotation. The eighth strand passes under the compensator roller and describes eight more loops over film rollers mounted similarly to the first set. The film finally passes over the last roller to a sprocket on the next subsequent shaft. Each sprocket is therefore the prime mover for the system immediately preceding.

The set-up of each top and bottom system results in fifteen fixed loops and a single automatically adjustable loop formed by the com-

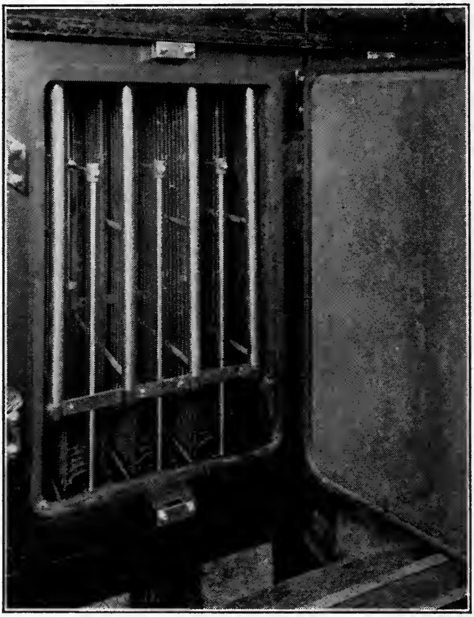

FIG. 3. Hard-rubber lined development tank, showing turbulator.

pensator, which is so located that it tends to draw by gravity the first seven loops in the forward direction but retards the travel of the subsequent eight loops. The top shaft, as previously described, carries sixteen independently rotatable rollers, all save one of which are of larger diameter than that of the sprocket (Fig. 1). The driven shaft sets up an individual torque on the various rollers which varies with the tension of each subsequent loop and, in the case of two rollers located immediately subsequent to the compensator, an excess torque is developed by reason of the enlarged shaft at this point.

The bottom loop-forming rollers are mounted on one shaft in groups of seven and eight with a spacer corresponding with the compensator position. All rollers are independently rotatable save the last in the series and the shaft itself is freely rotatable on cone bearings. In operation, the torque of the rollers causes the shaft to rotate with not more than one-half of one per cent lag, provided the bearings are in an ideal condition, and the wear on the rollers is therefore but one two-hundredth that of rollers on a fixed shaft. Because of the tendency of corrosion-resistant metals to gall and the impracticability of using dissimilar alloys because of electrolysis in certain baths, the final roller is affixed to the shaft thus assuring constant rotation.

Upon starting the machine, the sprocket raises the tension on the loop immediately preceding, which in turn increases the traction of the oversize roller on the rotating drive shaft. This is repeated in reverse direction to the film travel through six loops upon which the tension is applied to the two rollers mounted on the enlarged shaft. Here the increased torque applies replenishing energy to the compensator which has been in the meantime controlling the torque on the seven loops immediately preceding. The tension on the first loop preceding the sprocket tends to increase slightly with the speed of the machine, but the tension of the entering loop decreases under similar conditions. Thus the average film tension is practically independent of speed and the extremes vary but slightly. It will be noted that the positive, or pulling, side of the sprocket is subject to appreciably fewer shocks due to splices and film irregularities traversing the film roller system since they are effectively absorbed by the fixed roller on the bottom shaft, and the negative side of each sprocket is always feeding film into a loop which is never under tension. Thus the sprockets serve more as synchronous pacers than as pulling devices; in fact, the tension on the one loop under direct pull of the sprocket is much less than that on the compensator loop, the value of the former being about seven ounces and of the latter about nine ounces at maximum speed.

The three-loop rinse, the fixer, and the two wash systems are operated in a manner identical to that of the developer section previously described, but the dryer system is differently constructed since the film travel is not subject to the retarding effect of liquids, and a shrinkage problem is introduced, especially when film stock or even expanded leader is allowed to dry in the cabinet without motion.

In the dryer the top shafts are driven in the same manner as in the wet processes. Each top shaft is mounted with a sprocket, fifteen oversize rollers, and one small roller. The bottom shafts are fixed, and support fifteen rollers. In the direction of film travel, fifteen loops traversing rollers with fixed axes are followed by a single compensator loop. The compensator is energized by its sprocket, and the film is towed through largely by gravity, but, although both the top and bottom rollers are ball-bearing mounted, a measurable torque is imparted to the individual top rollers through the traction of the inner races on the driven shafts. Because of the ball-bearing rollers, it is possible to stop the machine for any length of time, even to the extent of drying a cabinet full of processed stock, without rupture or damage since the tension on any strand can not exceed seven ounces. As the film contracts, the rollers rotate backward, thus lifting the compensator assembly.

The sprockets are of corrosion-resistant metal and are made in three pieces, a flanged hub, a sprocket disk, and a flanged head. The sprocket roller is constructed with three lands, two of which straddle the sprocket disk. The land diameters are identical and exceed the pitch diameter of the sprocket disk by about 0.010 inch. Although the sprocket disks are carefully hobbed, it is impossible to obtain a smooth pitch circle and absolute absence of a fillet at the tooth root. In any event, the film should not be supported by the pitch circle since perforation burrs contact the surface in a disadvantageous manner. Hence the film is entirely supported on the roller lands which are highly polished in the direction of film travel. The lands are therefore the effective pitch diameter of the sprocket.

The sprocket formula is a radical departure from current practice. Sixteen-mm. safety film is subject to about two and one-half times the expansion and contraction that obtains when processing 35-mm. nitrate stocks; with the former a sprocket-hole pitch range of 0.0035-inch is common when old leader is employed and especially when the drying conditions are adverse. Since the standard sprocket-hole height is but 0.050 inch and a tooth root dedendum must be applied, it is impracticable to employ a tooth root exceeding 0.030 inch, even with a small arc of contact. Furthermore, there is but one line of sprocket-holes, and consequently except under the optimum pitch value for a given sprocket, a single tooth at a time takes the entire pull. Despite the fact that the tension on the film at the sprocket had been decreased to as little as six ounces, it was found that all the sprockets commercially obtainable caused picking and consequent damage to the sprocket-hole webs. Investigation showed that the pitch diameter of these sprockets was such that shrunken film fitted the sprocket with all teeth in engagement, and, of course, expanded film fitted the pitch circle with one tooth only in contact provided the tooth root dedendum was sufficient, lacking which the expanded film rode on the teeth and the damage to the film became enormous. It is apparent that the conventional design is based on an optimum when the film is at the point of maximum contraction, where the film is dry and toughest, but the tooth-to-tooth slip is greatest when the film is at maximum expansion at which point it is wet and liable to damage.

The pitch circle of the sprocket (*i. e.*, the land circumference), is such that film at maximum expansion fits with all teeth in engagement and the slip is greatest with shrunk film. Upon laying out models on a large scale based on these diametrically opposed systems, it was discovered that the conventional sprocket accommodates the wet, expanded film by a tooth-to-tooth impact against the sprocket-hole web in a forward direction and against the inertia of the film plus the lag of the loop. But the new design, having no slip at the optimum expansion operates by tooth-to-tooth retardation assisted by inertia and film lag when the film is contracted and tough. On the Cinaudagraph machine, these observations were confirmed by stroboscopic examinations.

The somewhat obscure impact effect inherent in the conventional sprocket may be made clearer by considering the lands as a simple pulley. If the effective diameter of the sprocket is such that contracted film will wrap around the lands with sprocket-holes just matching and assuming perfect traction, the sprocket-holes and the linear footage would have a certain ratio and the introduction of sprocket teeth would serve no purpose until traction is lost. Upon feeding expanded film over this roller the same footage would pass but too few sprocket-holes per revolution. Sprocket teeth must necessarily push the film forward by individual impact, one tooth at a time.

The Cinaudagraph sprocket is designed to roll film at optimum expansion with sprocket-holes in synchronism with the teeth. When shrunken film is fed, the lands tend to roll too many sprocket-holes per revolution, and the teeth merely retard the travel. Hence, the teeth of the conventional sprocket operate by impacting the web of the film perforation and under adverse conditions; but the teeth of the Cinaudagraph sprocket retard the overdrive tendency of the lands and the impact of the sprocket-hole web is against the teeth, which is minimized by the friction of the lands. Consequently, sprocket-hole damage is microscopic.

This sprocket was further improved by a departure from the involute tooth form to a curvature which results in a more uniform flow from tooth to tooth. With the present sprocket, a given tooth is out of contact with the sprocket-hole web immediately after the load is taken by the root of the succeeding tooth.

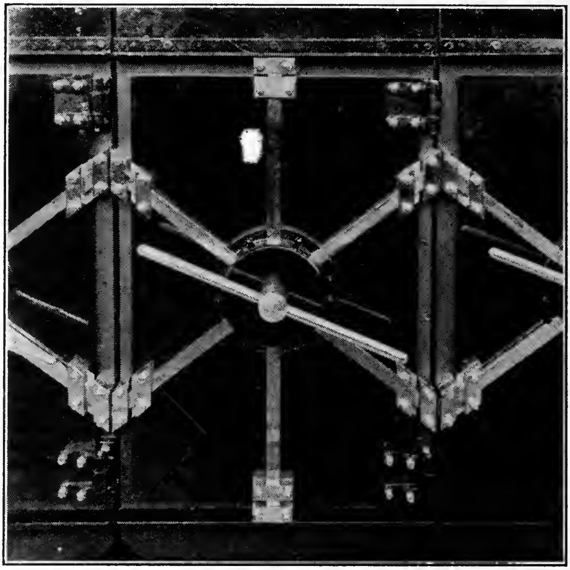

FIG. 4. Water-tight door to solution compartment.

The developer tank is equipped with a turbulation system which operates without foaming and with a minimum of surface oxidation (Fig. 4). The developer under pressure is conducted through a manifold to four cross pipes at the top of the tank. From each of these pipes, two vertical drops extend to the bottom of the tank, and these are in turn connected by five horizontal, submerged pipes. The latter are perforated in such a manner that the jets of developer are projected in the direction of the film travel but at a velocity exceeding that of the film. The jets are so proportioned that excess turbulation is maintained at the bottom because the gelatin is denser at this point and a higher velocity is necessary to attain a degree of osmosis equal to that at the top.

At the exit loop of the developer tank is located a low-pressure air-blast head which reduces the loss of developer. Similar devices are applied at the rinse and fixer exits. A vacuum head is installed between the dry elevator and the developer which effects a marked reduction in ground-noise, and a triple vacuum squeegee removes surface moisture before the film enters the dryer, without contacting either surface of the film.

The wash tanks are two in number and are connected at the top by a header of ample capacity. Wash water is introduced into the bottom of the tank nearest the dryer, and all this water is conducted into the first tank from which it flows to two nozzles in the top of the rinse tank and cascades down the faces of the rinse loops.

The water consumption is therefore very low, 12 to 15 gallons per minute, effecting satisfactory hypo elimination at 150 film feet per minute. Moreover, the entire volume of hypo wash water at an appreciably lowered *p*H is conducted down the rinse loops and immediately runs to waste.

The film rollers differ from the conventional design. Conventional rollers have lands corresponding to the perforation area but standard 16-mm. film has the sound-track along one edge and it was found that the celluloid beneath this area was being scratched thus introducing ground-noise. It was naturally supposed that the film was slipping on the lands in the direction of travel, but microscopic examination revealed that the scratches were parallel to the axis of the roller and the strobotac showed that by reason of the spiral threading over the rollers, the film entered near one flange and made its exit at the other, thus accounting for the side slip. The Cinaudagraph roller is designed with a radial crown extending the entire width of the film channel and on this is stretched a thin rubber band which conforms to the contour of the roller crown. In operation the film contacts the roller more nearly centrally and the slight side-travel is taken care of by the resilience of the rubber, with no loss of traction. Consequently no friction markings occur and great improvement in sound quality results.

The last sixteen loops in the dryer are threaded through a light-weight elevator which is operated by the take-up sprocket. The sprocket shaft, which also carries the take-up pulley, is driven from the main shaft through a two-speed gear changer. The gears are so proportioned that the higher speed is about one-third greater than the normal speed. In operation, the elevator is positioned about one-third down, and when a splice emerges the gear-shift lever is thrown into neutral, whereupon both the sprocket and take-up come to a stop and the elevator starts to drop. After removal of the finished film a core is fitted to the take-up hub, the film attached, and the change-gear shifted to the higher speed, whereupon the elevator commences to rise. After a stop the elevator requires about three times as long to rise as it took to fall, and the shock on the film in restarting is thereby made much lower than would be the case if the gear-changer were arranged for quicker recovery.

It will be noted that the film is made up on a reel but delivered on a core. This arrangement not only facilitates transportation of the finished film to the break-down table but compels at least a cursory inspection of leader before it can be again employed.

The turbulator differs greatly from any known device. A large number of jets are projected into the developer bath throughout its entire volume with the tank entirely full, but the direction of the jets is the same as that of the film travel, not the reverse.

The angle of application is about 20 degrees, and each jet sets up an individual eddy-current which eventually contacts the film; but, since the velocity at the point of impact is the greater, it is obvious that the film travel is slightly accelerated instead of being retarded. Bearing in mind that the bromide tends to migrate in the reverse direction to the film travel but the jets are promoting osmosis in the opposite direction because the impact velocity of the jets exceeds the linear film travel, it is obvious that bromide is rapidly diffused from the gelatin into the bath without retardation of the film travel. Because the application creates a bucking condition against the bromide migration in the gelatin, high jet velocities are unnecessary.

The velocity of the jets is not the same at the top and bottom of the tank. It is apparent that the orifice velocity at the bottom should be greater than at the top because of the difference in pressures, giving due consideration to the specific gravity of the bath; the gelatin is progressively compressed as each loop descends in the bath, and partakes of the nature of a harder gelatin. The turbulator was therefore designed to give a jet impact about 30 per cent greater at the bottom than at the top, with progressive decrease toward the top, thus maintaining uniform osmosis despite variations in counter-pressure and gelatin characteristics.

SOME GENERAL CHARACTERISTICS OF CHROMIUM-NICKEL-IRON ALLOYS AS CORROSION-RESISTING MATERIALS*

F. L. LAQUE**

Summary.—*A description of the features of chromium-nickel stainless steels that make these alloys useful as corrosion-resisting materials, and how they are influenced by the several alloying elements commonly present.*

Chromium is shown to benefit corrosion-resistance by the formation of inert films that prevent progressive attack. Data are presented to illustrate the effect of nickel in increasing the stability of the alloys and in supplementing the effects of chromium. The usefulness of molybdenum in improving corrosion-resistance under both oxidizing and reducing conditions is pointed out. Illustrations are given of its beneficial effects in connection with specific corrosives.

Included also is a discussion of intergranular corrosion, and the effects of carbon and stabilizing elements on this phenomenon.

This paper has been written with the belief that the members of the Society would be interested in a general discussion of the corrosion-resisting characteristics of the series of chromium-nickel-iron alloys that are being used more and more in the processing of motion picture film, and in cameras and projection equipment. Properties and applications of specific alloys within the group under discussion have been described in some detail in papers[1,2,3] presented to the Society previously. It is not the purpose of this paper to review the properties and applications of these alloys with specific reference to the motion picture industry, nor to indicate which alloy is best for each particular service condition, but rather to describe as simply as possible those features that make the alloys useful as corrosion-resisting materials, and how they are influenced by the several elements commonly present. The effects of the alloying elements on physical structures and mechanical properties will not be discussed, since these are in most applications incidental to the use of the alloys as corrosion-resisting materials.

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CHROMIUM

Whether the alloy consist principally of iron or principally of nickel, the corrosion-resisting properties that distinguish these alloys among corrosion-resisting materials are influenced more by chromium than by any other alloying element that may be present.

Chromium itself is chemically an even more reactive element than iron; consequently, it might be expected that the addition of chromium to iron would result in the formation of alloys that would be less, rather than more, corrosion-resistant than iron. That this is actually the case with certain acid solutions highly reducing in character is demonstrated in Fig. 1 referring to tests on a series of chromium-iron alloys in dilute sulfuric acid solution.[4] In contact with the same type of corrosive, chromium has a similar effect on nickel. For example, in 10 per cent hydrochloric acid at atmospheric temperature pure nickel was found to corrode at a rate of about 40 mg. per sq.-dm. per

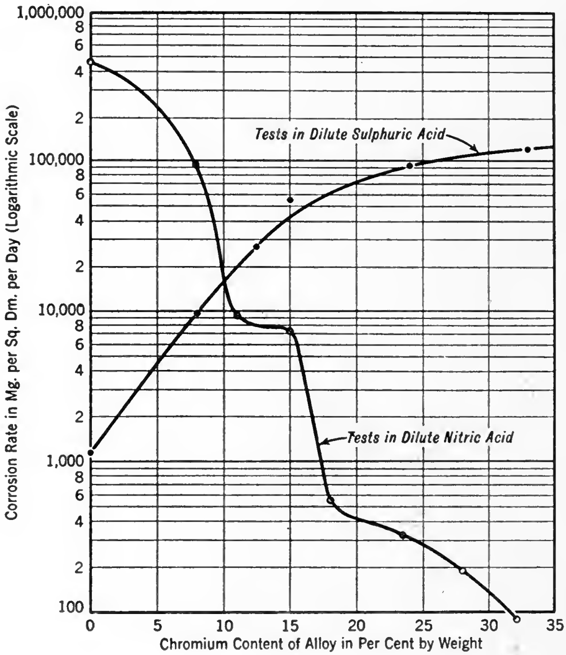

Fig. 1. Tests on a series of chromium-iron alloys in dilute sulfuric and nitric acids.

day, while nickel alloyed with 15 per cent chromium was corroded at a rate of about 400 mg. per sq. dm. per day, or ten times as fast.

Fortunately, the highly reducing conditions under which the greater reactivity of chromium causes it to have a detrimental effect on corrosion-resistance are only seldom encountered, and are reasonably well defined so that they can readily be avoided in the practical application of corrosion-resistant chromium alloys.

The high degree of reactivity of chromium just referred to, and demonstrated by the examples cited, is actually the principal basis for the utility of chromium as an alloying element in corrosion-resisting materials. With the possible exception of noble metals, such as platinum and gold, the resistance of metals and alloys to the chemical effects of active corrosives is very often determined by the ability of the materials to protect themselves through the formation of adherent, insoluble corrosion products that shield the underlying metal from progressive attack. An example is provided by the behavior of lead in contact with sulfuric acid, the lead quickly developing a coating of lead sulfate which is insoluble in the acid and arrests further attack. It is necessary, of course, that such protective corrosion-product films be impervious; that they form quickly enough to stop corrosion before it has progressed very far, and also quickly enough to repair any accidental breaks before much damage can occur; and they should have little tendency to become loosened or flake off as the material is bent or otherwise deformed in service. The versatility of such a material in resisting the attack of a variety of corrosives is determined by the number of corrosives that either will bring about the formation of a protective coating, or will be unable to destroy the protective coating formed during some previous exposure in another environment.

The film formed by the reaction between chromium and oxygen has, to an exceptionally high extent, all the desirable characteristics of a protective corrosion product. This accounts for the great usefulness of chromium as an alloying element in corrosion-resisting materials. Chromium is able not only to protect itself in this manner (as in the familiar example provided by non-tarnishing chromium plate), but is also able to confer this property on iron and nickel separately, or together, to form the group of alloys in which we are particularly interested.

Since, as previously shown, chromium is highly reactive, a protective film forms quickly and is able to repair itself quickly. Oxygen and other oxidizing substances required for film formation and repair are universally present in the air and are common constituents of corrosive solutions, so that protection is afforded under a great variety of conditions. Chromium oxide is quite insoluble in a large number of corrosive solutions, with the result that the protective film is stable in many environments; and even though the corrosive may be non-oxidizing in character, the corrosion-resistance of the alloy may persist through the inability of the corrosive to destroy the film previously formed. These protective films on chromium alloys are often referred to as *passive* films. When the films are intact, the alloy is said to be in its passive state. When they are absent, the alloy is said to be in its active state.

The effect of chromium in conferring corrosion-resistance on iron under conditions favorable to the formation of a protective film is shown by the curve of Fig. 1 referring to exposure of a series of alloys to dilute nitric acid. Thus, the importance of film formation is clearly demonstrated by a comparison of the behavior of the alloys in oxidizing film-forming nitric acid with their behavior in reducing film-destroying sulfuric acid.

The corrosion-resistance of chromium-iron alloys under oxidizing conditions, *e. g.*, nitric acid, tends to increase as the chromium content is raised, and there are rather definite improvements at about 12 per cent chromium, and again around 20 per cent chromium. The advantages associated with the higher chromium contents are utilized when a high degree of corrosion-resistance is required.

While 12 per cent chromium in iron base alloys confers resistance to progressive atmospheric rusting, higher chromium contents are required to achieve complete resistance to atmospheric staining. As the corrosiveness of the environment increases, or the necessity of avoiding even a small amount of contamination by corrosion products becomes evident, more highly alloyed materials must be used. These may be either nickel-base alloys containing about 12 per cent chromium, or iron-base alloys at the high end of the chromium range; or iron-base alloys containing 16 per cent or more chromium plus substantial amounts of nickel or nickel and molybdenum.

The common upper limit of chromium in the iron-base alloys is about 30 per cent, and in nickel-base alloys about 20 per cent. Higher chromium contents are either unnecessary or uneconomical.

Before concluding this brief discussion of the effects of chromium, it is desirable to repeat that it is a chromium-oxygen compound that is responsible for the good behavior of the alloys. Consequently, conditions of use should be arranged so as to permit free access of oxygen or other oxidizing substances to all parts of the metal surface. This means that cracks or crevices should be avoided in fabrication. Likewise, porous or semiporous substances that permit corrosive liquids to penetrate to the metal surface while shielding it from free access to oxygen should not be allowed to remain in contact with the metal.

NICKEL

Nickel is less reactive than either iron or chromium. This is illustrated by the data in Table I.

TABLE I

Behavior of Nickel, Chromium, and Iron in Dilute Acids

Material	Corrosion Rate in Mg./Sq. Dm./Day	
	In Boiling 10% Sulfuric Acid[5]	In 10% Hydrochloric Acid at Atmospheric Temp.[6]
Iron	Not Tested	4760
Chromium	5690	Not Tested
Nickel	256	43

As a result of this lesser chemical activity, it is not surprising that an important effect of nickel in chromium-nickel-iron alloys is to improve resistance to corrosion under conditions where the ability of chromium to form a protective oxide film either does not have a chance to manifest itself, or is not sufficient to provide an adequate level of corrosion-resistance. Likewise, this property of nickel accounts for the greater stability of the nickel-base alloys as compared with the iron-base alloys under conditions where the protective oxide films may be absent, or may be destroyed either locally or generally. Local corrosion or pitting tends to progress less rapidly in the high nickel alloys.

At the same time, nickel, like chromium, but to a lesser extent, has the property of being able to protect itself with a passive oxide film and to contribute this property to other metals with which it may be alloyed. This useful property of nickel seems to be intensified in the presence of chromium and also to intensify this effect of chromium, possibly by insuring that all the chromium in the alloy is in a state in which it can exert its most useful effects on corrosion-resistance. It is, of course, necessary to use these elements in the proper proportions to achieve a desirable physical structure which, in the most widely used alloys, is the austenitic state. The most common alloy of this type contains about 18 per cent chromium and 8 per cent nickel.

Bain[7] has stated, "there is reason to believe that nickel itself possesses to some extent the ability to protect itself with an oxygen layer—it may be demonstrated that the restoration of the inert film on a previously stripped nickel-chromium stainless steel is well nigh instantaneous, vastly more rapid than on the straight chromium alloy. There is the ample explanation for the wider range of industrial applications for the nickel-bearing alloys and for their complete imperviousness in a greater number of environments."

The effect of nickel in these alloys is, therefore, to increase their resistance to corrosion by both oxidizing and reducing solutions. Since nickel is known to be corroded severely by strong oxidizing acids, such as nitric, it is not surprising that the direct effects of nickel

TABLE II

Corrosion of Chromium-Nickel-Iron Alloys by 5% Sulfuric Acid at 20°C

Material	Corrosion Rate in Mg./Sq. Dm./Day
18% Chromium, Balance Iron	12,800
18% Chromium, 8% Nickel, Balance Iron	209
9% Chromium, 22% Nickel, 1.5% Silicon, Balance Iron	42

on corrosion-resistance are most pronounced under reducing rather than under oxidizing conditions. In tests in a number of aerated, corrosive solutions, Pilling and Ackerman[4] found that, irrespective of the chromium content of the alloy, the addition of nickel effected an improvement in corrosion-resistance which was achieved substantially with a nickel content of from 12 to 14 per cent. In the case of highly reducing solutions, the amount of nickel required may be considerable and it may be necessary to use nickel in excess of chromium to achieve the desired result.

Chromium-nickel-iron alloys in which the nickel content is considerably in excess of the chromium content are not as common as those in which chromium predominates. Notable exceptions are provided by Inconel (80 per cent nickel, 13 per cent chromium, 7 per cent iron), used to a considerable extent for corrosion-resistance, and certain heat-resisting alloys used occasionally for corrosion-resistance that need not be discussed here. Nevertheless, the advantage of a relatively high nickel content for conditions along the border line of being oxidizing or reducing has led to the commercial development of corrosion-resisting alloys in which chromium and nickel are used in the reverse ratio to the more common 18 per cent chromium, 8 per cent nickel type of stainless steel. The data[8] in Table II show the effect of nickel in alloys of this type. Small percentages of silicon and copper are often added to alloys of this sort to improve their resistance to acid attack. These same elements are also used for similar purposes in the alloys in which chromium predominates.

The degree of passivity exhibited by chromium alloys with a nickel base is lower than that with alloys of similar chromium content with an iron base. In other words, the response to the passivating or protective effect of oxidizing agents is greater with iron-base alloys than with nickel-base alloys. This lower degree of passivity of nickel-base alloys, while it limits their usefulness in some mildly oxidizing solutions, is advantageous in many cases, since there is less danger of intense local attack accompanying a breakdown in the protective oxide film. The reasons are that with a nickel-base alloy the metal exposed at a break in the oxide film is more noble and the surrounding oxide film is less noble than is the case at similar breaks in the film on an iron-base alloy. The net result is that the potential difference between the film break and the surrounding film is considerably less with the nickel-base alloy, and the intensity of local galvanic effects leading to pitting is correspondingly less. Pits that may start on a nickel-base alloy are more likely to spread and less likely to penetrate.

TABLE III

Behavior of Materials in Caustic Soda Being Concentrated from 75% to 100%

Material	Corrosion Rate in Mg./Sq. Dm./Day
Nickel	380
80% Nickel, 20% Chromium Alloy	550
18% Chromium, 8% Nickel, Balance Iron	9,890
18.5% Chromium, Balance Iron	15,050

Because of the exceptional resistance of nickel to corrosion by caustic alkalies, the high nickel alloys are superior to those of lower nickel content in resisting alkaline solutions. This becomes important under conditions of severe exposure to caustic solutions and is illustrated by the data in Table III.

In hot, concentrated sulfurous acid solutions nickel is beneficial to corrosion-resistance up to a certain point, beyond which further additions of nickel may be detrimental. It is difficult to set a precise limit on the nickel content, but it appears that it should be between 8 and 30 per cent for best results, the exact amount being determined by the other constituents of the alloy and the conditions of exposure. The most commonly used alloys contain from 25 to 30 per cent chromium with 10 to 14 per cent nickel, or 16 to 20 per cent chromium, 10 to 14 per cent nickel, and 3 per cent molybdenum.

Toward other sulfur compounds, such as hydrogen sulfide solutions and alkaline sulfide solutions, nickel has a beneficial effect on the corrosion-resistance of the alloys.

MOLYBDENUM

Molybdenum is used in chromium-nickel-iron alloys in amounts up to 20 per cent, and most commonly in the range from 2 to 4 per cent. Even such relatively small percentages of molybdenum have powerful effects in improving the resistance of iron-base alloys to chemical attack. The higher percentages of molybdenum are used in such nickel-base alloys as the Hastelloys, some of which contain chromium and small percentages of tungsten and other elements. The nickel molybdenum alloys are outstanding in their resistance to hydrochloric acid, and those containing chromium in addition to molybdenum are especially resistant to oxidizing halogen solutions. The alloy Illium contains about 60 per cent nickel plus chromium and molybdenum, with chromium predominating, and is resistant to both nitric and sulfuric acids.

TABLE IV

Corrosion of Metals by 20% Hydrochloric Acid at 112°C

Material	Corrosion Rate in Mg./Sq. Dm./Day
Iron	Totally Dissolved
Nickel (in 10% acid)	4200
Molybdenum	24
Nickel + 30% Molybdenum	154

Molybdenum appears to have the property of quickening the response of the alloys to the protective effects of oxidizing agents. Stated another way, molybdenum seems to reduce the intensity of the oxidizing effect required to insure passivity and also decreases the tendency of previously formed oxide films to break down under reducing conditions. It has a direct effect in decreasing the chemical activity of the alloy in reducing solutions where passive films do not form. This latter effect is probably connected with the high degree of corrosion-resistance possessed by molybdenum as indicated by the data[6] in Table IV.

The beneficial effects of molybdenum are especially pronounced in connection with reducing acids. For example, in tests[9] in 10 per cent hydrochloric acid at atmospheric temperature an alloy containing 18 per cent chromium, 8 per cent nickel, and 2.5 per cent molybdenum was attacked at a rate less than one-tenth that of a similar alloy containing no molybdenum. Similarly, good effects of molybdenum have been observed in connection with sulfurous acid solutions.

Molybdenum has specific beneficial effects in contact with organic acids, and especially organic acid vapors. This is illustrated by the data in Table V.

TABLE V

Results of Tests in Organic Acids

Material	Corrosion Rate in Mg./Sq. Dm./Day	
	Specimens Immersed in a Still Handling Acetic Acid from 80% to 100% Concentration	Specimens in Vapor Space of a Still Handling 90% Formic Acid at 212°F
Alloy Containing 18% Chromium, 8% Nickel	75	425
Alloy Containing 18% Chromium, 8% Nickel, 3% Molybdenum	0.5	10

In addition, the presence of molybdenum decreases the probability of pit formation. Halogen compounds and chlorides in particular are most likely to be troublesome so far as the pitting of chromium-nickel-iron alloys is concerned. Ferric chloride has such a powerful effect that it has been used as a tool in the study of pitting tendencies of various alloy compositions. Results of such tests[10] have demonstrated the value of molybdenum additions in reducing susceptibility to pitting by ferric chloride. Supplementary tests have shown that this extends to other chloride solutions as well.

CARBON

All the alloys under discussion contain a certain amount of carbon, derived principally from the component raw materials which can not be obtained commercially in a carbon-free state. The principal effect of carbon on corrosion-resistance is determined by the way in which it exists in the alloy. If it should be combined with chromium as a separate constituent, it may have a detrimental effect on corrosion-resistance by removing from solid solution in the alloy an appreciable amount of the chromium required for adequate corrosion-resistance.

The solubility of carbon in these alloys at atmospheric and moderately high temperatures is well below the amounts commonly present, but the excess carbon can readily be kept in solution, where it does no harm, by rapid cooling from an elevated temperature at which the carbon is completely dissolved. Subsequent heating at some lower temperature (between 800° and 1400°F), as in welding operations, causes the precipitation of carbon as a carbide containing chromium. This precipitation of carbon usually occurs at grain boundaries. It has been suggested that the loss of useful chromium that accompanies the precipitation lowers corrosion-resistance of the alloy in the vicinity of the carbides to an extent that brings about susceptibility to intergranular corrosion following the network of precipitated carbides.

This matter of carbide precipitation and consequent intergranular corrosion has received considerable intensive study, with the result that the causes are well understood and practical and certain methods of prevention have been developed. These methods of prevention include:

(*1*) Proper heat treatment as by quenching from about 1900°F or some higher temperature.

(*2*) The development of alloy compositions that contain stabilizing elements and may be used without heat-treatment even in the carbide precipitation temperature range.

(*3*) Proper technic in welding operations that avoids prolonged holding of the alloy in the critical temperature zone for carbide precipitation. Favorable conditions include very low carbon contents and high alloy contents. These particular precautions are effective only in service at temperatures below the carbide precipitation temperature range.

STABILIZING ELEMENTS

Certain elements are added to chromium-nickel-iron alloys to prevent intergranular corrosion following sojourn of the alloy within the temperature range in which precipitation of chromium carbide might occur. The function of these "stabilizing" elements is to combine with any carbon that might otherwise precipitate as a chromium carbide. This leaves the chromium in solid solution in the alloy where it belongs and thereby the full corrosion-resisting qualities of the alloy are preserved.

The elements most commonly used for this purpose are columbium[11] and titanium,[12] the latter occasionally with tungsten. Molybdenum has a somewhat similar effect, though less pronounced, and this property of molybdenum is usually incidental to the main reasons for its use as previously described. Columbium has an advantage over titanium to the extent that it is retained in weld deposits, and thus permits cross-welding without introducing any danger of subsequent intergranular corrosion of the weld metal when it is reheated within the critical temperature zone during the second welding operation. Columbium does not seriously reduce the resistance of the steels to general corrosion, but under certain conditions titanium does lower general resistance, especially toward organic acids.

These stabilizing elements must be present in sufficient quantities, usually from six to ten times the carbon content. Consequently, it is common practice to keep the carbon content as low as possible in "stabilized" alloys. Selenium is used in these alloys to improve their machinability. It generally produces a slight lowering of corrosion-resistance.

It may be seen from these general comments on the effect of the common alloying elements in the chromium-nickel-iron system that a wide variety of materials may be obtained to suit the particular requirements of different service conditions. It is hoped that this discussion will be of some value to the reader in enabling him to understand their behavior and to employ them to the best advantage from the standpoint of both the material and the user.

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DISCUSSION

Mr. Crabtree: Is there anything on the horizon that is more generally satisfactory than the *18-8* chrome nickel with about 3 per cent molybdenum in it? Would there be any objection to pushing up the molybdenum to, let us say, 10 per cent? Is the alloy too hard, or can it be worked or welded; or is it too expensive, or any better chemically than the 3 per cent?

Mr. LaQue: I would be reluctant to say that we have achieved the ultimate in corrosion-resisting alloys of this sort. At the present time it is probably true that increases in molybdenum would be beneficial under certain conditions. I can say also that it is not likely to be detrimental chemically. However, it does introduce manufacturing difficulty. The physical structure of the alloy is disturbed by raising the proportion of one of the elements without at the same time adjusting the proportions of the others, and it would not be practicable right now to add very much more molybdenum to alloys of this sort.

There is some thought of going as high as 5 per cent but the steel mills would rather stay under, I should say, three. Anything between three and five may introduce manufacturing difficulties that might outweigh the general advantages to be obtained.

Mr. Crabtree: You mean the mills might have to use rollers of molybdenum steel?

Mr. LaQue: No. I think it is more a problem for the metallurgists than for the rollers. Different phases are formed in the alloy that have different properties and interfere seriously with the hot working characteristics of the material. Right now I would say that high molybdenum contents are not justified by the number of environments in which their use would be beneficial—I mean over 5 per cent or even approaching 5 per cent. For most of the purposes in which these gentlemen are interested, around 3 to 4 per cent is plenty.

Mr. Kellogg: There are a number of methods of welding which do not involve the carbon electrodes; for example, an atomic hydrogen welding system developed at Schnectady a number of years ago. There is also the possibility of oxyhydrogen flame welding, and spot-welding. Are those available or useful to avoid the spoiling of the materials in the way you describe?

Mr. LaQue: The damage is done by the heat of welding, not by the particular technic of welding. For the same time and temperature, in the critical range of temperature, it does not matter what the source of heat is, whether atomic hydrogen, carbon arc, acetylene, or metallic arc. It is a matter of time and temperature rather than of the welding process itself.

I should like to emphasize the importance of time as well as of temperature. These very rapid spot-welding methods, such as the spot-welding as used on the high-speed trains, do not leave the metal in the critical temperature zone long enough to do any material damage for the type of service to which the equipment is put.

The welding technic is important in that the time should be reduced to the shortest possible, and the welding rod used that gives the greatest latitude; but as to the differences between the various welding methods, they are of less importance in the general subject.

MR. RACKETT: In case of a structure fabricated from stainless steel which is sufficiently complicated, or attached to a mechanism, to make it undesirable to immerse the material in nitric acid, is there some effective means of passivating by soaking with a sponge or some similar method? What do you recommend?

MR. LAQUE: This matter of passivation is complicated by the fact that passivation is carried out always at the mill to aid nature in forming protective oxide films on the alloy surface. Oxygen in the air will do the same job if given time. The nitric acid does it more quickly and surely.

The other effect of nitric acid is to dissolve off any extraneous material of foreign nature, such as bits of steel, that may have contaminated the surface of the metal, so there are two functions of the nitric acid treatment—one to clean and the other to passivate. The passivation can be accomplished provided you can, by some means, bring some nitric acid into contact with the surface and leave it there long enough, but I doubt whether it is essential to do that. Air, given free access and a reasonable length of time, will do the same thing.

ABSORPTION LIMITS FOR INTERFERENCE NODES IN ROOMS*

M. RETTINGER**

Summary.—*The first part of the paper deals with the determination of the minimum amount of sound absorption necessary in a room so as not to produce a space interference node at a certain distance from the loud speaker when that is emitting a steady tone. Two cases are investigated—the amount of sound absorption necessary in the room that will make it impossible to find a node within a given distance from the emitter; and the amount of sound absorption in the room that will make it improbable to find such a node within the same given distance from the emitter.*

The second part of the paper deals with the minimum amount of sound absorption necessary in a room so as not to produce time interference nodes during the decay of a tone in the room. Here again two cases are considered—the amount of sound absorption necessary to make it impossible to produce nodes during decay; and the amount of sound absorption as will make it improbable to produce such a node in the room.

In recording sound and in making acoustic measurements in rooms one is frequently confronted with the problem of considering the effect of interference, be it of the so-called time or the space type. The time effect enters during growth or decay of sound in a room, and makes itself shown in the irregular variations of sound pressure at a point in the room while the sound is in this transient state. "Space effect" represents a variation of sound pressure at different points in an enclosure while a steady or prolonged tone is sounded.

Of the mathematical concept that an enclosure can be considered as a bounded three-dimensional continuum, free to vibrate, one can say that during the period of growth of sound in a room the former type of interference consists of a superposition of the free, damped vibrations upon the forced vibrations, while during decay it is made up of superpositions of the free, damped vibrations only. Similarly, space interference can be explained as a superposition of the forced vibrations. However, the mathematical treatment of the forced vibrations presents a very difficult problem, particularly if the absorption in the room is to be considered.[1]

* Received March 15, 1939.

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The most undesirable points of a standing-wave system in a room are the nodes and antinodes, or points where the pressure or the particle velocity has zero or maximum amplitude. Nodes can not occur within a certain definite distance from the source of sound, since within this distance the direct sound will predominate over the generally reflected sound with which it will have to combine to produce zero amplitude of pressure (or velocity). Since it is often valuable to know how far from a source of sound a microphone may be located without meeting with these extreme effects of interference, we may first inquire as to the distance within which it is impossible to find nodes, and then, within which it is improbable to find them.

Let us first assume that the source of sound is within the room, that is, is radiating into 4π steradians of solid angle. For a simple solution we can make use of the equation of the "received reverberation."[2] This equation is (assuming a non-directional sound-collecting system):

$$\frac{E_r}{E_d} = \frac{16\pi d^2(1 - a)}{aS}$$

where E_r = generally reflected sound energy density
E_d = direct sound energy density
d = distance from the source of sound
S = total interior surface of room
a = average absorptivity of walls

If we set this equation equal to unity and then solve it for a, we get

$$a = \frac{d^2}{d^2 + 0.02S}$$

or solving for d

$$d = \sqrt{\frac{0.02Sa}{1 - a}}$$

The former equation tells us what the average absorptivity must be for a certain microphone distance if within this distance there are to be found no nodes. The second equation gives this distance for the particular absorptivity of the room with which we are concerned. Fig. 1 shows these results graphically.

The foregoing computations ignored the phase condition of the reflected waves. By doing this, that is, by assuming that all the reflections were appropriately out of phase with the direct sound, we have determined the minimum distance from the source within which nodes are impossible. Such a condition, of course, represents a bare theoretical possibility; in a room it would be an isolated, exceptional instance to find. For practical purposes, therefore, it may be more valuable to know the distance within which it would be improbable to find nodes, which represents the second part of our problem.

It may be in place at this point to say that no definite information is available regarding the possible or even probable number of interference maxima and minima in a given enclosure. Certainly the distance between the maxima or the minima in a room need not correspond to a half wavelength, as it does in the case of a standing-wave system produced by a plane progressive wave striking a rigid wall at normal incidence. It is possible, of course, experimentally

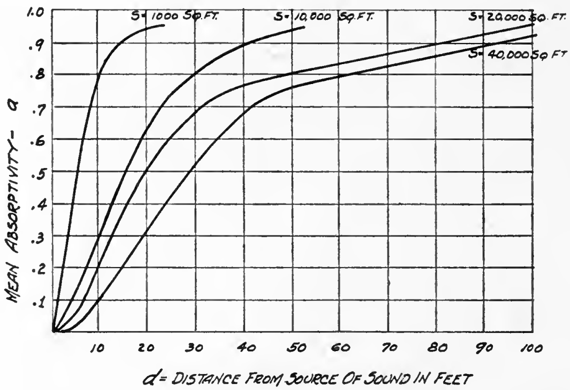

FIG. 1. Curves show the minimum average absorptivity of a room of total interior surface S for nodes to be impossible within the microphone distance shown by the abscissa of the figure when source of sound within the room is radiating into a 4π solid angle.

to map out the interference field in a room in similarity to a topographic chart, the curves showing the regions of equal pressure. Such charts, when made for different frequencies, usually indicate a proportionality between frequency and number of maxima and minima in the room. Charts made for the same frequency in equally sized but unequally damped rooms tend to show that the difference between the extreme irregularities of pressure becomes smaller as the average absorptivity increases.

To determine the probable distance from the source of sound within which nodes should not be found it is convenient to attack the problem by a method of statistical analysis. This method was first used by H. Frei[3] who considered the case of the sound source within the room. In the following it will be assumed that, in similarity to a theater, we have a rectangular room in which the source of sound is located in a wall. In such a room the pressure at any point in the room will, in addition to the direct sound, be made up of 5 reflections that have been broken only once, 13 second reflections, 25 third reflections, *etc.*, the number of reflections of order n being

$$N = \frac{(2n + 1)^2 + 1}{2}$$

The amplitude of the velocity potential of the direct sound is inversely proportional to the distance from the source of sound, d_0, or

$$A_0 \sim \frac{1}{d_0}$$

For the amplitude of the first reflection we may write

$$A_1 \sim \frac{\beta}{d_1}$$

and for the amplitude of the reflection of order n,

$$A_n \sim \frac{\beta^n}{d_n}$$

where β is the average absorptivity of the room, and d_n the length of path of the reflection of order n. This length is approximately equal to

$$d_n = (n + 1)D$$

where D is the mean free path of the enclosure, given by

$$D = \frac{4V}{S}$$

where V is the volume and S the total interior surface of the room.

The probable amplitude of the velocity potential consisting of the sum of N reflections of order n is

$$A_n = \sqrt{N}\frac{\beta^n}{d_n}$$

$$= \sqrt{\frac{(2n + 1)^2 + 1}{2}} \frac{\beta^n}{(n + 1)\, D}$$

The probable resultant of all reflections is

$$R = \frac{1}{D}\sqrt{\sum_{n=1}^{\infty} A_n^2}$$

$$= \frac{1}{D}\sqrt{\sum_{n=1}^{\infty} \frac{(2n + 1)^2 + 1}{2(n + 1)^2}\beta^{2n}}$$

For nodes to be probable we must set the above expression equal to $1/d_0$ (d_0 = path length of direct sound). Fig. 2 shows the numerical evaluation of this equation. The area below this curve shows the values of d_0/D and β for which nodes are improbable. To illustrate, consider a room 30 × 60 × 90 feet; with mean free path equal to 33 feet. If the average absorptivity is greater than 0.4 we shall probably not meet nodes within 33 feet ($d_0/D = 1$) from the source of sound. On the other hand, if this absorptivity is in excess of 0.65 we may go back as far as the rear wall without satisfying the condi-

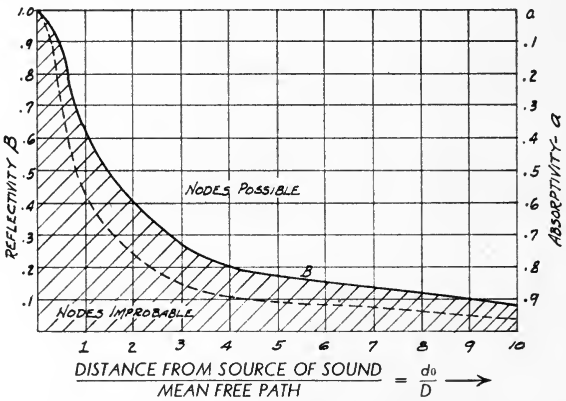

FIG. 2. Solid curve shows the minimum average absorptivity of a room for nodes to be improbable within the microphone distance shown by the abscissa of the figure when the source of sound is located in a wall of a rectangular room. Dotted curve refers to source of sound within room and radiating into 4π solid angle (*after H. Frei*).

tion of probability of meeting nodes. Since an average absorptivity of 0.65, however, represents quite a large value, such a condition would ordinarily be encountered only in sound stages and acoustic test chambers; in the ordinary theater, with mean absorptivity of 0.1 to 0.2, it would therefore appear quite unlikely not to meet nodes this far from the source of sound when a steady pure tone is sounded in the room.

The undesirable effects of interference are not eliminated with the use of two or more microphones in the room. Indeed, near cancellation can also occur in the open when two microphones are used. Consider Fig. 3 where O represents a loud speaker emitting a steady tone, and M_1 and M_2 two microphones of which M_1 is situated on the x axis, thought to be coincident with the centerline of radiation of the speaker. The outputs from the microphones will be in phase whenever

$$\sqrt{x^2 + y^2} - x = n\lambda$$

and out of phase whenever

$$\sqrt{x^2 + y^2} - x = {}^1/_2(2n + 1)\lambda$$

where n is an integer and λ the wavelength of the sound. Fig. 3 also shows the locus of the position of M_2 for these two conditions, for a tone of 1130 cycles per second ($\lambda = 1$). Complete cancellation is not possible, since the amplitude of the sound at M_2, due to the greater distance from O to M_2, will always be less than the amplitude of the sound at M (assuming also a not uncommon radiation characteristic on part of the speaker). A similar condition, of course, holds in a room, although there the amount and the phase relationship of the reflected sound will have an additional bearing on the degree of cancellation of the outputs from the microphones.

The above, while strictly applicable only to interference produced by a spatial separation of microphones in the open, has a pronounced bearing when acoustic tests are made with two or more microphones either in a highly damped room or close to the source of sound in the room. In either case it is possible that the acoustic test data are falsified by such interference effects, even as a dialog recorded with two or more microphones is likely to sound less smooth than a recording made with only one transmitter.

Space interference, as stated before, makes itself felt most conspicuously when the tone in the room is prolonged and of a single frequency. In the case of complex sound such as speech and music it may be that a number of these interference patterns become superimposed, and that an interference maximum of one frequency occurs at the place of an interference minimum of another frequency. The result will be a change in quality of the sound, particularly in the case of monaural hearing, represented by the microphone, and less pronounced for binaural hearing where the attention is able to some degree to suppress the undesirable effects of the reflected sound.

For very brief sounds, of course, space interference becomes much less important since the standing-wave patterns are in a state of rapid flux. It is, therefore, mainly in the case of reverberation measurements that the time effect of interference produces very annoying results, as with the most frequently used measuring equipment, namely, the high-speed level recorder, we wish to measure the slope of the decay curve. The question, however, what the minimum

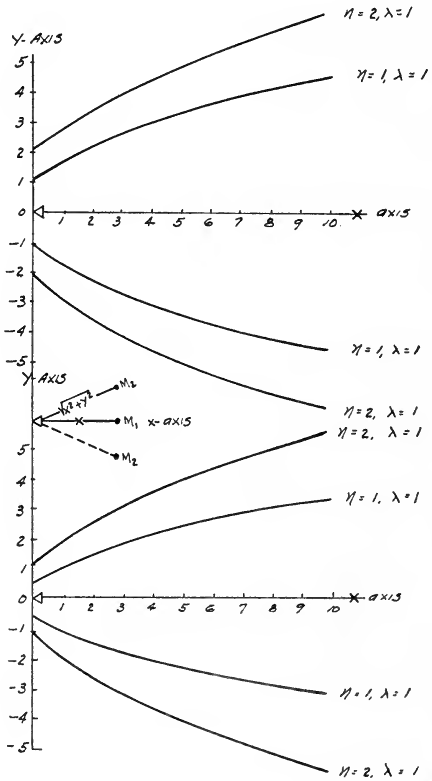

Fig. 3. Upper curves show loci of microphone M_2 for its output to be in phase with output from microphone M_1 when the microphones are situated as shown in insert. Lower curves give these loci for the out-of-phase condition of the outputs from microphones M_1 and M_2.

average absorptivity in a room must be that will not produce nodes during decay, is not readily answered.

Two sets of calculations will give us an idea of the magnitude of this absorptivity. In both these calculations we are considering the case where the source of sound has stopped, so that the sound pressure at any point in the room is made up of reflected sound only. Again we have first, second . . . and nth reflections whose amplitude is proportional to β, β^2 . . . β^n, where β is the average absorptivity of the room. As before, neglecting at first any probable phase relationship for all the reflections at a certain point in the room, these nodes at any time during decay are not possible when the nth reflection is equal to the sum of all the subsequent reflections, from the $(n + 1)$th reflection to the one whose amplitude is proportional to β^∞. This condition may be written as

$$\beta^n = \sum_{m=n+1}^{\infty} \beta^m$$

Dividing through by β^n we get

$$1 = \beta + \beta^2 + \beta^3 + \ldots.$$

or

$$\frac{1}{\beta} = 1 + \beta + \beta^2 + \beta^3 + \ldots.$$

The right-hand side of the above equation is a geometric progression of an infinite number of terms, and since β^2 is smaller than 1, we may write[4]

$$\frac{1}{\beta} = \frac{1}{1 - \beta}$$

or

$$\beta = 0.5$$

In the second set of calculations we shall assume a random phase relationship between the reflections so that the law of probability becomes applicable to our case. We may then write

$$\beta^n = \sqrt{\sum_{m=n+1}^{\infty} \beta^{2n}}$$

Dividing through by β^n we get

$$1 = \beta\sqrt{1 + \beta^2 + \beta^4 + \beta^6 + \ldots}$$

or

$$1 = \beta^2 + \beta^4 + \beta^6 + \ldots.$$

Let $\beta^2 = \delta$ so that

$$2 = 1 + \delta + \delta^2 + \delta^3$$

The right-hand side of this last equation is again a geometric progression of an infinite number of terms, so that as a final result we obtain

$$2 = \frac{1}{1 - \beta^2}$$

or

$$\beta = \sqrt{0.5} = 0.707$$

Thus in one case we get 0.5 and in the other 0.3 as the minimum average absorptivity of a room that can produce nodes during decay. Certainly nodes should be absent during decay when this absorptivity is in excess of 0.5.

It is doubtful whether these nodes during decay are of real significance as far as their detection by the ear is concerned. They are certainly never heard (barring the echo effect proper), even when they occur $^1/_{16}$ of a second after the tone is stopped in the room. This can readily be ascertained, for instance, by taking an oscillogram of a tone impulse and listening to the decay of this impulse first in the room with both ears and then through a pair of earphones connected to the oscillograph. No matter how many impulses are recorded by the oscillograph during decay, the ear hears always only one impulse and then a more or less prolonged decay tone depending on the total absorption of the material in the room. It may be, however, that the ear hears a change in the quality of the decaying impulse; if so, the recorded impulses during decay represent this change in quality.

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NEW USES OF SOUND MOTION PICTURES IN MEDICAL INSTRUCTION*

HENRY ROGER**

Summary.—*Problems are described that were encountered during the production of several motion pictures with sound for the New York State Department of Health. These films represent a type that has found new uses in instructing physicians and nurses, as well as the general public, in the treatment of pneumonia patients, as a part of a nation-wide campaign program against the spread of pneumonia.*

Those who are acquainted with conditions existing in the field of medical motion pictures, especially with sound, realize that progress is extremely slow; in fact, it can hardly be compared with the advance made in general educational or industrial motion pictures. Much has been said and done to prove the superiority of motion pictures over other methods of education and for the presentation of facts and it seems unnecessary to add any more here. Yet the medical profession, with exceptions, of course, does not avail itself fully of the enormous advantages the motion picture offers in the way of teaching general medicine, history of medicine, biology, physiology, surgery, laboratory technic, or of presentation of cases and various surgical technic. In addition the author, in previous articles,[1] has described and demonstrated methods establishing definitely the usefulness of the motion picture in research.

Only in the amateur field, due to the availability of good substandard equipment, some good medical films have been made in recent years by medical amateurs and hospital technicians, although the bulk of the material lacks workmanship and editorial quality to the same degree as in other amateur fields.

Let us now consider some of the reasons why motion pictures of the professional type have made comparatively little progress in medicine:

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* Presented at the 1938 Spring Meeting at Washington, D. C.; received April 15, 1938.

** Rolab Photo-Science Laboratories, Sandy Hook, Conn.

(*a*) There is a lack of sufficient time in a medical man's routine to appreciate fully the medium of motion pictures.

(*b*) Institutions and individuals are mostly unable to appropriate funds for film production or to hire the services of motion picture experts because of other, apparently more important, expenditures.

(*c*) Production costs of high-quality sound-films are above the level for this type of film, because they are based upon Hollywood standards and union regulations, which do not take in account the scientific angle.

(*d*) There are few motion picture producers who specialize in scientific films exclusively, which would seem necessary because of the special requirements with regard to experience and equipment.

Although the situation may not look encouraging there are indications that conditions are being improved gradually. For example, the Department of Health of the State of New York has made a great step forward in having realized the significance of motion pictures in its campaign program for the control of pneumonia, and having appropriated funds last year for the production of sound motion pictures. The films, after their completion last December, are now in circulation not only in New York State but throughout the whole nation. Their titles are: *Pneumonia Nursing—Half the Battle* and *Technique of Serum Administration in Pneumonia*, the first being a direct dialog sound-film intended to be used not only for training nurses but also for informing the public on how to take care of the pneumonia patient; the second, a sound lecture film, is intended to demonstrate to physicians and nurses the correct and generally acknowledged procedure of the administration of pneumonia serum, emphasizing the lower average death rate accompanying early treatment.

The latter film deviates from ordinary films in a number of ways. It is not a teaching film in the true sense of the word, as it shows, with the aid of considerable close-up photography, the details of a technic with which the physician is generally aquainted, or at least ought to be. It should serve to stimulate, perhaps, the production of more medical motion pictures with sound. It is hoped that in the future there will be closer coöperation between motion picture men and medical authorities, and that the medical profession may recognize more fully than heretofore the usefulness and importance of motion pictures in medical education and science.

Going now into the actual production of the two films for New York

State a few details will be mentioned that may be of interest. The State turned over all production responsibilities to the Rolab Laboratories and agreed to purchase the films after their completion. The State acted, therefore, only in an advisory capacity, by lending to the producer the services of a medical director and a registered nurse. For a number of reasons the producer was to provide complete legal protection against suit for malpractice of medicine, for bodily injury, disability, temporary and permanent, or even death, protecting all persons in any way connected with the making of the films. For example the person who received an entirely harmless and painless injection of a small amount of sterile saline solution in place of the serum actually used on pneumonia patients, was (without his knowledge) the object of much legal dispute before proper insurance could be procured, and at a price quite out of proportion.

The injection itself was administered by a physician of the Department of Health of New York State, who received special permission from the State of Connecticut to practice medicine at Sandy Hook, Conn., where the studios are located.

Only after the legal situation was entirely cleared could production take its normal course, which required an unusual amount of attention to details. Since these films were to be authorized and later distributed by the State, the procedures and medical technic to be demonstrated or, rather, advocated to physicians had to be correct and non-controversial in every small detail. It is safe to say that before the various sequences had been approved and taken, or taken and approved later, many a scientific discussion was held with regard to correct technic. The film *Technique of Serum Administration in Pneumonia* was shown at the conclusion of the paper.

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NEW MOTION PICTURE APPARATUS

During the Conventions of the Society, symposiums on new motion picture apparatus are held in which various manufacturers of equipment describe and demonstrate their new products and developments. Some of this equipment is described in the following pages; the remainder will be published in subsequent issues of the Journal.

THE PANORAMIC SCREEN AND PROJECTION EQUIPMENT

USED AT THE

PALACE OF LIGHT OF THE INTERNATIONAL EXPOSITION (PARIS, 1937)*

A. GILLETT,** H. CHRETIEN,† AND J. TEDESCO††

From the very time of its inception the cinema art seems to have been beset by the rigid limitations implied by the use of an almost square frame, and the sound-track has only accentuated the inharmonious proportions of the screen projection. Hollywood technicians have been fully aware of the esthetic shortcomings of the system. They sought to lessen the height of the picture by developing the "American" frame, bringing the sound screen to about the same size as the silent screen. How is one to overcome the insurmountable limits imposed by the standard size of the film? Instead of a screen five to six meters wide, it is possible to use, for example, a screen ten to twelve meters wide, but the height of the picture will increase accordingly, and what we shall see will be a more or less monstrous enlargement wherein the defects of the film, particularly the graininess, will appear grossly exaggerated.

Such attempts to get away from the conventional system are prompted by a desire to be liberated from the limitations of the exceedingly narrow frame, to suit the diverse needs of an art the very essence of which is motion and space. The technical solution to the problem was not actually attained until the appearance of the French invention of Professor Chretien.

In discussing this subject, it must be pointed out that it is believed that projection of such dimensions has never before been realized, either in a theater or outdoors. One of the largest projection screens was built and used by Lumière in 1899 in the Galerie des Machines of the Paris Exposition. It measured 30

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* Presented at the 1938 Spring Meeting at Washington, D. C.; received April 1, 1938.

** Brockliss-Simplex, Paris, France.

†University and Optical Institute of Paris, France.

†† Paris, France.

meters wide by 24 meters high and required a projection distance of 200 meters.[1] This panoramic screen had an area of 600 square-meters, 60 meters long by 10 meters high. The largest screen constructed for a theater is that of the Gaumont Palace, which has a normal area of 100 square-meters and may be enlarged to 200 square-meters when certain scenes of the film being projected permit a panoramic effect.

To obtain sufficient brightness of the projected images, it is necessary, on the one hand, to use extremely powerful arcs and, above all, to consider the problem of the reflective power of the screen. After repeated trials the best results were obtained with a screen consisting of a cloth to which were attached small and perfectly spherical glass beads. However, a beaded cloth of such dimensions could not be practicable for outdoor use. It was therefore necessary to develop a screen capable of withstanding the weather, and it was decided to study the possibility of placing the beads on a wall instead of on a screen.

This particular screen consists, first, of a support a few centimeters thick, consisting of a mixture of lime and sand in adequate proportions. When dry, this support was covered with several coats of insulating varnish to prevent any possible reaction of the lime and sand support upon the screen proper. This coating of varnish was, in turn, covered with six successive layers of zinc white; and, finally, these layers were coated with an adhesive varnish onto which the beads were thrown by means of a special compressed-air gun.

The resulting screen is, of course, directional, having its maximum reflectivity within an angle of approximately 43 degrees. Outside the 43-degree angle the reflective power is reduced about one-half. Nevertheless, the screen at the Palace of Light, its present position, permits an audience of 4000 persons, as a minimum, to enjoy the projection under excellent conditions of visibility and brightness.

One of the greatest difficulties was the problem of image brightness, and it was necessary to take into consideration the surrounding light, as adequate darkness within a radius of 200 or 300 meters around the Palace was entirely out of the question. However, the brightness of this gigantic image is even better than that obtained in many motion picture theaters using projection screens of average dimensions.

The screen was installed on the façade of the Palace of Light (Fig. 1), and was exposed to the weather during the period of the Exposition. The façade of the Palace, and the screen itself, were slightly concave, which helped to avoid the marginal distortion that would have occurred had the façade been flat, since the apparatus at the right projected the images on the left of the screen and *vice versa*.

In order to project films of standard size (18 by 24 mm.) upon this large screen, standard, the surface of which measures approximately 600 square-meters, new methods, in addition to the use of a screen of great reflective ability, projectors of tremendous power, highly luminous optics, and so forth, had to be adopted. A special difficulty was encountered with respect to the shape of the screen, the width of which was six times the height, whereas the width of the film images barely exceeds the height. This difficulty was overcome by the use of two connecting projectors, each equipped with a special optical device known as the "Hypergonar."

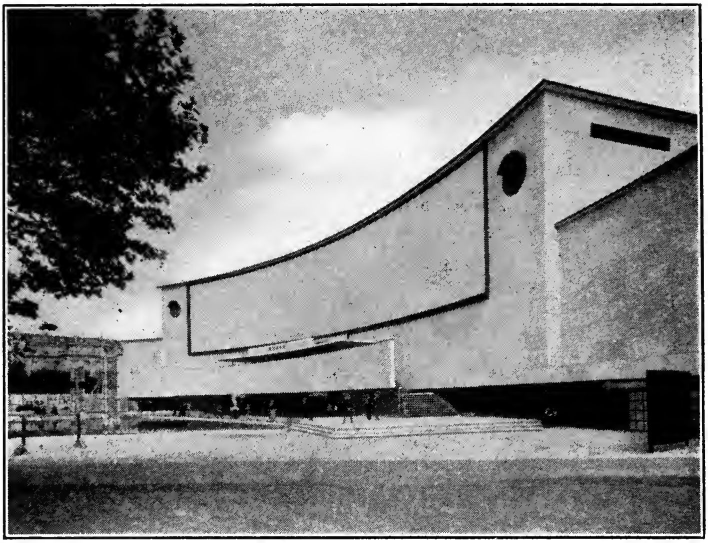

FIG. 1. Panoramic screen on the façade of the Palace of Light (Paris).

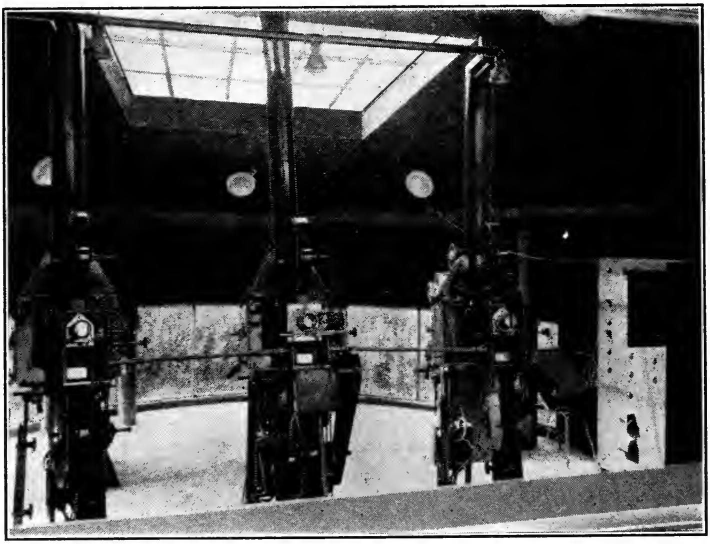

FIG. 2. Arrangement of projectors, showing interlocking scheme.

The Hypergonar lens was invented in 1927 by Professor Henri Chretien, of the University and Optical Institute of Paris. Mr. Chretien submitted it to the Optical Society of America some years ago. A description of the apparatus and its new possibilities with regard to motion pictures has been described by H. Dain in the JOURNAL.[2]

It is a sort of optical transformer. It does not produce real pictures by itself, but if set before an ordinary photographic objective doubles the field of the objective *in one direction only,* which in this instance is horizontal.

A picture 24 mm. wide may thus be registered on a film that would normally require a 48-mm. picture. When the picture is projected, a similar optical device, placed before the projector, spreads out the luminous beams horizontally, thus restoring the objects to their proper shape. The lenses used are not of the ordinary spherical variety, but are cylindrical, and are more difficult to grind to the required degree of perfection than ordinary lenses.

The total field required to cover the huge screen was obtained by juxtaposing two partial fields, each having been previously doubled by means of the Hypergonar. A special camera-type base permitted the automatic connection of the two equipments in accordance with the focal length of the objectives used and made it possible to drive them synchronously by means of an electric motor.

As a result of the combination of these methods, it was possible to project upon the largest screen in the world, with considerable brightness, pictures that had been magnified *six hundred times* in height and *twelve hundred times* in width, or seven million times in area; and this was accomplished in spite of the general illumination prevailing in the surroundings.

Natural vision is thus reconstructed on the screen in a most remarkable manner. Instead of viewing the film through a narrow space—a square loophole—we see it unfolded before us as it would be in nature. No doubt many cinematographic effects are lost through such a panoramic extension, but it is no less true, on the other hand, that with this device many pictures are re-created and endowed with the "aeration" they otherwise lack—the visual extension required to produce this effect, and, in short, the harmony and suppleness of expression of which the cinema had been long deprived—an art which from its very nature and scope was destined to develop freely and at ease after the panorama of nature and life.

The projection proper is provided by two standard Simplex projectors with rear ventilating shutters, which makes it possible to use 250 amperes per arc, without heating the film dangerously. These are driven in synchronism by a third Simplex apparatus, identical to the others, through two universal couplings. The third projector carries also a Thompson sound reproducer (Fig. 2). The central projector is driven by a $1^1/_2$-hp. motor.

Each Simplex projector is equipped with an "Ultimum" Taylor-Hobson, extra-luminous objective, with a fixed focus of 120 mm. and an aperture of $f/2$. In addition, each projector is equipped with a sliding device for inserting the Hypergonar lens. Each projector is also equipped with a Hall & Connilly lantern of the revolving carbon type, fitted with an automatic advance and thermostatic control. The current in each arc lamp is 250 amperes at 70 volts.

As this projection is in a class by itself and requires perfectly homogeneous luminous zones, it was necessary to use extra-luminous Bausch & Lomb condensers to concentrate the light of the arc upon the picture gate. The arcs are fed by a special 800-amp., 110-v. generator, and 16-mm. positive and 11-mm. copper-coated negative carbons are used.

To photograph the scenes two cameras are necessary, each taking simultaneously one-half of the picture. Each camera is equipped with a Hypergonar lens. Each half-image is projected simultaneoulsy by the two outside projectors, the right-hand projector projecting the image on the left-half of the screen, and *vice versa*. The junction of the two images is smoothed out by special masks consisting of two stationary shutters, the edges of which are cut like the teeth of a saw and set into the light-beams where the latter superimpose. Each of these stationary shutters was set about one meter in front of each projector, on the left and right, outside the beams. The shutters could be adjusted by means of a micrometer screw, thus concealing almost entirely the junction of the two images.

Standard film can be projected by the central projector, the outside projectors merely running idle. The projected image in such case measures 14 × 10 meters, the brightness being about the same as in the case of panoramic projection. The distance between the projectors and the screen was approximately 60 meters. Projection occurred daily from 9:30 A.M. to midnight, and the apparatus operated quite satisfactorily.

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A 16-MM. STUDIO RECORDER*

R. W. BENFER**

For the past few years we have witnessed an increased use of 16-mm. sound-film by educators, advertisers, and industrialists as a medium for exploiting their respective subjects through non-theatrical distribution. Projector manufacturers have responded to this expansion with improved sound equipment to keep pace with the demand for quality of reproduction approaching that of the theatrical field. It remains, therefore, to improve the sound-track of these non-theatrical subjects in order that the benefits of contemporary effort in this field be realized to the fullest extent.

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* Presented at the 1938 Fall Meeting at Detroit, Mich.; received October 5, 1938.

** Electrical Research Products, Inc., New York, N. Y.

At the present time 16-mm. sound-prints are derived largely from 35-mm. subjects by the process of optical reduction, usually from a duplicate negative of the original. The printing losses inherent in this process have been calculated and verified by experiment so that, knowing the frequency characteristic of the original negative, an accurate estimation of the 16-mm. print characteristic can be made. It should be noted, however, that the 16-mm. reduction print is always a derivative of the original and its characteristic is governed by that of the original. The recorder described in this paper is the result of an investigation made to determine how far the restrictions imposed by reduction printing could be removed by directly recording on 16-mm. film. By utilizing the technical knowledge acquired in the 35-mm. field, Electrical Research Products engineers were able to design a recorder that will produce negatives the sound quality and frequency characteristic of which result in a much improved presentation of the subject as a 16-mm. release.

The recorder is intended primarily for studio use, and its design is such as to permit recording 16-mm. variable-density negatives, first, from direct pick-up; second, to re-record from 35-mm. prints; and third, to re-record directly from 35-mm. negatives through the recently developed negative playback system. Release prints are then obtained by contact printing the sound-track in combination with optical-reduction printing of the picture from the 35-mm. negative in accordance with established practice.

To render the machine versatile in its application to the different types of studio equipment with which it might be associated for these purposes, a synchronous tail-shaft speed of 1200 rpm. was selected to permit either direct coupling or electrical interlock to the the studio equipment. Two sprockets in the left-hand compartment (Fig. 1) are driven through worm-gear reduction from this shaft which completes the gear-driven system of the equipment. The film is exposed at the periphery of a film-driven kinetic scanner having an oil-damped flywheel, resulting in uniformity of film motion comparable to that of the latest 35-mm. recorder. Removable magazines with self-engaging couplings to the chain-driven take-up clutch and the feed-reel brake permit professional procedure in pre-loading magazines in accordance with studio practice.

The sound-track is of the variable-density type, recorded by means of the recently developed variable-intensity modulator, appearing in the right-hand compartment. The light-valve admits light to a fixed slit through a relay lens system resulting in a variable-intensity modulation of the light-beam. The slit, in turn, is imaged on the film through a 6:1 reducing objective, resulting in an image height of 0.4 mil at the film and giving an extinction frequency identical to that of a 1.0-mil image for 35-mm. film at 90 feet per minute. Since the film sees only a reduced image of a fixed slit, the effects of valve-ribbon velocity relative to the film velocity are eliminated, and the physical dimensions of the slit and spacing of the valve-ribbons enjoy liberal dimensional tolerances. Adequate design provisions have been included to permit accommodating any future types of modulator that may prove desirable.

A transparent deflector bleeds parts of the modulated light emerging from the slit and directs it to the photoelectric cell and monitor amplifier (Fig. 2) which provides sufficient output for high-quality headset monitoring. The light-valve input circuit shares the same compartment, and the oil-damped flywheel appears

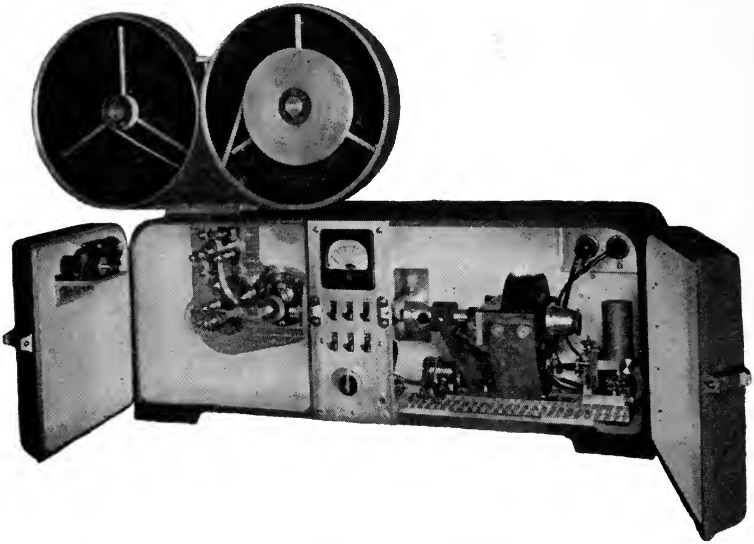


FIG. 1. Front view, doors open.

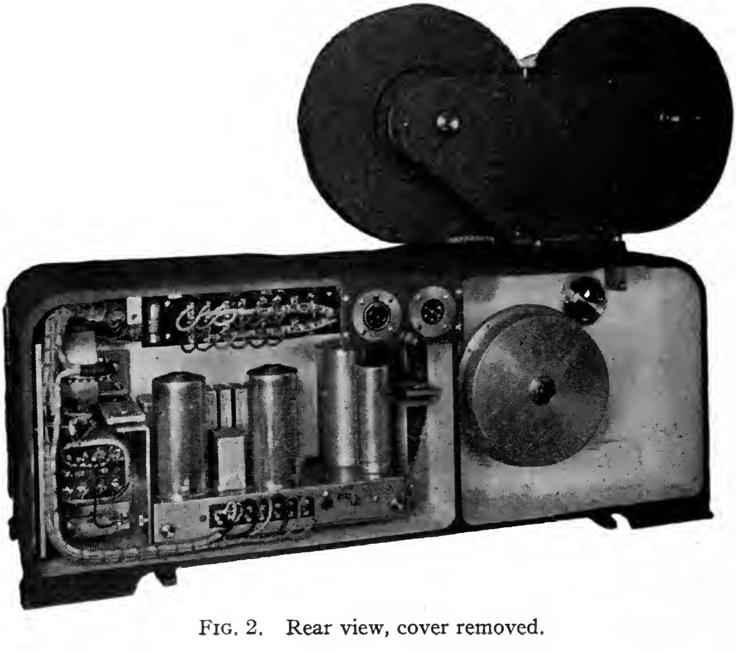


FIG. 2. Rear view, cover removed.

at the right. Both terminal strip and cord connectors are provided to accommodate whichever type of external wiring is desired. The monitor amplifier and the modulator, as well as the control panel, are all readily removable to give access to all wiring without disturbing the continuity of the circuits. The central control panel provides for all the conventional controls, including lamp, light-valve, and noise-reduction inputs.

Numerous experimental recordings have been made to determine the proper recording characteristic to result in a print characteristic having a pleasing frequency balance consistent with the inherent limitations of 16-mm. film, the speed of which is only 40 per cent of that of 35-mm. film. For direct pick-up, the pre-equalization characteristic has been made the inverse of the combined film and printing losses, so that the print shows a substantially flat characteristic to 6000 cycles per second, the higher frequencies being suppressed by a low-pass filter. For re-recording purposes it has been found desirable to determine the amount of pre-equalization not only from the standpoint of the film and printing losses but also from the characteristic of the original 35-mm. negative. By these processes it is possible to show a uniformity in the characteristic of the 16-mm. contact prints that is not always possible to attain by the optical reduction process.

DISCUSSION

MR. MCNABB: Approximately what equalization was used?

MR. BENFER: The recording channel was equalized to show a rising characteristic of about 8 to 10 db. at 6000 cycles, at which point the higher frequencies were suppressed by a low-pass filter.

MR. FRIEDL: I regard this as a very unusual demonstration of high-quality 16-mm. recording and reproduction. The question that occurs to me first is: Is a large part of that improvement due to the contact printing?

MR. BENFER: We have found that the prints from contact printers will have, as a rule, less flutter content than the print you get from the optical reduction process. That is not always the case. but it results in a more uniform product.

MR. FRIEDL: Is that because you used a specifically designed printer, say, a non-slip printer, whereas the optical prints are perhaps not made on equipment perfected to the same degree?

MR. BENFER: The only way I can answer that is to say these prints were made on a contact printer by DeLuxe Laboratories. We also made, for comparative purposes, optical reduction prints of the same subject, and the test of the two machines at this one laboratory showed that the contact printer was superior to the optical printer in terms of flutter.

MR. FRIEDL: That is optical printing from the 16-mm. negative?

MR. BENFER: No, from the 35-mm. negative.

MR. FRIEDL: The reason I bring this up is that I am again on a standards question. Contact printing normally places the emulsion on the positive on the side that we generally consider non-standard, or at least we would like to consider non-recommended practice.

You recall the confusion of 16-mm. standardization which caused this Society considerable concern and expense, and the final happy solution, as we consider it, of the international standardization on that subject.

For the sake of uniformity and simplicity we should try to keep the emulsion side for all 16-mm. sound prints on the side away from the light-source as normally viewed in a regular front projector. If contact prints are circulated with the emulsion on one side and optical reduction prints as made from 35-mm. are circulated with the emulsion on the other side, it is going to be very difficult to instruct, educate, or inform the non-technical user to adjust his reproducing equipment properly. Not only that, but it introduces an extra cost in the production of that apparatus, because you have to put on this scanning system a device permitting you to change the focus point of the scanning beam. In making a change like that, it would have to be a very precise adjustment, because the lens assemblies of 16-mm. designs are usually of cylindrical type, the light incident on the film being at a relatively steep angle. Therefore, any displacement from the actual focal plane will introduce losses in the high-frequency spectrum which we are so carefully trying to guard against.

MR. BENFER: You may have the impression that as we ran this film the emulsion was reversed according to the standards for optical reduction printing. That is not so. The sound-track printed by the contact-printing method from a negative to a positive print will agree with the SMPE standards for optical reduction printing. The picture, however, could not be contact-printed as taken by a 16-mm. camera. The picture must be optically printed from the 35-mm. negative. Through that combination of events you arrive at a film that agrees with the SMPE standards, and in support of your statement concerning the standards, if the point ever comes up to combine a direct contact print of both picture and sound negative, then the standards fail to agree and you come up against the obstacles of having to reverse one or the other.

MR. FRIEDL: There is a trick in the system. There is just a little flip-flop somewhere which must come out as you say. Do you record through the stock of the film?

MR. BENFER: No, the recorder exposes the film on the emulsion side in accordance with all conventions. The negative agrees with the SMPE standard "for special processes." The contact print obtained from that negative is contact-printed emulsion to emulsion and comes out with the sound-track in the proper direction when the emulsion is in the right position in accordance with the standards for optically reduced film. The picture must be optically printed from the 35-mm. negative to agree with that particular layout of emulsion and sound-track.

MR. KELLOGG: Do you get better resolution or high-frequency response on the 16-mm. film by contact printing than you can by direct optical reduction from the 35-mm. film, in sound-track production?

MR. BENFER: I am not prepared to say that. All other things being equal, with the same amount of perfection in each system, I believe they would be identical.

MR. KELLOGG: The advantages you mentioned of the contact printing then were confined to better propulsion?

MR. BENFER: That is the advantage as far as the two printers are concerned. Another advantage of contact printing is the ability to record a 16-mm. negative specifically for 16-mm. release, and to utilize the advantages you get from professional treatment on your original recording rather than to be restricted by the characteristic that was put on the 35-mm. negative which was probably made for some other purposes than 16-mm. release.

MR. FRIEDL: Suppose the 35-mm. were made intentionally for optical reduction printing to 16-mm. in which event proper consideration could be given in the original recording, say, for example, raising the high end to compensate some for the printer loss, how would we come out?

MR. BENFER: I think you would come out nearly the same. We have taken both types of recording and compared both types of processes, and if you start originally with 16-mm. printing in mind, it is possible to obtain comparable prints from either process.

MR. FRIEDL: Then the advantage is what: the cost of the 16-mm. stock?

MR. BENFER: The advantage is that the present source of the 16-mm. subjects is 35-mm. film, and I doubt whether many of them were recorded with that in mind. Added to this is the fact that the optical-reduction process requires precision equipment and excellent maintenance to assure a uniform product. The straightforward process of contact printing results in uniform prints with a minimum of trouble.

MR. FRIEDL: That is a challenge to the manufacturers of optical reduction equipment.

MR. BENFER: As long as you ask me point blank, I will have to put it that way. It has taken seven years to get a good optical-reduction print but only seven weeks to get a good contact print, and we can repeat it from now on.

MR. FRIEDL: If you make this one 16-mm. negative from which you contact print, in order to make this commercial for wide distribution—I assume you have to make two negatives from that—then is the technic of making 16-mm. dupe negatives as well advanced as making 35-mm. dupe negatives?

MR. BENFER: That is a little out of my territory, but I think it is. We have been encouraged in this process by the laboratories themselves. They would rather attempt to perfect this type of practice than the other.

MR. FRIEDL: Is shrinkage for 16-mm. a limitation?

MR. BENFER: The shrinkage problem would be the same problem you have in 35-mm. and must be treated the same way.

MR. FRIEDL: 35-mm. negative is usually nitrate, whereas 16-mm. is acetate and can be made in nothing but acetate stock.

MR. BENFER: Perhaps we should ask the film suppliers for 16-mm. nitrate, since this is to be used in studios for negative purposes.

MR. FRIEDL: I am afraid you will not get that. Dr. Carver will confirm that, from our discussion in the Standards Committee.

DR. CARVER: I do not think there is any hope of getting 16-mm. nitrate. There is great fear that some of it will get into someone's home and set fire to it.

MR. BENFER: I can say one thing, the negative stock we have used has been acetate base. We have had no trouble with it through the laboratories on reprints. This demonstration negative is a composite negative, some sections of which were taken almost a year ago. The print you heard here was printed last week, from a combination of the negatives that have been recorded during the past year. We have had no complaint either from the results we have experienced ourselves or from the laboratory in handling it on the basis of shrinkage or anything of that nature on the acetate-base 16-mm. film.

MR. DEPUE: If you have a very fine and expensive production, would you risk making just one negative on 16-mm?

Six years ago the company with which I am connected made direct recordings of voice—not music but voice—that have been holding up very well. Prints have been made from it just recently, and there has been no trouble, but we have always been fearful that, if anything should happen to the negative we should have nothing to go back to. If we had a standard size we would reproduce and make another negative.

MR. BENFER: If the 16-mm. field is to grow and assume a professional aspect, then all conventions and things found advantageous to the professional field should be adhered to in the 16-mm. field. When the production is of sufficient importance to warrant duplicate negatives taken simultaneously, the same procedure could be followed in the 16-mm. field. This recorder is an attempt to give the 16-mm. industry the facilities for professional recording and distribution of its product.

A NEW SINGLE-SYSTEM RECORDING ATTACHMENT FOR STANDARD CAMERAS*

A. REEVES**

When sound was first introduced, it was believed that there existed but two possible classes of users of sound-camera equipment: the studio, which could use a large permanent or semipermanent double-film recording installation; and the travelling cameraman, best exemplified by the newsreel cameraman, whose ends seemed best served by a portable, single-film sound-and-picture recording camera.

During recent years it has been found that there is another important group, the specialized needs of which have as yet received little attention. This group comprises those who use direct-recorded sound, but need to use it only occasionally, being able to film much of their footage silent and later "dub in" whatever sound, narration, or music may be necessary. This group includes many newsreel cameramen (for fully half of today's newsreel scenes are made silent, and later dubbed to a narrative or musical sound background); the makers of travel-films; many makers of commercial, industrial, or educational films; studio cameramen sent to distant locations for the making of process backgrounds; and the very considerable army of owners of professional silent picture cameras whose work does not warrant the discarding of their expensive silent picture equipment or the purchase of conventional sound equipment. All of them could make use of direct sound recording if it did not involve an undue amount of bulky added equipment.

* Presented at the 1938 Fall Meeting at Detroit, Mich.; received October 26, 1938.

** Art Reeves Motion Picture Equipment Co., Hollywood, Calif.

It is primarily to meet this need that the Art Reeves single-system sound recording attachment has been developed (Fig. 1). This device is precisely what its name implies: a single-system recording unit which may be attached to any standard camera using outside-type magazines. Granting, of course, that the camera has been mechanically silenced for use with sound, no alteration in the camera itself is necessary, other than the use of a longer take-up belt.

FIG. 1. The Art Reeves Single-System Sound Recording Attachment in use on a Mitchell Camera. Recording unit is mounted between camera-head and magazines and may be removed at any time.

The recording unit consists of a small housing which is simply interposed between the camera-head and the film magazines (Fig. 2). In it the unexposed film from the feed magazine passes over a relieved idling roller and then forward to pass over the recording drum. From this drum the film curves back and downward over another idler, and passes into the camera-head in the usual manner. The feed to the take-up magazine is a straight line from the camera-head to an idling roller which guides it through the take-up magazine's light-trap.

The recording drum is of conventional type, driven only by the friction of the film passing over it. The drum is direct-connected to a heavy, magnetically damped flywheel which ensures uniform motion of the film. Stroboscopic measurements of the film motion past this drum show its movement to be equal to that on the best double-system recorders.

Recording is done at this drum. While any type of recording unit may be employed, the device is designed for use with the Art Reeves "Line-O-Lite" recording glow-lamp and its apertureless optical system. This lamp is more than ordinarily well suited to single-system recording, for sound and picture exposures may be balanced more closely with it than by most other methods.

In addition to a strong visual radiation, the "Line-O-Lite" has a remarkably strong ultraviolet radiation, and gives most of the advantages of ultraviolet recording. It has been found that the most suitable gamma for sound-tracks re-

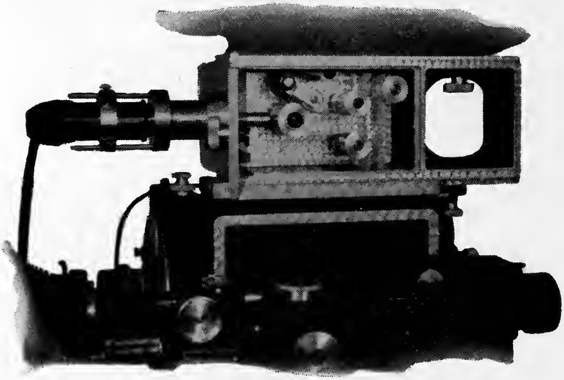


FIG. 2. Close view of Reeves Single-System Sound Recording Attachment. Sound-track is recorded by standard Reeves Line-O-Lite glow lamp, which permits sound-track gamma of 0.6 to 0.65.

corded with this lamp is in the region between 0.60 and 0.65. This is identical with picture negative gamma in most of the best laboratories. Thus the negative may be developed for picture values with assurance that if the picture is correctly exposed, the sound-track negative will also be satisfactory. The first of these devices made was fitted to a standard Mitchell camera, and has already seen extensive use on commercial production. The author has several times seen sound-and-picture negative made with it, and sent to the laboratory with the simple notation, "Develop for picture," and later viewed the scenes so treated. The sound quality was fully comparable to that secured with a good double-system recorder.

The amplifier and battery cases for this equipment have been designed for extreme portability and simplicity. Each of these two cases is less than a foot square and is covered with galvanized metal to resist hard usage and tropical weather conditions. The amplifier uses four tubes, and has been simplified to make its use in the field simple, even to individuals not trained in the technic of sound recording. When the main switch is turned, one control brings a needle on the filament-current indicator to a red-marked "normal" point. Another control adjusts the volume indicator to a predetermined minimum-level point. The main gain control is then simply operated as may be required to keep the maximum volume from overrunning a marked maximum limit.

An equalizer is fitted to the circuit, and may be cut in or out by throwing a single switch. This equalizer is useful for minimizing the "tubby" effect so often encountered when recording in places where acoustics are poor. A noise-reduction circuit is also an integral part of the amplifier, and a plug is supplied for monitoring head-phones.

The frequency-response of the amplifier is flat from 100 cycles to a point considerably above 7000 cycles. The response of the glow-lamp is flat over the entire usable frequency range.

There is, it must be admitted, one slight disadvantage to this system, albeit a small one. The standard separation between sound and picture projection apertures is $19^1/_2$ frames, with the sound ahead of the picture. The construction of this attachment throws the sound 21 frames behind the picture. Thus, in printing, the sound must be moved forward $40^1/_2$ frames to be in synchronism. But since virtually all sound prints, including many made with single-system recorders, are printed in two operations, this is hardly to be regarded as a serious disadvantage.

On the other hand, the extreme portability of the outfit, and the fact that it is a detachable unit and does not require any alteration of the camera, offer definite advantages. When sound is not needed, the unit may be completely removed from the camera, leaving a standard silent picture camera. When sound may perhaps be needed, the unit complete with batteries, microphone, and cables, may be carried with ease, even in a small car. With the exception of the microphone stand, the entire sound unit occupies less space than a single camera-magazine case.

The advantages of such equipment for modern newsreel and commercial camerawork will be obvious. In addition, the author visualizes extensive application in several other fields. First is in the making of travelogues, where in perhaps a majority of instances silent scenes, later to be accompanied by narrative or music, may be most common, but where actual, synchronized recording of unusual tribal music, unusual scenes where actual sound is an important factor, may also be desirable.

Second is the making of studio process backgrounds on distant and unusual locations. In such assignments, the picture is, of course, of chief importance; but frequently it may be desirable to make direct recordings of the sounds actually related to these scenes, as in some cases they can not authentically be recreated in a studio sound department.

NEW SOUND RECORDING EQUIPMENT*

D. R. CANADY AND V. A. WELLMAN**

Recorder for 16-Mm. Film.—The use of 16-mm. sound-film is growing rapidly though it is yet in its infancy. It has been maintained so frequently in the field that good recordings can not be made directly on 16-mm. film but must be first made on 35-mm., that the statement has become generally accepted as true. It has been rather general practice in the past to attempt to make 16-mm. recordings on 35-mm. equipment with narrow sprockets and the recorder geared down to the proper speed for 16-mm. film. This slowing down of equipment, although fairly satisfactory at the high speed of 35-mm. film, has indeed produced results at slow speed that could not be called satisfactory.

We have designed a recorder for 16-mm. film that produces records comparing favorably with the very best made on 35-mm. equipment and far better than the average 35-mm. output, and having none of the defects looked for in other direct 16-mm. recordings; with the added advantages of convenience, and lessened cost of the direct recording, and without the printing losses necessarily accompanying optical reduction of the 35-mm. record.

Fig. 1 gives an idea of the appearance of the recorder. It is of cast aluminum, of convenient dimensions, light weight, neat in appearance, and the parts so arranged that the threading is simple and convenient notwithstanding the difficulty usually experienced in handling the narrow film. Either the galvanometer or the glow-lamp may be used, but the glow-lamp is recommended because of its simplicity. Cast aluminum magazines of 400-ft. capacity are provided, with friction take-up. The recorder is driven by a synchronous dynamically balanced motor.

The heart of the recorder is, of course, the recording drum, with a newly designed stabilizer exhibiting the same constancy of speed characteristic of all our recorders—such constancy that records made on this equipment compare very favorably in the high-frequency range with the very best 35-mm. records. The recording drum is not oil-damped and is not affected in its operation by any temperature changes, high or low.

Noise Reduction Unit for Glow-Lamp Recording.—The noise-reduction unit shown in Figs. 2 and 3 is self-contained, of either portable or panel mounting type. Its use requires no change in the amplifier already in use, except that as it provides the polarizing voltage for the recording lamp it does away with the batteries or generator now supplying that voltage. Its action is wholly electrical and automatic, without shutters or mechanical parts. The unit follows the general practice in that a portion of the signal is picked up by any convenient method, depending on the amplifier used; this signal current is amplified, rectified, and fed into the compensator, which is the heart of the unit. The polarizing voltage is furnished by an a-c. power pack of conventional design and, by action of the compensator, is adjusted according to the demands of the signal.

* Presented at the 1938 Fall Meeting at Detroit, Mich.; received October 13, 1938.

** Canady Sound Appliance Co., Cleveland, Ohio.

The variation may be such that the current in the recording lamp can be changed over a range of 5 to 25 milliamperes, although such extreme variation is not needed. During the operation of the unit the wave-form of the signal is in no wise altered, and since there is no reactive connection with the amplifier there can arise no motorboating or other reactive difficulty in the amplifier. Convenient means are provided for pre-setting the minimum and maximum current through the lamp, and either may be set anywhere within the above-mentioned range of 5 to 25 milliamperes. After once being adjusted, nothing the signal does can cause the recording-lamp current to go below the minimum or above the maximum value so set, the action of the unit between these limits being entirely automatic. The unit can be used only with Canady glow-lamps.

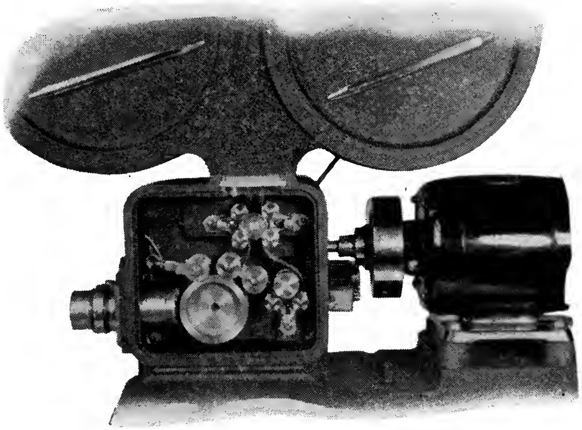


FIG. 1. Sixteen-mm. recorder.

Since early glow-lamp recordings were not entirely satisfactory there has grown up in the studios a prejudice against glow-lamp recording and a belief that glow-lamp equipment can not produce good records. With the addition of this noise-reduction unit there is nothing possible on other types of equipment that can not be reproduced with this glow-lamp equipment, including squeeze-track, and in addition this equipment will produce records not obtainable with any other equipment. In the JOURNAL there has been considerable discussion as to the superiority of recordings made on the straight-line portion of the H&D curve over those made at the toe of the curve. It is generally believed that glow-lamps other than the Canady lamps make toe recordings only because they can not rise to the straight-line portion, and there has been some argument to the effect that toe recording is equal to or better than straight-line recording. However, with this lamp the recording may be done at the toe or at any other portion of the H&D curve that the recording engineer may prefer; hence this objection to glow-lamp recording no longer holds.

Referring to Fig. 2, showing the front panel, the socket at the left is the input from the amplifier, the middle one the output, and the right-hand socket the a-c. input. The left knob is the adjustment for the minimum current, the right knob for the maximum current, and the upper knob for a rough adjustment of the polarizing voltage. The tubes shown in the rear view (Fig. 3) are of the conventional type obtainable anywhere.

FIG. 2. Noise-reduction unit.

Galvanometer.—The galvanometer shown in Figs. 4 and 5 embodies no new principle but does represent a very definite engineering advance in that every element is so conveniently placed and so adjustably arranged that it can be applied to almost any recorder and varied to suit the individual ideas of the recording engineer.

The lamp house is of cast aluminum, structurally strong, properly ventilated, with cooling vanes machined in the casting. The lamp socket is machined from heavy brass and is adjustable up and down as well as circumferentially, and the

FIG. 3. Noise-reduction unit (rear view, cover removed).

lamp assembly adjustable from side to side. The slit and condensers may be adjusted in their mountings; the galvanometer is adjustable in all directions, as is the cylindrical lens and its mount. The objective may likewise be given various adjustments. This freedom of adjustment of all the component parts permits the engineer to use a wide variety of lamps, slits, condensers, and lenses to suit his own desire and the work contemplated. The galvanometer mirror is oil-damped and has a straight-line output to 10,000 cycles.

Background Projector, Motion Picture.—The projection from the rear of a background, either still or in motion, before which the action takes place, has become commonplace in the studios producing theatrical motion pictures, but its value to the producer of non-theatrical and advertising pictures is just beginning to be learned.

The requirements of the projector of background motion pictures are extremely rigid. First, the picture must be rock-steady, otherwise the mountains

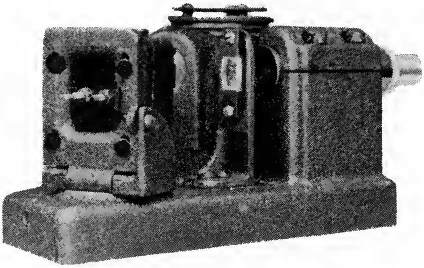


FIG. 4. Galvanometer.

in the background will be dancing behind the actors. No standard met within ordinary motion picture projection is even approximately satisfactory. Second, the projector must be as noiseless as the camera; in fact, it may be nearer the microphone than the camera.

To meet these requirements there has been brought out the projector illustrated in Fig. 6. The steadiness of the film is insured by the use of a claw move-

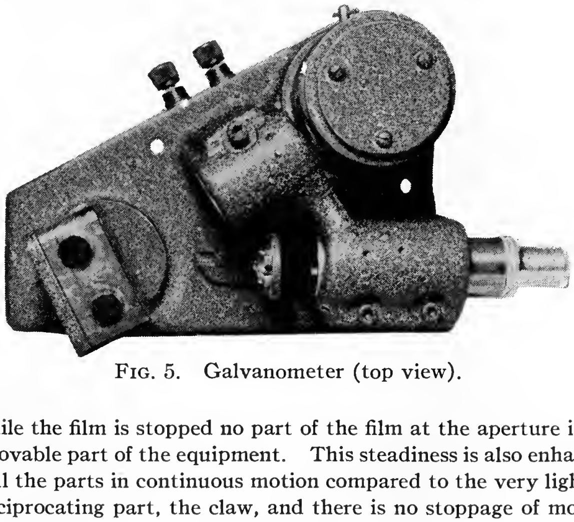


FIG. 5. Galvanometer (top view).

ment. While the film is stopped no part of the film at the aperture is in contact with any movable part of the equipment. This steadiness is also enhanced by the weight of all the parts in continuous motion compared to the very light weight of the only reciprocating part, the claw, and there is no stoppage of motion of any part of the equipment. The claw is actuated by a cam on the shutter-shaft, eliminating all lost motion between the shutter and the movement of the film.

The shafts, including the shutter-shaft, run in ball-bearings. All moving parts are sealed in an oil-tight case and are oiled by a circulating oil pump. The sprockets are of large size, driven through a silent chain, running in oil. The driving power may be applied either to the shutter-shaft or to the gear-shaft extending through the case. The case is of heavy castings, insuring steadiness on the stand, and is solidly bolted together to make it oil-tight and to deaden all noises of the

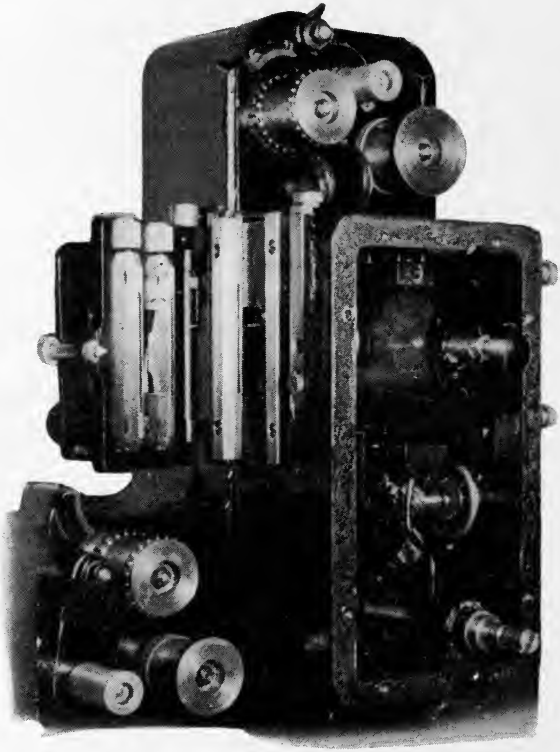


FIG. 6. Projector head for rear projection.

running parts. The noise of the film movement being the only sound heard, a blimp such as surrounds the camera prevents all sound from reaching the microphone.

The tension shoes are very long and the tension is adjustable. There are three claws on each side which, with the long tension shoes and low tension on the film, insure long life of the film. A loop of film has been run through the projector 20,000 times without noticeable wear.

A NEW CAMERA TIMER FOR TIME-LAPSE CINEMATOGRAPHY*

HENRY ROGER**

By "time-lapse" or "stop-motion" cinematography we mean motion pictures of comparatively slow actions that appear to be speeded up when projected upon the screen. We may presume that film records of actions taken at any lower frequency than normal projection speed would belong to this category because they are more or less speeded up when projected. For practical reasons we may say, however, that useful time-lapse work ranges between one frame per second and one frame per hour.

Historically speaking the use of time-lapse cinematography may be traced back to the early days of the motion picture art. It has been employed extensively in the natural sciences to demonstrate, for example, the process of plant growth, the opening of flowers, slow chemical reactions, *etc.*

The taking of motion pictures of this type is, of course, very simple, aside from some experience in determining the proper time-intervals between exposures. Provided the illumination is constant, the camera needs only to be operated at the proper speed by hand or motor. When focusing upon the object sufficient space should be allowed in the field of view for its increase of size. Pictures have occasionally been taken over a period of several days, two or three cameramen working in shifts.

Many types of driving mechanism, more or less complicated, have been constructed, mostly home-made affairs, serving only limited purposes, and it has been felt, due to an increase of time-lapse work in recent years, that there is a demand for a standard device available to everybody.

The camera timer to be described (Figs. 1 and 2) is the result of 20 years of practical experience in time-lapse cinematography as applied in a scientific and industrial research laboratory where accuracy and excellence of results are of prime importance and where the attention of the operator should be focused upon the object itself rather than upon the manipulation of the camera. Therefore, such a timer must be compact and portable, automatic, and easy to operate and foolproof.

The timer consists of a number of units assembled in a box that may be set upon a tripod or other suitable stand and connected to the camera by a telescope shaft with two universal joints or by a flexible shaft. Shaft extentions are on either side of the timer so that the instrument panel faces the operator at all times, whether the camera is horizontal, as for straight photography, or vertical for close-up and microscopic work.

The apparatus consists of the following parts: (*1*) Minute device, (*2*) hour device, (*3*) camera motor, (*4*) frame (exposure) counter, (*5*) relay mechanism for intermittent and continuous operation, (*6*) automatic light-control mechanism, (*7*) instrument panel; *Auxiliaries:* (*1*) Voltmeter and ammeter for measuring light output, (*2*) time limit switch, (*3*) auxiliary light circuit,

* Presented at the 1938 Spring Meeting at Washington, D. C.; received April 15, 1938.

** Rolab Photo-Science Laboratories, Sandy Hook, Conn.

(*4*) receptacle for panel light, (*5*) remote-control button for single exposures and animation work.

The minute device consists mainly of a synchronous motor, a contact disk assembly, and a commutator switch. It can be set to take 1, 2, 3, 4, 6, and 8 pictures per minute.

The hour device is of similar construction, with synchronous motor, contact disk assembly, and commutator switch for 1, 2, 3, 6, 12, and 24 pictures per hour. It has, in addition, a contact mechanism that insures uniformly exposed pictures.

FIG. 1. Camera timer.

FIG. 2. Camera timer mounted on stand.

The camera motor is of the silent precision type, with speed governor and gear-shift assembly for two speeds. The frame-counter counts single exposures and can be re-set at any time.

The mechanism for intermittent and continuous operation plays an important part in the timer, and the intermittent operation may be considered a most valuable feature. It may be pointed out here that the majority of home-built devices, operating continually, have a definite drawback because any change of time-interval requires lengthy readjustment of gears, pulleys, light, and camera objective, besides the making of exposure tests. In the Roger camera timer a change of frequency may be accomplished simply by turning a dial on the instrument panel. This does not change the exposure-time previously found to be correct, and was made possible by the intermittent operation of camera and light-source. Between exposures, and after having turned one revolution, the motor stops completely at the moment the camera shutter is closed. A cycle begins with an impulse from the minute or the hour device, which activates the relay and starts the motor with intermittent mechanism. The light turns on and off in synchronism with the camera shutter, and the motor stops again at the end of one revolution.

A single lever on the panel may be turned to disengage the intermittent mechanism with the result that the camera now operates continuously with two adjustable speeds for frequencies over 8 pictures per minute.

The timer, as mentioned before, is composed of a number of units. It is therefore possible to make up simplified models to suit particular purposes. The following outfits are being manufactured:

Camera timer with hour device only.
Camera timer with minute device only.
Motor and intermittent mechanism only, for animation work; hour or minute device may be suppled separately if needed.
The camera timer can be supplied without meters and time-limit switch.

Forerunners of this timer have been in use about ten years in a number of laboratories. At the Rockefeller Institute for Medical Research it has been used by Dr. Alexis Carrel and the author for making micro-cinema studies of living cells of tissue and blood, and of bacteria. Some of the results have been reported previously in the JOURNAL. The U. S. Department of Agriculture has been using a timer in its Motion Picture Department for about four years, for recording plant and animal life. Timers have been and are being used extensively by the Rolab Laboratories. Some of the work that has been done includes the following subjects:

Growth of various plants, mushrooms, and other fungi; opening of flowers; budding of yeast starting from a single cell; growth of bacterial colonies and single bacteria; action of bacteriophage on coli bacteria; capillary action of dyed liquids in the grain of wood; formation of ice crystals and their penetration into pores of wood to prove adhesion (legal evidence),

Growth of tissue and blood cells, including cell division and phagocytosis; growing nerve fibers; blood circulation,

Formation of wax crystals in various motor oils at very low temperatures, to show point of solidification with regard to winter starting; taken in freezing chamber using polarized light.

Behavior of thin layers of paraffin at low temperatures; formation of Liesegang rings; swelling experiments, cataphoresis of colloidal particles for the motion picture *Colloids and Their Behavior*,

Animated pictures of various kinds and animated plastilina models.

Camera timers may also be used for the reading of instruments of various kinds of periodic time-intervals.

NEW PIEZOELECTRIC DEVICES OF INTEREST TO THE MOTION PICTURE INDUSTRY*

A. L. WILLIAMS**

High-Fidelity Record Cutter.—Basically, a Brush crystal unit is an ideal driver for a record cutter due to its inherent great stiffness. Due to this stiffness, its amplitude and frequency response are almost completely unaffected by depth of cut, variations in hardness of the record blank, *etc.*

Normal recording practice calls for constant velocity over most of the range. This means that the amplitude will increase as the frequency decreases. As this would call for too wide spacing of the grooves if carried on down to, say, 30 cycles, it is customary to change to constant amplitude for frequencies below somewhere between 250 and 1000 cycles. A crystal-operated cutter will tend to give constant amplitude at all frequencies. This is modified by including in the cutter circuit sufficient resistance, either mechanical or electrical, or both, to attenuate the higher frequencies. As the load presented by the crystal itself is similar to a condenser, its impedance will decrease with increase of frequency, therefore the higher the frequency, the greater the attenuation produced by the series resistance.

Fig. 1 shows the construction of the new crystal cutter, type *RC-1.* A large four-ply crystal unit ($2^1/_2 \times 1 \times {}^1/_4$) is used to drive the stylus. This is considerably larger than necessary and provides a large factor of safety as the crystal will stand 500 volts, while the normal recording in the constant or maximum amplitude part of the range requires about 50 volts. At higher frequencies the voltage will be proportionately less. Total power consumption is a fraction of a watt.

Fig. 2 is a photograph of the "Christmas tree" pattern from 30 to 12,000 cycles made by applying constant voltage to an *RC-1* with appropriate series resistance to cut at constant velocity above 300 cycles; while Fig. 3 is a curve of the output of a *PL-12* pick-up and filter on this same record.

PL-12 and PV-12 Phonograph Pick-Ups.—These two pick-ups are similar in construction, the only difference being that the *PL* was designed for lateral recordings and the *PV* for vertical recordings. The main objective in their design was to produce a rugged reliable device with flat response to at least 10,000 cycles, in which the wear on the record would be reduced to a minimum. This called for an extremely light flexible stylus and a consequent sacrifice in output. On open circuit, the output of this pick-up is proportional to amplitude, irrespective of frequency, but when fed into a resistance load lower than its own impedance at any frequency, the output will be proportional to velocity. In order to correct for the fall-off that would occur at the constant-amplitude portion of a recording, all that is necessary is to place a capacity in series with the resistance load so that the load impedance will increase correctly at these low fre-

* Presented at the 1938 Spring Meeting at Washington, D.C.; received April 15, 1938.

** Brush Development Co., Cleveland, Ohio.

quencies and result in correct input to the amplifier down to 30 cycles without further compensation.

Fig. 4 shows the construction of the pick-up. A sapphire stylus is set in a small screw which fits the thread in a hollow magnesium chuck. The motion

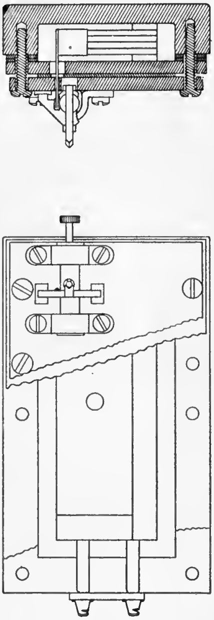


FIG. 1. Brush type *RC-1* record cutter.

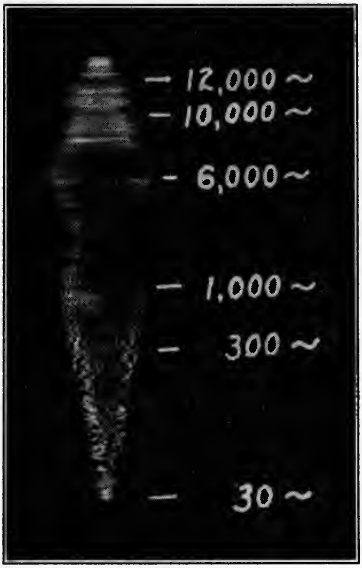


FIG. 2. "Christmas Tree" pattern, from 30 to 12,000 cps.

of this chuck is converted into torsional strain in a beryllium bronze wire which conveys a twisting force to the crystal in a hermetically sealed compartment. This twisting force is exactly in proportion to the deflection of the stylus and is converted into electrical energy by the crystal.

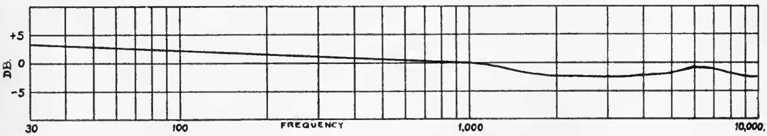


FIG. 3. Overall response of Brush *RC-1* cutter and *PL-12* pick-up on direct acetate recording, constant input voltage to cutter.

Fig. 5 shows some of the mechanical characteristics of the system. Curve *1* shows the amplitude of the cut on an average record for a constant high output at all frequencies and assumes the amplitude to become constant below 250 cycles. The force required to overcome inertia in rotating the stylus and stylus-arm assembly at constant amplitude is proportional to the square of the frequency, and depends upon the moment of inertia of the assembly. Due to the decrease in amplitude above about 250 cycles, the force required will vary directly with frequency, as shown in Curve *2*. The stiffness or restoring force of the beryllium bronze wire and its composition bearings has maximum effect at the low frequencies and was designed not to exceed greatly the force required to overcome inertia at the high end. In any oscillatory system, the natural period is a function of the moment of inertia and the restoring force. When the stylus is not in contact with the record, this occurs at about 2000 cycles. At this frequency a minimum side pressure is exerted by the record when the stylus is in the groove. Curve *3* shows the restoring force plotted against frequency and Curve *4*, the damping component. Curve *5* shows the pressure required from the side wall of

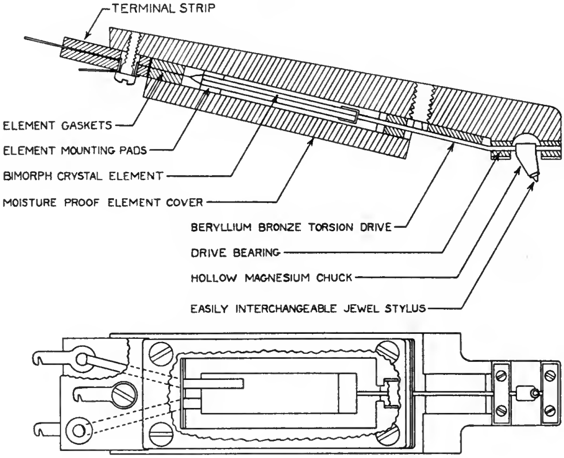


FIG. 4. Type *PL-1* high-fidelity phonograph pick-up.

the record groove to move the stylus, having constant output at all frequencies. The weight of the stylus and stylus-arm assembly is approximately 0.005 ounce. From Curve *5* it will be seen that the maximum side pressure on the stylus is about 0.18 ounce at the low end, falling to a minimum and then rising to a little over 0.1 ounce at 10,000 cycles. The natural period of the crystal is over 14,000 cycles. Due to these small forces it is possible to use as little as 0.5 ounce of weight on the head and the wear on the records and stylus is extremely low.

Fig. 6 shows the values of the correcting filter supplied. The filter is arranged to give three sets of values and the curves show the effect on the response from a Victor 30- to 10,000-cycle test-record.

Standard shellac pressings may be played as many as 3000 times without appreciable wear on record or stylus. Direct nitrate recordings may be played hundreds of times, but what is possibly more important is that it is possible to play back from the soft nitrate direct recordings frequencies up to over 12,000

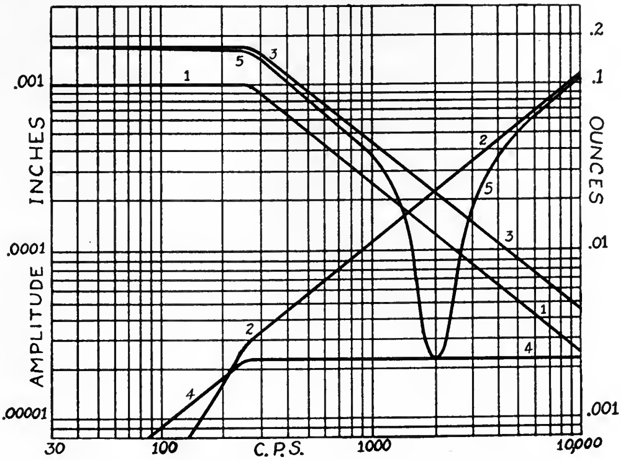
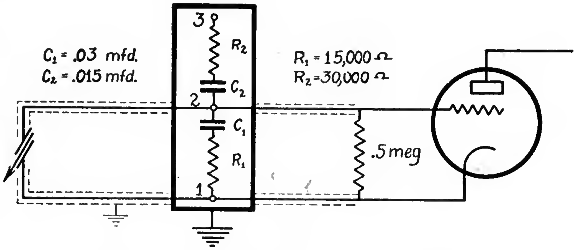


FIG. 5. Pressure from side wall of groove to move stylus.



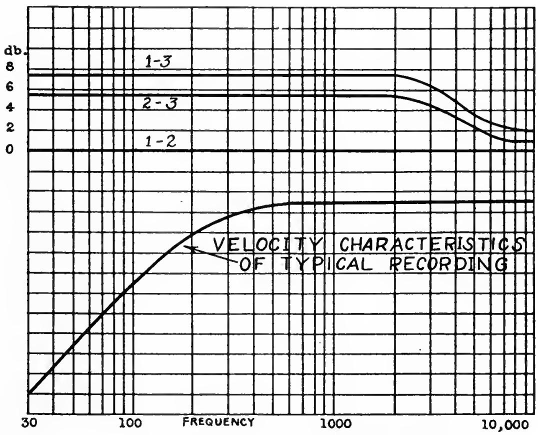


FIG. 6. Values of correcting filter.

cycles. This is not possible without serious loss of the higher frequencies with an ordinary pick-up due to the inertia of the heavy moving parts.

Unidirectional Microphone.—The unidirectional microphone, Type *UD-4*, obtains its unidirectional characteristics by combining a nondirectional or pressure microphone with a bidirectional or pressure-gradient (or velocity) microphone resulting in a cardioid-shaped field.

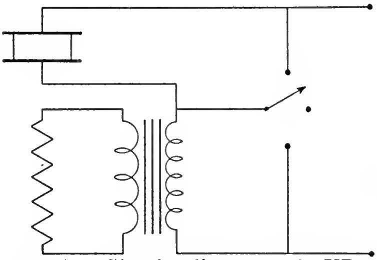


FIG. 7. Circuit diagram of *UD-4* microphone.

To obtain correct addition of the outputs from the two elements for sounds originating from the front, and cancellation from the rear, the outputs must be equal and in correct phase relationships.

A few years ago, Brush brought out their Type *UD-3* unidirectional microphone in which the pressure-gradient unit consisted of two sets of opposed pressure cells whose outputs and phase relations had to be corrected before mixing with the straight pressure cell. This called for a special and complicated amplifier or, if done before amplification, a rather low output. In the new instrument, Type *UD-4*, a ribbon microphone replaces the differentially connected pressure units. The stiffness-controlled capacity pressure unit is in phase with the mass-controlled inductive velocity unit without compensation.

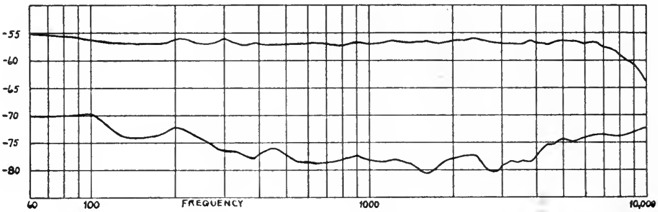


FIG. 8. Response characteristic of *UD-4* unidirectional microphone, front and back.

Fig. 7 shows the arrangement diagrammatically. To match outputs, the ribbon is stepped up to a convenient impedance by means of a transformer whose secondary is in series with the sound cells, which are placed in the same vertical plane as the ribbon. A switch is provided to cut out one or the other, making the microphone unidirectional, nondirectional, or bidirectional at will. A fourth position also is provided to cut in an appropriate resistance to reduce the bass for close speaking. The sound cells are so placed in the case that the natural position for close speaking is much closer to the sound cells than the ribbon in order to minimize the familiar bass accentuation common to a velocity unit in a spherical wave.

Fig. 8 shows a typical response curve from the front and rear of this microphone, switch in *UD* position.

The microphone is relatively small and compact, as it does not require the acoustical labyrinth that is necessary when a ribbon pressure unit is used. The output is quite high, being about −54 db. (zero equals 1 volt per dyne per sq.-cm.) from the front (unidirectional position) with the high-impedance model. A low-impedance model will also be available with slightly lower output. The average difference back to front is 10 to 1.

High-Fidelity Head-Phones.—The Type *A-1* phones were primarily designed for monitoring in film and broadcast studios and for testing hearing. They are similar to Type *A* phones in appearance and weight. Fig. 9 shows a cross-section

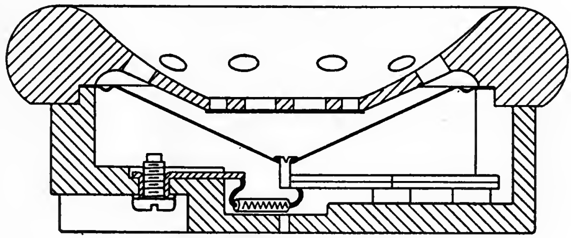


FIG. 9. Type *A-1* high-fidelity receiver.

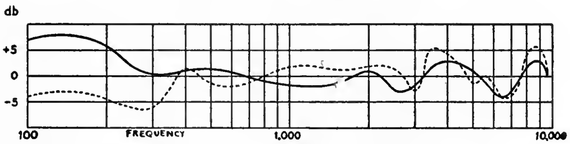


FIG. 10. (Solid curve) pressure calibration; (broken curve) subjective calibration.

of the unit. Great care has been taken to correct serious dips and peaks in the response curve, resulting in very uniform output from 100 to 12,000 cycles. They have been made extremely sensitive to the higher frequencies (*i. e.*, with a rising characteristic) which have been again reduced to normal by means of a high series resistance (150,000 ohms) in each unit. This resistance, besides aiding uniformity of response, guarantees that the phones will have no effect on the line across which they may be shunted.

As is well known, a very small air leakage between phone-cap and ear will cause serious loss at the lower frequencies. This loss has been somewhat compensated for in the Type *A-1* phones and Fig. 10 shows typical response curves taken on an artificial ear and taken subjectively.

The voltage sensitivity is approximately one volt per dyne, which is satisfactory for use at zero level on a 500-ohm line. For great sensitivity it is perfectly satisfactory to use a step-up transformer wound for, say, 5000 ohms to 50,000 ohms or 80,000 ohms, without impairing quality or affecting the line. Each unit weighs two ounces and they are extremely rugged.

THE COPPER-SULFIDE RECTIFIER AS A SOURCE OF POWER FOR THE PROJECTION ARC*

C. A. KOTTERMAN**

A rectifier may be defined as a device for converting alternating current into unidirectional current by mechanical, chemical, or electrical means.

Probably the most common mechanical rectifier is the motor-generator set. Another familiar type is the rotary converter. All rotating mechanical rectifiers are equivalent to converting the alternator source to a direct-current generator. Another mechanical rectifier that has wide application in the low-current field is the vibrator type, employing a tuned reed. This rectifier is used in about 90 per cent of all automobile radios, although in many cases, in this application it acts as an inverter instead of a converter. Another form of mechanical rectifier is the mercury-jet type, wherein a jet of mercury oscillates at appropriate frequencies between contacts performing the commutation. All mechanical rectifiers depend upon physical connection and the opening of an a-c. circuit at the correct times.

The chemical rectifier is referred to more to round out a résumé of rectifiers than for its commercial practicability, at least as a power-supply for the projection arc. The most common chemical rectifier is the electrolytic type, in which rectification depends upon a film formed on a metal electrode immersed in an electrolyte, with another electrode of inert material for contacting the electrolyte. A commercial rectifier of this type employs an electrode of tantalum, with lead as the other element, immersed in dilute sulfuric acid.

For the sake of simple classification, thermionic rectifiers such as vacuum-tubes, gas-filled tubes, and mercury arcs, fall into the electrical group. The vacuum-tube rectifier employing a hot filament is a familiar example, as it is found in practically every home radio set. A less familiar type, but of wide commercial usefulness, is the mercury-arc rectifier. One form consists of a hot cathode spot on a mercury pool to which the anode current flows. In another type a hot cathode operates in mercury vapor.

A rectifier falling in the electrical class and with which the balance of this paper will deal, is the magnesium-copper-sulfide dry disk or plate rectifier, first developed about fifteen years ago by S. Ruben. It consists of an electropositive conductor and an electronegative semiconductor in more intimate contact than physical juxtaposition and pressure can give. The electropositive element is magnesium; the electronegative element, copper sulfide. The rectifier is electronic in operation, the current flowing from the sulfide element to the magnesium element. In this, the conducting direction, the voltage drop across the junction is extremely low, remaining practically constant, regardless of load. In the non-conducting, or blocking direction, the resistance of the rectifying junction is quite high. Electric current flows when the magnesium is made negative with respect to the polarity of the sulfide side, and blocks the flow of electricity when made the positive side.

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* Presented at the 1938 Fall Meeting at Detroit, Mich.; received January 1, 1939.

** P. R. Mallory & Co., Inc., Indianapolis, Ind.

The magnesium-copper-sulfide rectifier is known as the non-integral type, because the two components of the rectifier have a rectifying film formed between them by an electrical process. Because of the unique way in which the rectifying film is built up, it can stand overvoltage which, if it results in breakdown of the rectifying film, instantaneously heals itself without damaging the rectifier.

Any attempt to explain exactly how a contact rectifier operates usually becomes very much involved. It is beyond the scope of this article, therefore, to enter into

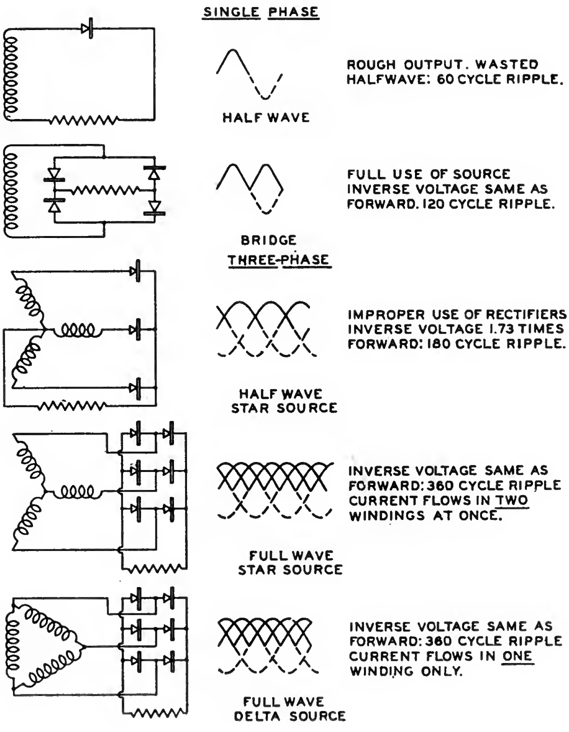

FIG. 1. Various circuit systems used with sulfide rectifiers.

a highly theoretical discussion of the physical principles underlying its operation. Suffice it to say that a rectifier that depends upon electronic action may be likened to a valve or gate: it opens the a-c. circuit 60 times per second when the half-cycle is of one sign, and closes the circuit when the half-cycle is of the opposite sign. Such rectifiers are all metallic, and have no moving parts, hot cathodes, glass parts, or other fragile constructional components.

The theater projection arc affords an ideal application for the copper sulfide rectifier. These arcs usually operate on currents varying from 50 to 65 amperes at 35 volts. These values are particularly well suited to the copper sulfide rectifier, which is fundamentally a high-current, low-voltage type of rectifier.

In order to evaluate the magnesium-copper-sulfide rectifier in terms of useful power-supply devices for projection, it will be necessary at this point to describe

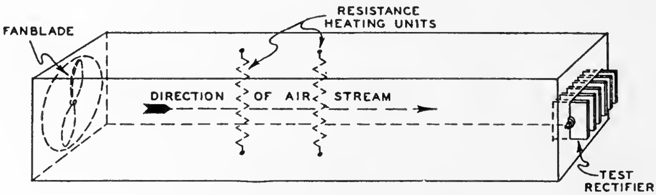

FIG. 2. Wind-tunnel test of rectifier ventilation.

several fundamental facts by which the performance of the sulfide rectifier is measured.

The first fact to establish is how much a-c. voltage will one rectifying junction block; in other words, how much a-c. voltage can be applied across the components of a junction without breaking down the insulating film between them? The magnesium-copper-sulfide rectifier will stand 3 to 3.75 volts rms. on load per junction. These are working voltages. Blocking peak voltages would be 1.4 times

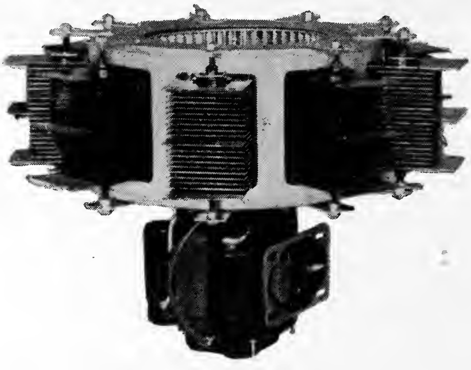

FIG. 3. Blower mounted inside drum structure, for forced ventilation.

these values. When these values are exceeded by 15 or 20 per cent there is the possibility of breakdown, resulting in rapid deterioration of the junction if the condition causing the breakdown persists. However, as previously stated, occasional overvoltage due to line surges, *etc.*, causing momentary breakdown in the rectifying film, will not affect the normal operation of the rectifier or its life.

Closely related to the permissible volts per junction is the ratio of d-c. output voltage to a-c. input voltage. For three-phase full-wave bridge operation it has been found that the voltage ratio of the magnesium-copper-sulfide rectifier is about 85 per cent. In the case of the rectifier for projection, this means that 44 volts a-c. are impressed across a sufficient number of junctions in series to produce 35–36 volts d-c. at the arc. Another important factor is the current ratio; that is, the ratio of the direct-current output to the alternating-current input. The rectifier has approximately a 120 per cent current ratio for three-phase, full-wave circuit systems.

Having reviewed rectifiers in general and discussed the mechanism of the contact rectifier in particular, we can now consider details of design for a rectifier power supply for the projection arc. The essential features are:

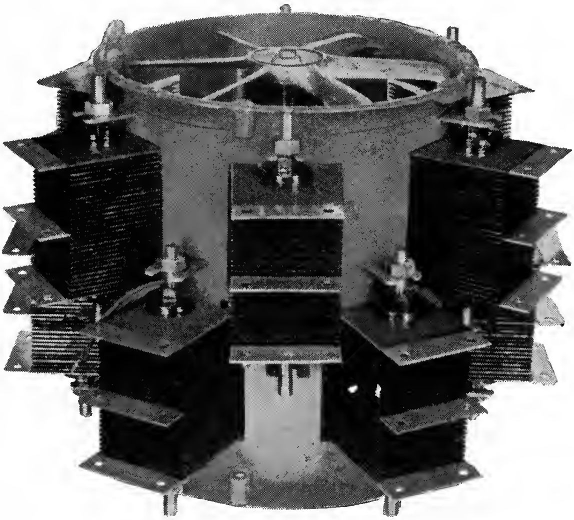

FIG. 4. Showing propeller-type fan for forced air cooling.

(*1*) Most suitable type of a-c. circuit system.
(*2*) Current-handling capacity of the sulfide rectifier as a function of life and operating temperature.
(*3*) Cooling or ventilating methods.

As most projection arc rectifier applications call for d-c. voltages varying from 35 to 50 volts, it is necessary to employ a transformer to step down the 110- or 220-volts a-c. source to a suitable value to be used in the projection arc circuit.

Two basic circuits are employed with all contact rectifiers: the half-wave and full-wave bridge, single-phase, or polyphase. The full-wave bridge requires twice as many rectifier elements as the half-wave for the same voltage input. Fig. 1 shows various circuit systems.

The three-phase, full-wave bridge connection with the windings of the source delta-connected, has the lowest blocking peak voltage per element (it is the same as the forward voltage) and requires fewer junctions than some of the other polyphase systems. Because this is very desirable from an application viewpoint, this circuit is considered the best, giving, as well, a ripple six times the input frequency of 60 cycles. It may be mentioned that where filtering out the ripple is necessary, the higher its frequency the easier it is to filter.

All contact rectifiers are resistance devices; therefore, they generate heat when rectifying. The normal life expectancy of such a rectifier is based mainly on its operating temperature. The lower the operating temperature, the longer the life when other operating conditions are normal. Heat generated at the junction must, therefore, be removed faster than by simple convection cooling if the rectifiers are to handle large currents such as those associated with the carbon arc. The magnesium-copper-sulfide junction, designed for carbon arc use, having 1.7 sq.-in. of rectifying area with associated radiator plate of $12^1/_4$ sq.-in. of area,

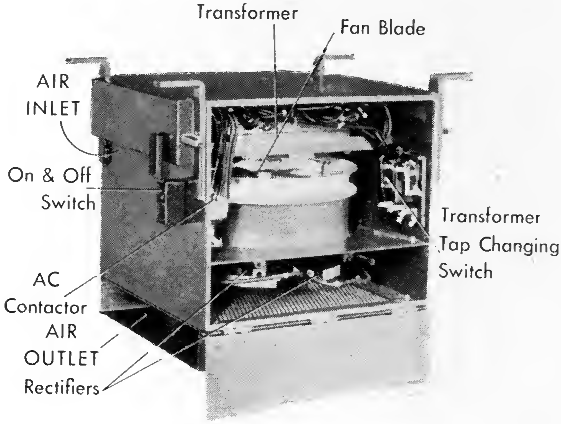

FIG. 5. Arrangement for ventilating rectifier for large power output.

will handle 38 d-c. amperes per sq.-in. safely and continuously. These current-densities are based on three-phase, full-wave operation.

One of the outstanding features of the copper sulfide rectifier is the ability to withstand unusually high operating temperatures. Fig. 7 shows a life-test curve on a copper sulfide rectifier purposely operated at temperatures considerably in excess of those encountered in the projection arc type of rectifier. Remembering that 100°C is the temperature of boiling water, it is readily understood that a rectifier that can withstand such a temperature continuously is truly remarkable. Any other type of contact rectifier would absolutely fail at such a temperature or at even much lower temperatures.

For low current-densities per rectifying junction, where the operating temperature will never exceed 130°C, the simplest method of cooling is convection cooling. Where the rectifier is required to handle large currents, as in the projection arc application, it is necessary to employ forced draft or so-called fan cooling.

A thorough study of rectifier ventilation has been made through the use of a wind-tunnel. Fig. 2 shows the set-up. The test rectifiers were mounted in a window opening at one end of a 10-ft. box. A fan, placed at the opposite end of the box, provided air velocities up to 5000 ft. per min. Electric resistance heaters were located inside the box midway between the ends, to raise the temperature of the air-stream to permit a study of the behavior of the rectifiers at elevated temperatures. The compiled data from the wind-tunnel tests makes it possible to design a transformer-rectifier combination to meet specific needs and to predict

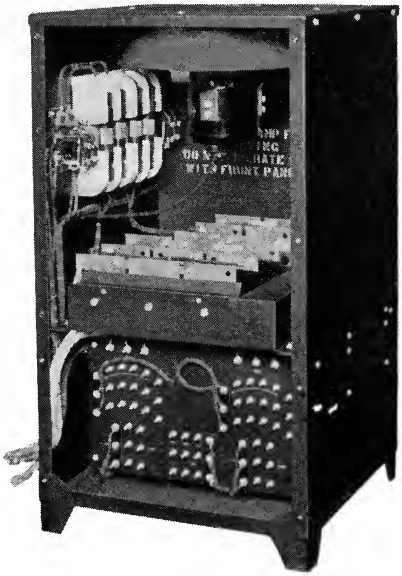

FIG. 6. Commercial form of sulfide rectifier with forced ventilation, for projection arc power supply.

within practical engineering limitations the operating temperature of a power rectifier for any given application.

To increase the current-handling capacity of the magnesium-copper-sulfide rectifier, fan or forced cooling was developed. This led to the study of accelerated air-flow through rectifiers and designs for compact assemblies. One form was to support the rectifier elements in the wall of a hollow drum structure, mounting a pressure-type centrifugal blower wheel inside the drum (Fig. 3). Air is drawn in through the opening in the squirrel-cage, then discharged from the blades through the rectifiers. This permits very compact construction, together with good cooling efficiency.

The rectifiers are placed symmetrically around the fan-wheel housing, which construction lends itself to very simplified wiring of the rectifiers. The whole structure is usually supported on top of another housing in which the power transformer is placed. Air, discharged through the ventilating fins of the rectifiers, is first drawn up and around the coils of the transformer, thereby subjecting the transformer to forced cooling. In this way, smaller and lighter-weight transformers may be employed.

Where the rectifier cooling fins are close together, in order to make the assembly as compact as possible, high air velocity through the fins is desirable. Working closely with manufacturers of propeller-type fan blades, a satisfactory propeller blade was developed. The method of employing this type fan is shown in Fig. 4. A fractional horse-power motor is supported inside a drum cage. The motor shaft has a double extension, so that two fans, one right-hand and one left-hand, may be rotated simultaneously. Air is drawn in by both propellers, building up a pressure inside the drum, and is discharged out through the rectifiers which are mounted in openings in the drum. As a matter of passing interest, one power

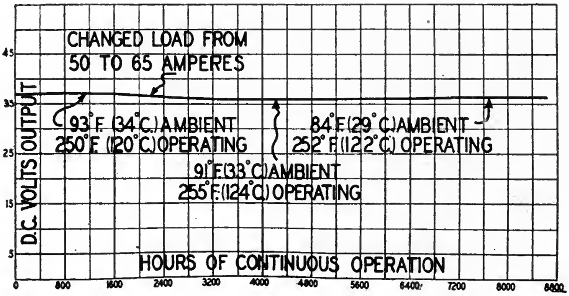

FIG. 7. Life-test of copper-sulfide rectifier designed for projection arc supply.

rectifier of this type (Fig. 4), employing rectifier junctions identical to those used in the rectifier for projection purposes, is only 16 inches in diameter and 12 inches high, weighs but 100 pounds including the ventilating system, and delivers 200 amperes at 40 to 50 volts. These figures, of course, do not include the transformer.

In the two cooling methods just described, the rectifiers are mounted around a drum or cage. A departure from this method is employed in a very recent development of fan-cooled rectifiers for large power outputs. In this equipment the rectifiers are mounted radially in a plane around the motor which drives a single large propeller developing an air pressure inside the housing and forcing the air out through the rectifiers (Fig. 5).

Where the rectifiers are operating at comparatively low current-densities, as in the case of the rectifier for the theater carbon arc, a simple adaptation of some of the foregoing cooling principles may be employed. Such an adaptation has been worked out excellently in the rectifier shown in Fig. 6. The transformer is placed at the bottom of a steel cabinet. The two banks of rectifiers (in the case of a twin arc power-supply) are supported in trays immediately above the transformer. The space around the trays is baffled to concentrate the air-flow through the cooling fins of the rectifiers. A propeller-type fan blade of sufficient air capacity to maintain the operating temperature of the rectifiers considerably below their maximum safe operating temperature is driven by a motor mounted at the top of the cabinet. This simple cooling arrangement draws air in from the bottom, over and around the transformer, then through the rectifier cooling-fins, with discharge at the top, providing efficient cooling in a compact assembly.

Any discussion of the power-supply for the projection arc immediately raises the question of the relative merits of rotating equipment *vs.* rectifiers. Probably the most essential feature of a power-supply for the theater carbon arc is dependability regardless of the type of source. All other factors are of less importance. The theater operator or owner likes to feel that the equipment will operate satisfactorily and continuously and that the show will go on. Rotating equipment requires periodic servicing and maintenance. The magnesium-copper-sulfide rectifier, if properly ventilated and not subjected to abnormal operating conditions, performs satisfactorily over a long period of time without any attention whatsoever. Because of the large margin of reserve capacity in this rectifier designed for theater use, fan failure will not darken a theater. Instances have been reported from the field where the fan associated with a copper sulfide rectifier for theater use had failed and could not be replaced immediately, but the rectifier carried on for days until a new fan was installed. Such operating conditions are not to be encouraged, but they go to show that in the copper sulfide theater rectifier there is a power-supply available requiring practically no maintenance and one that will stand considerable punishment without failure.

Naturally, the theater owner is interested in the all-around performances of this power-supply and how long it will last. An extensive life-test has been run on the copper-sulfide rectifier employed in projection arc power-supplies. Fig. 7 shows the results of a test run on the machine shown in Fig. 6 extended to the equivalent of 10,000 hours of normal theater operation.

Improvement in the technic of processing the copper-sulfide rectifier and the experience gained during the past two years in building heavy-current rectifier power-supplies such as for electroplating, delivering 3000 d-c. amperes and upward, indicate that these improvements now being incorporated also in the projection arc rectifier will give the theater owner a more dependable source of power than ever before with an exceedingly long life.

DISCUSSION

MR. GESSIN: What is the average life of the copper-sulfide rectifier?

MR. KOTTERMAN: That depends upon a number of conditions: Operating temperature for one thing, variation in load, and the type of adaptation. For theater use, with the improved type of rectifier we are now building, we anticipate a useful life of five years.

MR. CRABTREE: What is the effect of high humidity?

MR. KOTTERMAN: None. The radiating fins and the rectifying elements are clamped together on a very heavy bolt, with spring washers at either end, to maintain constant pressure regardless of contraction and expansion during operation. The assembly is vacuum-impregnated with special varnish which prevents moisture from getting into the rectifier elements.

MR. CRABTREE: Magnesium is, of course, readily oxidized.

MR. KOTTERMAN: That is one reason why we are very careful to prevent moisture and air from getting to it.

MR. FINN: What is meant by "a useful life of five years"?

MR. KOTTERMAN: The life under operation conditions, depending upon the use of the equipment. It might be perfectly all right at the end of five years. We have rectifiers delivering much smaller outputs than the carbon-arc rectifier demands which have been in service ten years.

MR. FINN: The General Electric Co. ran some accelerated life tests on the copper-oxide type of rectifier equivalent to ten or eleven years of continuous running.

The phrase "useful life of five years" does not seem right. If General Electric ran them for ten years, exposed to all sorts of weather conditions, I do not see why this particular rectifier should be limited to a useful life of five years, provided the safety factor remains constant. I know that some railroad rectifiers have been running ten years.

MR. KOTTERMAN: We have been making this heavy-current type of construction only about two years, and the only thing we could do was to have an accelerated life-test, which we think is equivalent to five years. We stopped it at the end of that period in order to study the rectifying junctions. We have started another life-test that we may run an equivalent of ten years.

MR. FINN: We are not dealing with high amperages, only 50 or 60 amperes.

MR. KOTTERMAN: I think that is a rather high current. It means that the copper-sulfide rectifier is operating at a current-density of 38 amperes per square-inch.

I might qualify the term "useful life." One buys an automobile and expects a useful operating life of three years. It may continue to operate after that, but might not be quite as useful as it was during the first three years. Conceivably this rectifier may still operate at the end of five years and still be useful; or the voltage output may fall off to the extent where it is no longer giving useful service for the projection arc.

DR. CARVER: What happens when the rectifier does go bad? Does it go bad suddenly, or does it give warning?

MR. KOTTERMAN: It gives warning. The output begins to fall off.

MR. ROBERTS: What is the voltage drop through the rectifier unit on an arc application? What is the efficiency of the unit?

MR. KOTTERMAN: The rectifying efficiency of this type of copper-sulfide rectifier is 50 to 55 per cent. Depending upon the circuit conditions, the overall efficiency of the transformer-rectifier combination would be lower than the rectifying efficiency alone.

MR. ROBERTS: What is the drop through the unit?

MR. KOTTERMAN: One-half volt per junction.

MR. CRABTREE: What is that in comparison with the copper-oxide rectifier?

MR. ELDERKIN: The copper-oxide rectifier gradually ages. The output drops from the time it is new until you can not use it any longer. The resistance increases steadily; sometimes it will be so high as to cause overheating. This rectifier does not do that. It does not age. The efficiency is the same throughout a longer period of life. The copper-oxide rectifier will show a little higher efficiency at the start, and lower efficiency when it is older. The average efficiency over a given length of time will about be the same for the two.

MR. CRABTREE: What is the ratio of input to output?

MR. ELDERKIN: That depends upon the circuit, the output, and the number of units used. In this particular application the efficiency will start at 60 to 65 per cent; with the copper-oxide it will drop to 40 or 45 per cent.

MR. CRABTREE: There must have been some outstanding advantage of this type of rectifier as compared with other types to spur your engineers to develop such ingenious equipment. What is this outstanding advantage?

MR. KOTTERMAN: In our opinion, the chief advantage of the copper-sulfide rectifier over the copper-oxide rectifier is its tremendous reserve capacity and the fact that it operates at an exceedingly high temperature without causing destruction of the rectifier elements. Also that we can build a rectifying device that will deliver the amperage associated with the carbon arc in a very small assembly.

One form of copper-sulfide rectifier measures 16 inches in diameter and 12 inches in height, weighs 100 pounds, and delivers 10 kw. of direct current. Of course, those figures do not include the transformer. I do not think there is any type of contact rectifier or other type of d-c. generator equipment that can deliver 10 kw. in so small a compass as that.

MR. THOMAS: What are the characteristics of this equipment on 25-cycle current, and what happens to the d-c. output in relation to an a-c. input voltage drop?

MR. KOTTERMAN: Laboratory measurements have shown very little difference between the overall efficiency at 25 cycles and at 60 cycles. Much larger transformers are required to operate on 25 cycles than on 60, but the results are practically identical.

MR STRICKLER: We use from 50 to 100 of the tungar outfits for portable projection, travelling all over the country and encountering all kinds of conditions The weight and size are very important. We have small arc lights using about 25 amperes. Would your rectifier be less in weight or in bulk than similar contact outfits? Single-phase supply is what we meet in almost all cases.

MR. KOTTERMAN: For single-phase operation I doubt that there would be much advantage as to size or weight over the tungar equipment. However, for polyphase operation there would be.

MR. STRICKLER: We are not so much interested in efficiency because we are in operation only for an hour or so at one time, but when a man has to set up a complete outfit in ten or fifteen minutes, equipment weighing 500 pounds in cases, put on a show in a room similar to this, tear down the equipment and put it into cases, and then put on another show in the afternoon of the same day several miles away, we have to consider size and weight. Our present units are stripped down to about 50 pounds per case. Would such capacity be possible with your outfit of similar size and weight?

MR. ELDERKIN: The rectifier units required, according to the voltage, would obviously be heavier than the equivalent number of tubes. Otherwise, the weight of the transformer, *etc.*, would be the same. The bulk would be greater.

MR. THOMAS: Does the reserve of the rectifier compensate for a-c. line fluctuations?

MR. KOTTERMAN: No, that is a matter of transformer design. With sufficient reactance in the transformer you will maintain reasonably constant d-c. output under wide variations of a-c. voltage. A 10-volt variation in a 220-volt line might cause a variation of only 0.5 to 1 volt in d-c. output. Some very recent developments using highly reactive transformers are better than that.

MR. THOMAS: What happens when we strike the arc? Does the voltage jump, and then return to the proper value for operating the arc?

MR. KOTTERMAN: To answer your question completely and accurately it would be necessary to put an oscillograph on the output of the rectifier.

However, I have measured the current at the instant of striking the arc, and have found it to be of the order of 200 amperes. However, that only lasts but a fraction of a second, and immediately the carbons are separated the current and voltage return to normal.

MR. FIFERLIK: Is the rectifier likely to heat up if connected when the arc is not burning?

MR. KOTTERMAN: The rectifier for the projection arc or any other heavy-current application can withstand normal line-voltage input without suffering damage in any way. The leakage current of the copper-sulfide rectifier is much higher, of course, than that of the copper-oxide rectifier, but is not high enough to result in any dangerous temperature.

MR. DASH: With regard to "useful life," I should like to mention that there are motor-generator sets in operation in theater service that have had 20 years of useful service, and are still operating well. The presence of rotating parts does not limit the life of equipment if the equipment is well designed.

MR. CUTHBERT: Is there any disadvantage in breaking the d-c. circuit instead of breaking, as you normally do, the a-c. rectifier circuit?

MR. KOTTERMAN: It is more desirable, of course, to break the a-c. circuit because it is more sensitive to excess voltage than other types of contact rectifiers. But as I have said, we endeavor to engineer into each rectifier application the correct electrical characteristics so that if you do break the d-c. side or operate it under other circuit conditions, it will stand such operation without harmful results.

AUTOMATIC EMERGENCY SHUTTER SWITCH FOR THEATER FAN AND LIGHT CONTROL*

E. R. MORIN**

Everyone in the industry is impressed with the special fire hazards incident to the use of nitrocellulose film, and many precautions are taken for the abatement of fire and panic hazards in theaters. Herein is described a recent and very important development designed to control film fires in projection rooms by the installation of an automatic emergency control switch in addition to the usual

* Presented at the 1938 Spring Meeting at Washington, D. C.; received Sept. 17, 1938.

** Connecticut State Police, Hartford, Conn.

manually controlled switches. This automatic switch is installed on the front wall of the projection room and is connected with the automatic shutter control

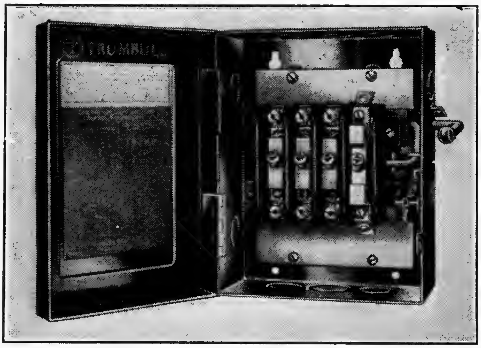

FIG. 1. Automatic emergency shutter switch for theater fan and light control.

operated by the melting of a fusible link so that in the event of fire the action is automatic, instantaneous, and positive.

This development was primarily instigated by the Inspection Department of the Connecticut State Police, who have felt for some time that there was a definite need and requirement for a safety device of this type. This Department spent considerable time and effort in study and experimental work on the problem, with the primary objective of producing a device that would speed up emergency

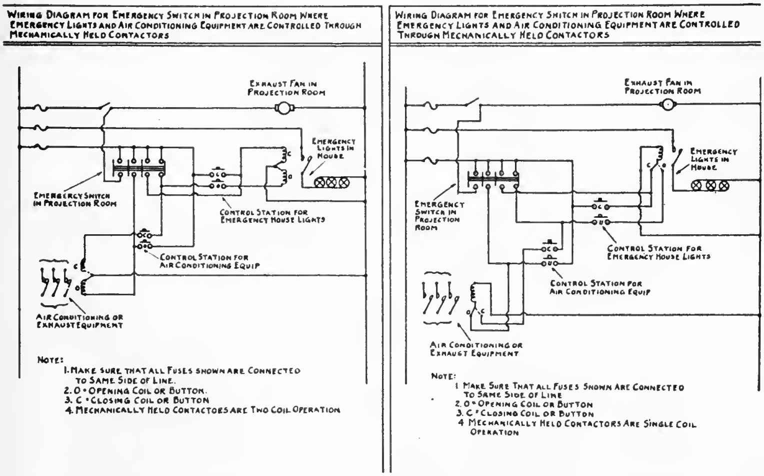

FIG. 2. One of many possible arrangements of the switching circuits.

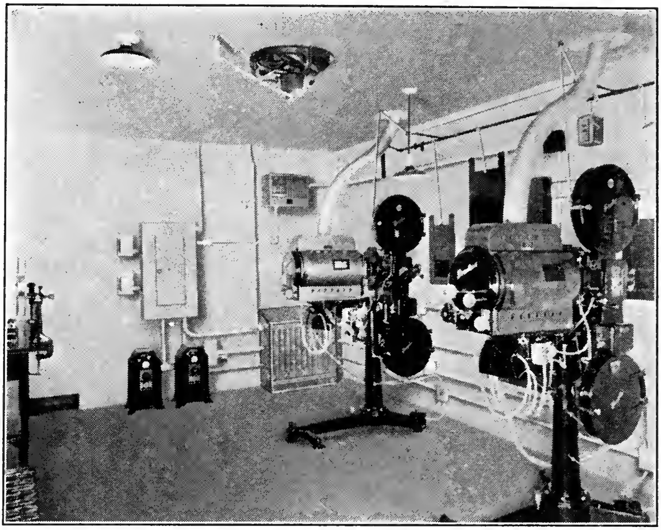

FIG. 3. Projection room layout.

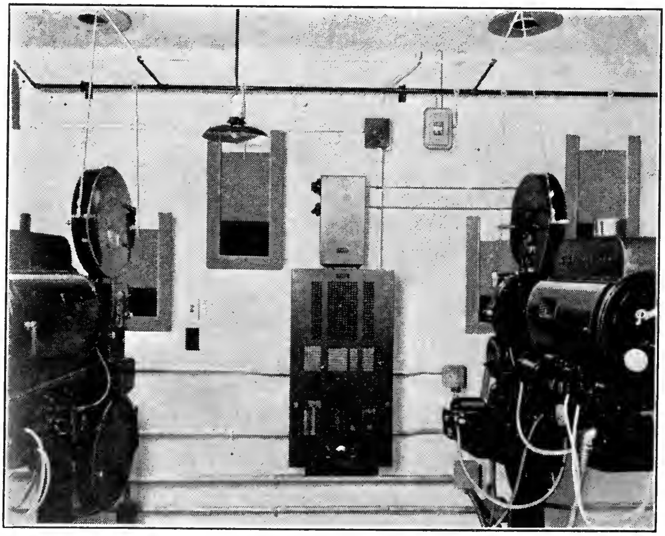

FIG. 4. Projection room layout.

action. They felt that this function was of such importance that it should operate automatically in the time of need without the hazard of human element.

As a result of this study, and after further experimental work on this problem, the Trumbull Electric Manufacturing Co., of Plainville, Conn., have developed a switch that will meet the needs and requirements for this particular application. The device is a four-pole, no-fuse, manually or automatically operated switch, with one normally closed and three normally open contacts. The construction of the switch can be varied to suit local needs and requirements, both in the number and arrangement of the poles. Its construction is flexible enough so that it may be incorporated in the wiring layout of any theater and may be used in combination with present existent equipment. The switch is shown in Fig. 1, and a representative arrangement of it is shown in Fig. 2.

Briefly, some of the duties and functions that this switch will perform are as follows:

(*1*) Start projection room exhaust fan.

(*2*) Throw on auditorium lights to their full brilliancy. Where the auditorium lighting is controlled through dimmers, the switch can be connected to the cut-around switch so that it will operate regardless of the position of dimmers or control switches.

(*3*) To stop all auditorium supply and exhaust fans.

(*4*) To stop the operation of air-conditioning equipment in compliance with local codes.

(*5*) To stop the operation of oil burners, principally those utilized in heating the auditorium or assembly hall.

This switch will prevent the operation of any or all of the above equipment from any point on the premises until such time as the shutter switch has been reset to its normal position.

In many instances, it is practically impossible for a man to work in a projection room with the projection room exhaust fan on, especially in the winter time. Through the medium of this device, it is possible for him either to put in a speed regulator or shut off the fan if the draft becomes too severe.

The purpose of incorporating the control of house lights on this device is to prevent a panic, and should one of the projection room shutters fail to close, would prevent glare at the time of fire. It is also quite desirable, in most cases, to stop the operation of the house ventilator in case of fire, because in most instances, the exhaust in the auditorium is likely to be greater than in the projection room and if any of the shutters fail to close, all the smoke and flame would automatically be drawn into the auditorium.

When the auditorium ventilator is shut down, the port opening would become an intake, instead of an exhaust.

In a good many cities, especially in Connecticut, fire marshals require an emergency switch in the ticket booth to shut down all heating, refrigeration, and air-conditioning equipment in case of fire. For this reason, provision has been made on this emergency switch to provide control for this type of equipment.

Figs. 3 and 4 show projection room layouts incorporating the switch.

A NEW DENSITOMETER*

H. NEUMANN**

The change from variable-density to variable-area sound recording in Europe has made necessary new instruments for film processing control both in the studios as well as in the printing laboratories.

None of the existing density-measuring devices were found capable of meeting the requirements of variable-area recording because they were not sensitive enough to measure very small areas whose density ranged from 1 to 2.5. All instruments that employ an optical system were found to have the additional disadvantage that their indications were influenced by densities immediately adjacent to the area being measured. For example, the smaller the area under measurement, the smaller the density indication as compared to the actual density. This is caused by the diffusion of the light. Consequently these densitometers were useless for measurement of variable-area sound-tracks, which have very high density in some places and low density in others.

The densitometer to be described is not intended for laboratory use where extremely high precision is required, but for frequent checks in processing control; hence stress was given to objective density indications. To accomplish this, the densitometer is provided with a blocking layer type of photocell, and the current measured with a highly sensitive microammeter.

In order to eliminate the error introduced by changes in the lamp and the condition of the battery, a secondary light path is provided which, by means of an adjustable diaphragm, directs to the cell the same amount of light as is received through the primary or measuring path, when no film or a density standard is in place.

The density values do not correspond to those obtained with diffused light. This difference can be neglected without serious error, because all film emulsions employed for variable-area recording are of the fine-grain type, and show the same Callier factor. Therefore, the densities measured with this instrument always vary by a constant amount from the standard density. This factor is 1.18.

It is important that irradiation errors do not occur when measuring very small areas. The measurements made with this densitometer are rendered quite independent of the density of the immediately adjacent areas, by the use of a metal aperture plate held in close contact with emulsion side of the film. The aperture measures 2.5 mm. in the direction of the film and 0.03 mm. at right angles to it.

It is likewise possible to measure finished variable-area negatives and positives because of the ease with which the small aperture can be positioned. In order to facilitate observation of the spot on the film being measured, a magnifying glass with suitable illumination is provided.

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* Presented at the 1938 Spring Meeting at Washington, D. C.; received April 21, 1938.

** Klangfilm G. m. b. H., Berlin, Germany.

The arrangement of the essential parts of the densitometer are shown in Fig. 1. The photoelectric cell *6* is illuminated when, in the checking position, by light from lamp *1* passes through the adjustable diaphragms *2* and *3*. When the sliding member containing the cell is moved to the right, to the film position, the cell receives light from the lamp *1* after passing through the optical system aperture *5* and the film. Clamps hold the film in position. To prevent overloading the galvanometer, a blue glass filter *4* is provided. This can be swung in

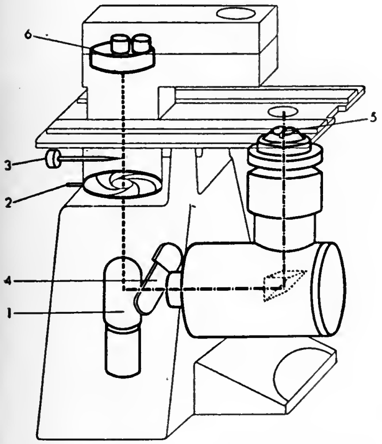

FIG. 1. Arrangement of densitometer.
(*1*) Exciter lamp (*3*) Adjustable diaphragm
(*2*) Adjustable diaphragm (*4*) Blue glass filter
(*5*) Aperture
(*6*) Photocell

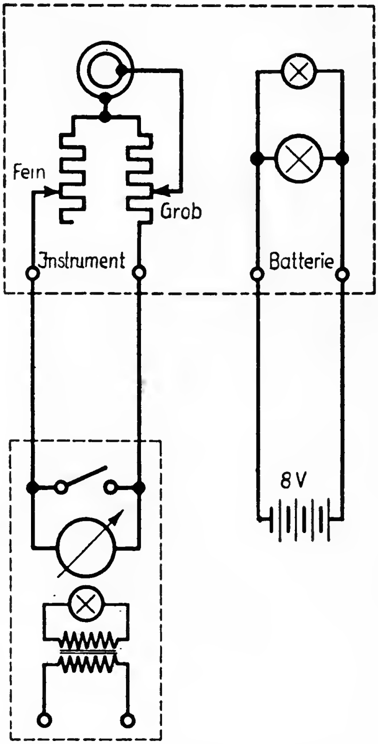

FIG. 2. Wiring and electrical control.

and out of the light beam. Fig. 2 shows the wiring and electrical control arrangements.

The procedure in making density measurements is as follows. The photocell is first moved to the measurement position. Then the indicating meter is set to full deflection by means of both the coarse and fine rheostats, without film. Film is then inserted, causing the meter to deflect to a value corresponding to the amount of light passing through the film. The density can be read on the scale of the instrument.

To increase the accuracy of density measurements for values greater than d-1 the full deflection of the galvanometer is adjusted by means of a density standard having a value of unity. Readings obtained with this multiplier in place must be increased by 1.0.

To check constantly this preliminary adjustment, the cell is moved to the secondary light-path and the diaphragms adjusted until the full deflection of the meter is obtained. It is then possible to move the cell to the secondary position at any time during a series of measurements, and thereby correct for any change in the lamp or battery.

There is an intermediate position to the sliding member that brings the magnifying lens over the spot being measured, thus making certain that the soundtrack on the film is in the correct position over the aperture.

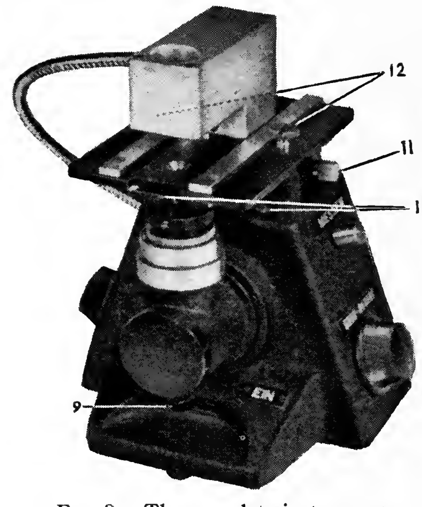

FIG. 3. The complete instrument.

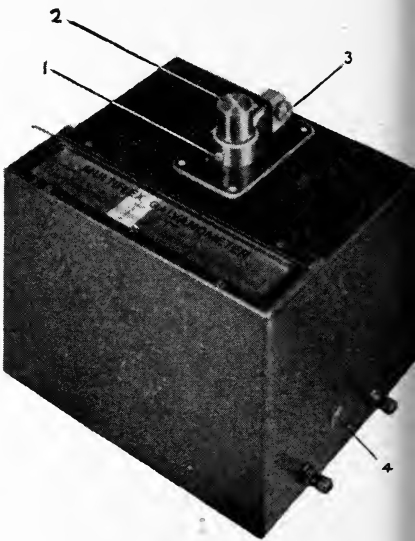

FIG. 4. The galvanometer.

The procedure after calibration is as follows:

(*1*) Insert the film.

(*2*) With magnifying glass in position, place the desired area to be measured over the aperture.

(*3*) Draw the photocell back to the secondary position and readjust for full deflection if necessary.

(*4*) Move the cell over the film and read the density.

Fig. 3 shows the complete instrument and Fig. 4 the galvanometer.

SUPER 16-MM. SOUND AND PICTURE PRINTER*

O. B. DEPUE**

When the Society adopted the sound standards as used today, it perhaps did not consider the problem of contact printing. The most important goal sought was to provide ample space for the sound-track without sacrificing the picture area. The optical reduction of picture and of sound was, and undoubtedly will continue to be, the most perfect method of printing. Printing by contact, however, is likely to be done more and more, especially in the case of large-quantity production; and on account of constant improvements in 16-mm. recording, the contact method will be more to the front in the future. The many improvements in sound recorders are being paralleled by more perfect projectors. Therefore, it is necessary to keep abreast of these two branches of the art by the third important link in this chain.

Continuous contact printing with double-row perforations offers no real problem. But printing sound on the same machine raises a difficulty not present in standard-size printers, namely, the edge support of the sound-track side. If a shifting aperture is used for picture and sound or both, the narrow margin of 0.018 inch is the maximum. Now, this is greatly reduced by the shrinking of the negative in developing, as much as 0.004 or 0.005 inch. Then there is the variation of film width, as much as 0.002 or 0.004 inch. The sum of these two factors may reduce the edge support to 0.010 or 0.012 inch. This very narrow support on the sprocket support can and unfortunately sometimes does buckle, and the film may leave the supporting edge flange of the sprocket wheel.

The pressure shoe should have but limited pressure on the positive for this reason. To overcome this defect in the system of printing with various apertures, we have tried to devise a system that would retain as much as possible the common practice in construction and operation. Figs. 1 to 4 show various views of the printer. The one-edge sprocket wheel has no center shaft supporting the sound-track edge, but the full width of the sound-track is supported on a flanged ball-bearing roller and turns by and with the negative and positive. Thus the sound-track edge has as wide a support as the perforated edge, nearly an eighth of an inch. The result is a much more perfect contact while printing the picture. The pressure shoe can have a wider pressure surface, minimizing the danger of buckling the films.

The sound-printing ball-bearing drum has full picture-width support and only the sound-track edge extends over this otherwise solid drum. Therefore the picture and sound-track have adequate support at the point of printing.

The printing lamp is located in the center of this ball-bearing support (Fig. 2) and is a 110-volt, 15-watt Mazda lamp. It draws the direct current from the generator that furnishes current for the 40-watt picture-printing lamp. The cover

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* Presented at the 1938 Fall Meeting at Detroit, Mich.; received October 20, 1938.

** Burton Holmes Films, Inc., Chicago, Ill.

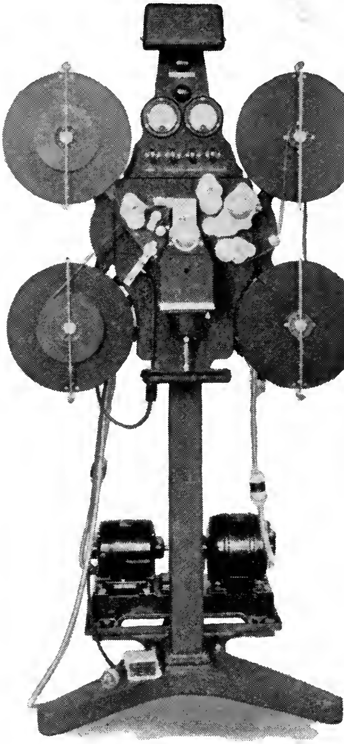

FIG. 1. The printer.

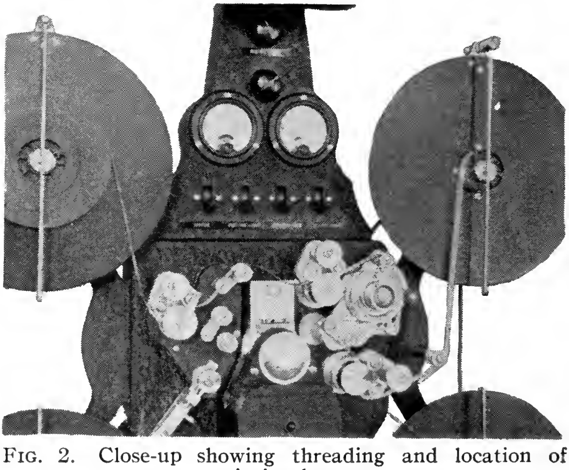

FIG. 2. Close-up showing threading and location of printing lamp.

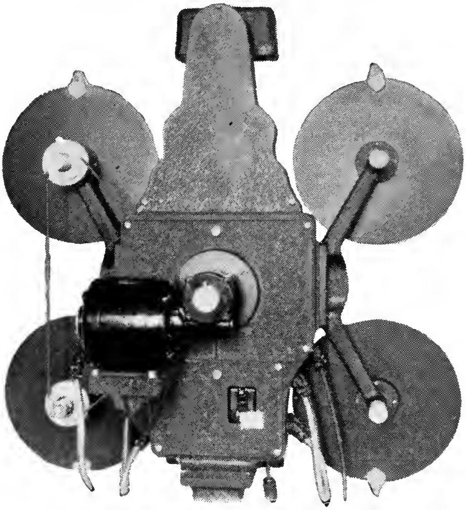

FIG. 3 Motor drive.

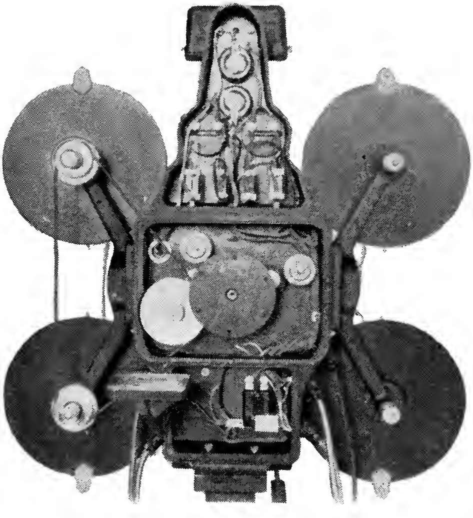

FIG. 4. Automatic cut-out in base of main casting.

for this lamp has provision for a small ultraviolet filter easily inserted and removed. The picture-printing sprocket, having no center shaft, allows the free passage of light to the center of the sprocket and pressure shoe.

At this point, midway between the points where the teeth enter and leave the perforations, there is least movement of the two films, and therefore the more perfect exposure at this point, and a noticeable improvement.

The motor drive (Fig. 3) is a $^1/_8$-hp. synchronous gear reduction 15 to 1. There is a rubber disk 5 inches in diameter and $^1/_4$ inch thick having six holes connecting the motor to the printing sprocket, giving a smooth filtered motion to the mechanism. The gears are grease packed, ball-bearing, and "steel to non-metallic" throughout. All other bearings are oilless or "olite" bronze bushings and will run thousands of hours without re-oiling, requiring but a few drops at times. The motor and generator require oil occasionally. The grease-packed ball-bearings will last the normal life of the bearing, but can be repacked.

The generator voltage is regulated by the field winding rheostat immediately over the voltmeter (Fig. 1). Any voltage from 90 to 130 can be had. The sound-lamp control-knob is immediately over the voltage-control knob and the milliampere indicates the current needed (average about 0.8 ma.).

The automatic cut-out located in the base of the main casting (Fig. 4) will operate on a slow overload or on a dead short circuit, and protect the entire machine. A snap of the lever returns it to normal duty.

All sprocket-wheels are stainless steel and all idlers and rollers are of stainless stee or hardened steel. The speed is 75 feet per minute and the automatic light-control is 112 changes, 22 densities; 75 or 152 change controls can be had.

The printing is regular standard practice where the double system is used; *i.e.*, the picture is printed first. The print is rewound and threaded up with the sound-track and the negative passes through the sound unit only. If a composite negative having picture and sound on the same base is used, then the negative and positive are threaded up over the sound-drum and the sound added in same operation. The positive film is not carried completely around the drum with the negative, but is passed over the two rollers which separate the two except where the exposure is made, immediately under the black rubber roller. Thus the positive is in contact with the negative only slightly more than one inch, and creeping or buckling is eliminated.

A FILM-CEMENT PEN*

R. J. FISHER**

Ever since film cement has been used for splicing motion picture film, many different methods of applying the cement to the splice have been used. The most common of all is the small bottle and brush. Prior to the invention of the pen described here there has been no really practical method.

* Presented at the 1938 Spring Meeting at Washington, D. C.; received April 20, 1938.

** Rochester, N. Y.

The pen is as easy to use as a fountain-pen or pencil, and makes a neat splice and saves a lot of time. It is constructed so that any quantity of cement can be released from its point. The point, which spreads the cement, is made of brass and acts as a plunger in the valve. Pressure on the brass point opens the valve and allows the cement to flow.

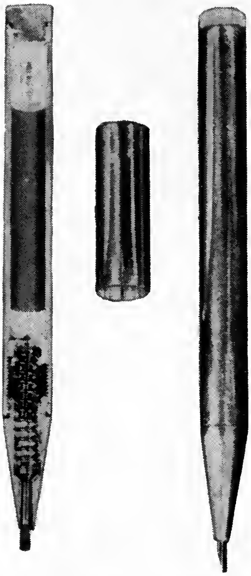

FIG. 1. Film cement pen.

The valve is a plunger operated by a coil spring, which controls the plunger or brass point. The valve is lapped in its seat to guard against leakage of cement or intake of air, thereby keeping the cement fresh at all times. One filling of the pen will make 1000 splices. The pen is made of light-weight material and can be carried in the pocket like a fountain pen, and the valve can easily be taken apart and cleaned.

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, N. Y. Micro copies of articles, in magazines that are available may be obtained from the Bibliofilm Service, department of Agriculture, Washington, D. C.

American Cinematographer

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ABSTRACTS OF PAPERS FOR THE HOLLYWOOD CONVENION

The following abstracts were received too late for inclusions in the April Journal and are published here for reference purposes:

"Use of an A-C. Polarized Photoelectric Cell for Light-Valve Bias Current Determination;" C. R. Daily, *Paramount Pictures Inc.*, Hollywood, Calif.

When a low-frequency, low-voltage polarizing potential is applied to a gas type PEC, the cell operates as a non-linear half-wave rectifier. The voltage drop obtained across the PEC load resistor may be amplified and measured on a conventional full-wave copper-oxide rectifier meter. This conversion from d-c. to a-c. of the output current of a PEC may be applied to a PEC monitor system to provide a convenient means of determining the required light-valve bias current. Measurements indicate that the amplified current output varies linearly with respect to light changes to the PEC over a range of 16 db. Changes in bias current can, therefore, be read directly on a monitor output meter. The method may be used in place of light interrupting tone wheels, harmonic methods, stroboscopic observations, direct d-c. measurements with a microammeter of PEC current, or other means which have been employed for this purpose. With a calibrated system, variations in lamp current and valve spacing may also be detected.

"A Densitometric Method of Checking the Quality of Variable-Area Prints;" C. R. Daily and I. M. Chambers, *Paramount Pictures, Inc.*, Hollywood, Calif.

The dynamic measurement of the rectification component of a modulated high-frequency is normally used to check the processing of variable-area prints. An approximate indication of print quality may also be obtained by measuring on a PEC densitometer the difference in the average transmission of unbiased, modulated and unmodulated tracks. A comparison of routine dynamic cross-modulation measurements and static transmission measurements on cross-modulated and unmodulated track indicates that (*a*) for prints exhibiting optimum processing as determined by the dynamic method, the differential static transmission is substantially zero; (*b*) for light or dark prints the transmission of the cross-modulated track is greater or less, respectively, than for unmodulated track. The static measurement, therefore, tells the direction as well as the approximate amount of the print density deviation from optimum. Similar static measurements on 7000-cycle instead of cross-modulation track indicate that the print density required for zero differential transmission is considerably less than the optimum determined by dynamic cross-modulation measurements.

With a suitable double-aperture densitometer, the PEC's being connected to a balanced bridge circuit, the approximate processing condition of the print may be determined with only a few inches of film, saving film and eliminating the necessity of threading and running a reproducer. This facility may be of some advantage to laboratories releasing considerable amounts of variable-area track since short sections of suitable unbiased, unmodulated and cross-modulated track could be spliced to the end of each reel of negative and routine measurements made of the differential transmission on all prints. Occasional calibrating checks by the dynamic method would still be indicated.

"Modern Instantaneous Recording and Its Reproduction;" N. B. Neely and W. V. Stancil, *N. B. Neeley Enterprises*, Hollywood, Calif.

Many papers have been written on lateral recording heads, mediums, and reproducers, so the present paper is intended to be a short, non-technical discussion of two unique units that have put lateral instantaneous recording on a par with any present recording method.

The cutter described gives exceedingly good results in the range afforded by the present method of disk recording. The reproducer is of D'Arsonval moving-coil principle made with a permanent stylus, and with an effective needle point mass of 14 milligrams. The extremely low needle point pressure, together with the very high compliance of the moving element suspension, permit an acetate disk or pressing to be played repeatedly without damaging the record.

"Flicker in Motion Pictures;" L. D. Grignon, *Paramount Pictures, Inc.*, Hollywood, Calif.

Flicker in motion pictures has been receiving attention ever since the beginning of the art, and most of the sources of this defect have been minimized, if not eliminated, by technical accomplishments. The paper constitutes a qualitative review of the now prevalent sources of flicker, presenting some new concepts, emphasizing the sources of major importance at the present time, and reporting on two investigations made on the problem. Flicker and "registration jump" are differentiated, and the latter, which is really a separate problem, is not considered. Some data are presented to indicate the magnitude and characteristics of the flicker effect.

"Controlled Sound Reflection in Review Rooms and Theaters;" C. M. Mugler, *Acoustical Engineering Co.*, Los Angeles, Calif.

This paper avoids technicalities and formulas, reaching back to elementary acoustics which are often side-tracked. Controlled reflection plays the leading role, with the minor parts delegated to sound diffusion and uniform energy distribution. Although much can be mathematically proved, the only satisfying conditions are the apparent ones, which are judged and gauged by the normal human ears.

Audio effects due to the physical characteristics of both sound absorbents and building materials are explained and their proper locations emphasized. Although a room can have the desired optimal reverberation time over the entire frequency response characteristics, it can still be unsuitable for the rendition of speech and music that is clear and distinct; the shape, size, and contours of the six surfaces in a room, plus the incidental equipment and purpose, are the deciding factors on how much and where the reflecting and absorbing materials should be placed.

"The Fluorescent Lamp and Its Application to Motion Picture Studio Lighting;" G. E. Inman and W. H. Robinson, Jr., *General Electric Co.*, Cleveland, Ohio, and Los Angeles, Calif.

The great variety of lighting problems encountered in motion picture production, the many new and interesting effects constantly called for, has made the studio electrical staffs particularly alert to take advantage of the many new lamp developments of the past year. Most outstanding of these has been the fluorescent lamp, introduced generally last April and adopted for studio dressing rooms and for the mixing of paints and set painting where a true daylight was required soon after. Subsequently it has been used for regular production lighting.

The phenomenon of fluorescence and phosphorescence by ultraviolet light is not a new one, but nevertheless much development work had to be done to make a commercially practical lamp and to control accurately the various colors. Since the energy required to activate these "phosphors," as the several fluorescent and phosphorescent materials are termed, can best be produced by a low-pressure arc, the design of suitable automatic starting and stabilizing controls constitutes another important factor in the commercial application of this source.

The increasing number of productions in color, generally with a process balanced to daylight, has made it necessary that the sets be painted and the properties be chosen under daylight. Make-up must be applied under daylight conditions, which these lamps accurately provide.

The freedom from glare and high actinicity of the light has resulted in a number of cameramen's using fluorescent lamps for regular motion picture photography, particularly for "close-ups."

"A Cardioid Directional Microphone;" R. N. Marshall and W. R. Harry, *Bell Telephone Laboratories*, New York, N. Y.

A microphone is described which has uniform directivity over a wide frequency range. This is made possible by placing in a single instrument a dynamic type pressure microphone element and a ribbon type "velocity" element, and electrically equalizing the outputs before combination. The resultant directional pattern is a heart-shaped curve or cardioid, giving a fairly wide pick-up zone in front and a substantially dead zone at the back of the instrument. Because of the unusually rugged ribbon employed, the new microphone is much less susceptible to wind noise than ordinary ribbon types. Housed in an aluminum case the microphone weighs only $3^1/_2$ lbs. High output level, low impedance, and high quality together with the excellent directivity, promise to make the cardioid microphone an important tool for the motion picture sound engineer.

SOCIETY ANNOUNCEMENTS

HOLLYWOOD CONVENTION

As the Hollywood Convention, announced in previous issues of the JOURNAL, will barely have ended by the time this issue goes to press, it will not be possible to include further details here. However, in the next issue of the JOURNAL will be published a complete account of the highlights of the Convention and the final program as followed at the meetings.

Abstracts of a majority of the papers were published in the April issue. A few additional abstracts are included elsewhere in this issue.

MID-WEST SECTION

At a meeting held in the meeting rooms of The Western Society of Engineers, Chicago, on March 28th, Mr. T. B. Sliz, patent engineer of Chicago, presented a talk on the subject of "Patent Engineering Relative to Motion Pictures."

Following the talk was an exhibition of 16-mm. sound pictures by Mr. Stevens, of the Cineculture Co., Chicago.

The meeting was well attended and a special meeting is being arranged for April.

ATLANTIC COAST SECTION

On April 6th a meeting of the Section was held in the Eastern Service Studios, subsidiary of Audio Productions, Inc., located at Long Island City, N. Y.

Mr. Frank Speidell, President of Audio Productions, Inc., gave an interesting lecture on the subject of "The Motion Picture in the East."

Groups of members were conducted through the various departments of the studios, including the Sound Department, the Camera Department, and the stages, where typical motion picture sets were viewed. Technicolor camera equipment was also exhibited. Considerable interest was shown in Mr. Speidell's lecture, and the tour through the various departments was very valuable as illustrating many of the points made in Mr. Speidell's talk.

The next meeting of the Atlantic Coast Section will be held on May 10th at the Hotel Pennsylvania, New York, at which time the following papers will be presented: "Television Studio Technic," by A. W. Protzman, "Television Lighting," by William C. Eddy. Messrs. Protzman and Eddy are engineers with the National Broadcasting Company.

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 400 feet long.

Price $25.00 each.

JOURNAL
OF THE SOCIETY OF
MOTION PICTURE ENGINEERS

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JOURNAL
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MOTION PICTURE ENGINEERS

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RECOMMENDATIONS ON PROCESS PROJECTION EQUIPMENT*

RESEARCH COUNCIL OF THE ACADEMY OF MOTION PICTURE ARTS AND SCIENCES

PREFACE

In furthering developments in process projection equipment and technology, the Research Council of the Academy of Motion Picture Arts and Sciences is carrying out its fundamental purpose of assisting to achieve new production economies and furthering technical progress.

Process projection methods continue to become increasingly important:

Economically, they offer opportunities for still greater savings in production costs.

Technically, developments in equipment and technique continue to expand the possibilities in this field until, some day, it will be the exception, rather than the rule, to send a cast on a distant location.

Artistically, as this equipment and technique is further developed the extent of its use will be limited only by the imagination of the production personnel; whereas, up to the present time, the equipment has been the limiting factor and only the ingenuity and resourcefulness of the technicians have made its wide use possible.

The Process Projection Equipment Committee of the Research Council, under the chairmanship of Farciot Edouart, of Paramount Studios, was appointed in March, 1938. The Committee went into immediate conference to plan its program.

Eleven meetings and two demonstrations, consuming approximately one thousand man hours, were held, and at least an equal amount of time was consumed by the Committee Chairman and

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* Reprinted from the Technical Bulletin of the Research Council of the Academy of Motion Picture Arts and Sciences, Hollywood, Calif., February 3, 1939.

members in conferences, preparing for meetings, tests, and demonstrations, and preparing this Report.

This Report, therefore, represents over two thousand man hours of technical effort and combines the views of approximately fifty experts in the field of process projection.

The Research Council gratefully acknowledges the coöperation of the National Carbon Company for sending its Research Director, Mr. David Joy, to Hollywood in connection with the development of carbons for process projection work. Mr. Joy remained in Hollywood approximately three weeks conferring with the Committee.

The Research Council also gratefully acknowledges the coöperation of the Bausch & Lomb Optical Company for sending its representatives, Mr. Haller Belt and Mr. Allan Cook, to Hollywood in connection with the development and standardization of optical systems for process projection work. These men remained in Hollywood two weeks conferring with the Committee and individual members of the Committee.

The Council also gratefully acknowledges the coöperation of the International Projector Corporation, the Mitchell Camera Company, the Technicolor Motion Picture Corporation, the General Electric Company, the Mole-Richardson Company, Paramount Studios, RKO-Radio Studios, and Selznick International Studios, in the work of this Committee to a far greater extent than is ordinarily required of participants in the Council's program.

In presenting this Report to the industry, it is only proper that the Research Council commend every active member of the Committee for his part in this important project.

The active membership of the Process Projection Equipment Committee consists of:

FARCIOT EDOUART, *Chairman*	Paramount Studio
F. R. ABBOTT	Bausch & Lomb Optical Company
J. A. BALL	Technicolor Motion Picture Corporation
JACK BURROWS	20th Century-Fox Studio
F. C. COATES	Mole-Richardson Company
RALPH DENSMORE	Paramount Studio
ARTHUR DE STEFANO	National Theatre Supply Company
JACK DURST	International Projector Corporation
E. H. FENDER	Mitchell Camera Company
CHARLES HANDLEY	National Carbon Company
FRANK HARRIS	B. F. Shearer Company
WINTON HOCH	Technicolor Motion Picture Corporation

STANLEY HORSLEY	Universal Studio
FRED JACKMAN	Jackman Process Company
WALLACE KELLEY	Paramount Studio
GROVER LAUBE	20th Century-Fox Studio
ROBERT LAYTON	United Artists Studio
WILLIAM MILLER	Paramount Studio
EMIL OSTER	Columbia Studio
H. W. REMERSHIED	Bell & Howell Company
ELMER RICHARDSON	Mole-Richardson Company
W. H. ROBINSON, JR.	General Electric Company
WILLIAM RUDOLPH	Metro-Goldwyn-Mayer Studio
ROY SEAWRIGHT	Hal Roach Studio
W. B. SLAUGHTER, JR.	Metro-Goldwyn-Mayer Studio
GLEN SLIPPER	B. F. Shearer Company
OTTO STAPLEFELD	Zeiss-Ikon Corporation
HERB STARKE	RKO Theatres
GEORGE TEAGUE	Universal Studio
WILLIAM THOMAS	Warner Brothers Studio
HOWARD R. TRISSEL	Trissel & Landers, Inc.
GLEN WAHL	Carl Zeiss, Inc.
VERNON WALKER	RKO-Radio Studio
GEORGE H. WORRALL	Mitchell Camera Company
FRANK YOUNG	Hal Roach Studio
ARTHUR ZAUGG	Paramount Studio
A. C. ZOULIS	Paramount Studio

This Report presents, for the first time, the coördinated viewpoint of the majority of the Hollywood studios on this subject and should be of great value to all the studios and to the manufacturers of process projection equipment.

NATHAN LEVINSON, *Acting Chairman*
Research Council
Academy of Motion Picture Arts and Sciences.

FOREWORD

The material included in this Report has been prepared by the Committee after thorough consideration of the basic requirements necessary for such an equipment as well as the refinements and developments to be expected in the future. The specifications and recommendations contained in the Report have been prepared for the guidance of the engineering departments of the producing companies participating in the Research Council coöperative technical program in purchasing new process projection equipment.

Copies of the Report have been distributed through each company's representative on the Council to the proper officials in each company.

Copies of the report are also available, upon request, to all process projection equipment manufacturers, or companies manufacturing particular parts of such equipment, to be used as a guide in the designing, testing, and manufacturing of equipment, and to commercial organizations doing background process or miniature work for the motion picture producing companies.

As part of the program, the Committee has made tests on a number of particular recommendations contained in this Report to determine their practicability before inclusion in the Report.

In order to specify clearly the relative importance of the various recommendations included in the Report, each sub-heading in each part is indicated by one of the three following classifications:

Basic—Recommendations so indicated incorporate definite requirements and principles. (Printed in bold face type.)

Auxiliary—Recommendations so indicated are suggested methods of meeting basic requirements. (Printed in light face type.)

Accessory—*Indicates optional special refinements which add to the ease of operation of equipment. (Printed in italic type.)*

Since the very inception of Transparency Process Projection methods, it has been found in general that available projection equipment for this type of work is principally composed of an assembly of units never originally designed in their entirety or engineered to be combined and worked together in such capacity. Basic elements of these assemblages were never intended to fulfill and meet such strict requirements as have been imposed upon such equipment by the consistent demand for higher-quality rear projection results, and of the ever-increasing scope required in the present stage of the motion picture art.

These recommendations are based upon ***maximum light delivery*** with the following primary requisites: ***Absolute steadiness*** of the projected picture with a ***minimum of light variation*** on the screen, and ***increased efficiency of the light.***

The designer and manufacturer should regard any tolerances affecting these three principles as concessions to practicability, and any method of decreasing these concessions will be considered definite advancements in design.

FARCIOT EDOUART, *Chairman*
Process Projection Equipment Committee

RECOMMENDATIONS ON PROCESS PROJECTION EQUIPMENT

PART I

The Base

Construction (*Basic*): The base shall be so designed that it provides: (*1*) A rock-like stability during operation, when locked off, and facilities for panning and tilting with absolute smoothness and precision; and (*2*) sufficient portability so that the whole equipment may be easily moved about on its special carrier or dolly on the recording stage by not more than two men.

Construction (*Auxiliary*): It has been suggested that the portability be accomplished by the use of a special carrier or dolly of the four-wheel type (on which the base will be mounted), equipped with solid rubber tires to insure safety and stability during movement of the equipment. The wheels should have the ability, free from any side play or sway, to swivel and lock off in any direction for possible dolly shots. To increase stability, suitable jacks should be provided to lift the equipment off the wheels for stationary shots. Adequate bubble levels should be provided for leveling up the equipment.

Pan and Tilt Mechanism (*Basic*): In the design of the base, provision shall be made for a free-moving and easily operated tilt and pan mechanism, giving a smooth movement when in operation, but including a positive locking device, giving locked-off stability equal to the stability obtained were this pan and tilt mechanism not provided. There should be no backlash or play whatsoever in the pan and tilt mechanism and means for adjustment should be provided to keep all working parts tight at all times. (See "Rotation of the Projector Head.")

Pan and Tilt Mechanism (*Accessory*): *The design of the base should also provide for the addition, when required, of a variable-speed motor control of the pan and tilt mechanism, operating remotely from the camera position. The design of this remote control mechanism should provide for a gear ratio in the order of 900 to 1 between the drive motor speed and the speed of operation of the tilt and pan mechanism (to minimize over-control) as well as a gear box providing two lower gear ratios, making available all the necessary different speeds of operation.*

Minimum Degree Pan and Tilt (*Basic*): The base shall be designed to provide an angle of pan of at least 15° to both right and left of the center line between the projector and the screen, making a total minimum horizontal coverage of 30° and to provide an angle of tilt of at least 10° above and below the horizon, making a total minimum vertical coverage of 20°.

Interchangeability (*Basic*): The base shall be so designed as to allow for free, quick interchange of projection heads and lamphouses, registered with dowel pins or other positive means so that a minimum of adjustment is required for lining up when a change in head or lamphouse is made.

Interchangeability (*Accessory*): *In the event that devices other than the regular base mentioned above are provided to hold the projection head and lamphouse, the base on which the projection head and lamphouse rests should be designed so that projection heads and lamphouses are easily and quickly interchangeable to such devices.*

Sound Insulation (*Basic*): The base shall include sound insulation to eliminate the transmission of noise.* (See "Maximum Noise Level.")

Height of Optical Axis (*Basic*): The base and special carrier shall be so designed that the equipment's optical axis, when parallel to the stage floor, shall be 5′ 6″ from the stage floor.

PART II

The Light Source

Efficiency of the Carbon Light Source (*Basic*): The type and size of carbon shall be carefully chosen for maximum efficiency in relation to the selected type of optical system and lamphouse.

Efficiency of the Carbon Light Source (*Auxiliary*): It is recommended that all motion picture producing companies and commercial organizations using process projection equipment follow the manufacturers' rated burning conditions under which the maximum efficiency and minimum flutter and flicker are obtained from the carbon light source. (See "Light Control.") It is further recommended, to insure freedom from moisture or dampness, that carbons be kept for 48 hours before use in an electric heating oven operating at not to exceed 125°F.

Tolerances in the Straightness of Carbons (*Basic*): Carbons for process projection shall be so selected by the manufacturer for straightness and concentricity of the core, that when burned in a lamphouse developed and constructed to meet these Recommendations, the equipment shall be able to fulfill the Tolerances under "The Feeding Mechanism," as well as the recommended "Tolerances in Light Variation of the Light Output."

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*NOTE: It has been observed that sufficient sound insulation has been provided by insulating the setting jacks of the dolly with hard rubber. However, it must be remembered that any material so used must not, in any way, detract from the absolute steadiness of the whole equipment.

Magnetic Shielding (*Basic*): The current to the arc shall be so conducted into the lamphouse that no magnetic fields disturbing to the arc are set up.

Incandescent Light Source (*Basic*): It is recommended that further development work be conducted on incandescent and hi-pressure mercury vapor lamps for general and special application to background process projection.

Power Supply (*Auxiliary*): It has been suggested that a separate power supply be provided for the light source, inasmuch as a constant line voltage to the arc is imperative to accomplish the results to be obtained from equipment meeting these Recommendations.

PART III

Maximum Variation in Light Output of Equipment

Tolerances in Light Variation of the Light Output (*Basic*): The design of the whole equipment shall be such that the illumination from the carbon arc light source approaches as closely as possible the steadiness of an incandescent source. In any event, the amount of light variation during the projection of a scene shall be less than ±2% per minute but with a maximum of ±5% for any consecutive nine minute shooting period.

This tolerance is to apply only after a proper crater has been formed in the arc.

Definition of Light Variation (*Basic*): There are two distinct types of variation in the light output of an arc lamp, which can be designated as "flicker,"* viz.: *a sudden sputter or brief increase or decrease in brightness*, and as "fluctuation,"* viz.: *moving in a slow wave of increasing or decreasing brightness*.

Flicker—Method of Measurement (*Basic*): Flickers are generally too fast to be measured by any presently known meters, but shall be measured by photographing a clear screen illuminated by the arc lamp source. Each frame of the exposed, developed negative, over given portions, can then be read on a densitometer.**

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*NOTE: Flicker may be caused by the core of the positive carbon having different consistency in various spots, causing the arc to momentarily sputter, or by sudden air drafts or misdirected magnetic flux, or by misalignment of the negative carbon with respect to the crater.

Fluctuation is a mechanical or electrical problem and is caused by off-center rotation of the crater, the carbon feeding in an irregular manner, crooked carbon, or disturbances in the line voltage.

**NOTE: It is recognized that this method of measuring flicker may not be the most accurate, due to variations in film development, but is one simple means available at present. The Committee will welcome suggestions on more accurate methods which may be devised.

Fluctuation—Method of Measurement (*Basic*): Fluctuation can be easily read and recorded with an accurate, sensitive light recording photometer.

PART IV

The Lamphouse

General Recommendations Applying to Both Mirror and Condenser Type Lamphouses

Capacity and Optical Speed (*Basic*): Recommendations covering capacity and optical speed for each type of lamphouse are given in that Section of this Part of the Report specifically applying to each type of lamphouse.

Noise Level (*Basic*): The noise level of the lamphouse in operation shall be 3 db below the noise level specification given for the whole equipment in that Part ("Noise Level") of these Recommendations. This specification must be met without the use of booth or blimp on the lamphouse.

Noise Level (*Auxiliary*): It has been suggested that acoustic treatment of the lamphouse might prove effective in meeting the above basic Noise Level Recommendation.

Striker Means (*Basic*): The lamphouse shall be provided with a striker, hand or motor, which produces no detrimental magnetic effects on the burning of the arc and which will not shatter the crater.

Viewing Ports (*Basic*): Large adequate viewing ports shall be provided in both sides of the lamphouse, located at the most advantageous position.

Lamphouse Doors (*Basic*): The lamphouse door shall open upward rather than outward (forward or backward) and shall be provided with a positive holding device when open.*

Control and Meter Panel (*Basic*): Controls and meters shall be centrally located at one position on the operating side (the right side facing the screen) for ease of operation of the equipment (except for special purposes).

Operating Position (*Accessory*): *The lamphouse should be adaptable to operation from either the right or the left side for special purposes.*

Lining Up Method (*Basic*): A small port shall be included in the rear housing of the lamphouse in line with the optical center of the equipment so that, with no carbon in the mechanism, preliminary lining up may be accomplished by sighting through the carbon jaws and aperture.

Interchangeability of Burner Elements (*Basic*): The burner elements, both the positive and negative, shall be easily removable from the lamp-

*NOTE: It has been suggested that the lamphouse doors be of the type which fold or collapse into a smaller unit when opened.

house in order to replace parts and to facilitate cleaning, and shall be interchangeable between lamphouses of the same type.

Ash Trays (*Accessory*): *Removable trays in the bottom of the lamphouse should be provided to catch debris and to facilitate keeping the lamphouse clean.*

Ventilation from Maximum Degree Tilt (*Basic*): The design of the ventilating system shall be such that the ventilation will not be reduced when using the lamp at a maximum angle to tilt of 30° above or below the horizon.*

Heat Insulation (*Basic*): The walls of both type lamphouses shall be so designed and treated that the heat will be conducted through the chimney rather than radiated out through the side of the lamp, thus lowering the temperature of the lamphouse.

Heat Insulation (*Auxiliary*): It has been suggested, that should the lamphouse not be used with a portable equipment, that a metal cover be provided over the upper part of the lamphouse with sufficient clearance to set up a draft between this cover and the lamphouse, to carry the heat transmitted through the lamphouse up the chimney.

Materials of Construction (*Basic*): All parts of the lamphouse and shield (baffles) shall be constructed to distribute the magnetic flux in a manner that will not disturb the proper burning of the arc.

Visual Indicator Devices (*Basic*): An indicator shall be provided comprising a compact, rigid optical system having a visual target index to show the burning relation between the carbons. An indicator shall also be provided to show the length of trim left in the lamp.

Metering Facilities (*Basic*): An accurately calibrated and dependable ammeter and voltmeter shall be provided in the electrical circuit to show the arc current and voltage.

Recommendations Applying Only to the Mirror Type Lamphouse

Capacity (*Basic*): The lamphouse shall be designed to be convertible to accept either 11 mm. or 15 mm. carbons.

Ventilation of the Lamphouse (*Basic*): The ventilation of the lamphouse shall be so designed that the lamphouse will be able to handle as high as 150 amperes without detrimental heating, this to be accomplished with minimum draft at the carbon arc so as not to impair the arc steadiness. (See Note, "Flicker.")

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*NOTE: In the opinion of the Committee, a 30° angle is the maximum tilt at which it will be necessary to burn the lamp. This angle is greater than the minimum degree of tilt specified for the projector, but may at times be reached in operation due to the equipment as a whole being purposely set off-level in some particular setup.

Speed of Mirror (*Basic*): Interchangeable mirrors with speeds capable of filling *f*/2.0 and *f*/1.6 projection lenses shall be provided.*

Adjustments (*Basic*): The mirror shall be provided with universal adjustments so constructed as to maintain their settings.

Distribution of Light on the Screen (*Basic*): An optical system should be developed to provide a more uniform distribution of light on the screen than is now obtained from mirror type lamps. (See "Capacity of the Feeding Mechanism.")

Recommendations Applying Only to the Condenser Type Lamphouse

Capacity (*Basic*): The lamphouse shall be designed and constructed to accommodate 13.6, 16, and 18-mm. carbons and to accommodate in the case of the relay setup, condensers capable of filling an *f*/1.6 lens and cover the camera apertures as specified under "The Film Gate and Projector Head."

Adaptability (*Basic*): The condenser lamphouse shall be so designed that it will be adaptable to a relay condenser system at such time as this system may be desirable.

Adaptability (*Auxiliary*): In the opinion of the Committee, the basic recommendation on "Adaptability" will probably call for greater latitude in positioning and adjusting of condensers, and it has been suggested that the front end of the lamphouse be so constructed that it will be adjustable to accept different types of optical systems as well as those existing at present and those expected to be developed in the future. One method suggested has been the use of an adapter plate or series of rings on the front of the lamphouse which will allow, at the present time, a stepping down of the size of the opening in the front of the lamphouse to present systems, and the addition of faster systems, at a later date, merely by removing the adapter plates or rings.

Ventilation of the Lamphouse (*Basic*): The lamphouse shall be so designed that sufficient ventilation will be provided for the use of currents as high as 250 amperes without detrimental heating, this to be accomplished with minimum draft at the carbon arc so as not to impair the arc steadiness. (See Note, "Flicker.")

Feeding Mechanism and Accessories (Applying to Both Type Lamphouses)

Capacity of, and Tolerances in, Light Variation from the Feeding Mechanism (*Basic*): The carbon feeding mechanism shall be designed so that the light projected on the screen is not subject to periodic changes

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*NOTE: Present mirror reflectors do not produce adequate results in an *f*/2.0 or *f*/1.6 system and efforts to improve this condition should be made.

of level attributable to the feeding mechanism (see "Light Variation") and must be capable of handling the carbon sizes specified under "Capacity."

Tolerances (*Basic*): Feed and contact brushes for the positive carbon shall be so designed and made that the crater, during operation, will not change its focal position by more than ±0.025 inch. The positive head shall be designed so that the positive carbon axis at the crater will rotate within a circle of a radius of 0.010 inch.

Burning Position of Carbon (*Basic*): The feeding mechanism shall be so designed that the negative carbon will burn at an angle, in relation to the axis of the positive carbon, to obtain optimum efficiency. With present equipment and carbons this angle is approximately 53°.

Feeding Control Mechanism (*Basic*): An automatic control for the proper motor feed shall be provided to keep the crater in its correct burning position. Electrical feeds shall be provided for both carbons of sufficient latitude and control that the carbons may be motor driven under all burning conditions after having once been set in the burning position, this to be accomplished by the use of separate independent motors for the automatic drive of both carbons, with alternate control for both positive and negative to permit hand feeding, both backward and forward, when desired.

Feeding Control Mechanism (*Auxiliary*): It has been suggested that the automatic control for keeping the positive carbon in a correct relative position (basic recommendation above, "Feeding Control Mechanism"), be met by the use of a thermostatic or photoelectric cell control on the motor feed, either control to be actuated by a beam of light from the crater of the arc.

Feeding Mechanism Adjustment (*Basic*): The negative feed mechanism shall be provided with a readily accessible adjustment *to move it both vertically and transversely in relation to the axis of the positive carbon.*

Feeding Mechanism Adjustment (*Accessory*): *Consideration should be given to the possibilities for providing a visual target to show the negative carbon burning position along the longitudinal axis.*

PART V

The Optical System

Speed (*Basic*): The optical system shall have a speed of *f*/2.0 or greater.

Speed (*Auxiliary*): The above recommendation should not be construed to mean that developments beyond a speed of *f*/2.0 are not anticipated. On the contrary, an *f*/1.6 system is to be expected in the future.

Adjustment (*Basic*): Adequate lateral, vertical, and longitudinal adjustment facilities shall be provided for all units of the optical system, irrespective of the projection lens.

Color Balance (*Basic*): The optical system shall contribute no noticeable color and that same order of spectral uniformity should extend to a wavelength of 3800 Å.

Color Balance (Mirror System) (*Basic*): All mirrors used in the mirror type optical system shall be surfaced with aluminum, or at least its equivalent.

Primary Condenser

Focal Length (*Basic*): The primary condenser shall be of a focal length to give a maximum amount of light output using an *f*/2.0 system. (See "Speed, Auxiliary.")

Protective Devices (*Basic*): The condenser mounting shall be so designed as to give sufficient clearance within the lamphouse to allow for expansion of the condenser due to increase in temperature during operation. Protective devices should also be provided to eliminate destructive air currents from the condenser when the lamphouse door is open. (See "Ventilation of the Lamphouse.")

Protective Devices (*Auxiliary*): An attempt should be made to design a method whereby the lamp could be retrimmed without subjecting the condenser to drafts or sudden temperature changes. (See "Ventilation of the Lamphouse.")

Construction (*Auxiliary*): The element of the condenser nearest the crater should be designed and constructed somewhat thicker than at present so that pitting of this condenser can be removed by regrinding and polishing as required.*

Condenser Relay Type System

Focal Length (*Basic*): The relay condenser type system shall be designed to permit as short a setup as possible and still deliver the maximum amount of light with an *f*/2.0 beam or cone of light. (See "Speed, Auxiliary.")

Adjustment (*Basic*): The condenser relay mount shall be so designed as to permit both horizontal and vertical adjustments in both directions with a suitable pitch thread, so constructed as to maintain their setting.

Protective Devices (*Basic*): The mountings of the condenser system shall be designed to give sufficient clearance to allow for expansion of the condenser during temperature rises.

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*NOTE: It has been suggested that the use of an auxiliary thin quartz plate between the arc and the preliminary element of the condenser might furnish a protection for this condenser element provided too great a light loss is not introduced.

Lenses

Aperture (*Basic*): A lens shall be provided with an aperture of $f/2.0$ or greater. The screen brightness should be controlled by a diaphragm in the case of an excess quantity of light, provided such a design could be made practical.* (See "Speed, Auxiliary.")

Color Correction (*Basic*): The lens shall be panchromatically corrected to conform as nearly as possible to the correction of the best camera lenses; that is, the lens should be corrected not only visually but photographically. The secondary spectrum should be as flat as possible.

Distortion (*Basic*): The distortion shall be less than six parts in a thousand.

Distortion (*Auxiliary*): It has been suggested that the above basic recommendation on distortion be reduced if possible. However, this should not be done at the expense of other types of lens correction.

Definition, Resolving Power, Coverage, and Flatness of Field (*Basic*): The definition, resolving power, coverage, and flatness of field shall be comparable, as nearly as possible, to good anastigmatic photographic lenses.

Construction (*Basic*): The lens shall be accurately constructed so as to be centered both optically and mechanically.

Standards of Lens Mount Diameters (*Basic*): The Committee recommends that the following be adopted as standard for lens mount diameters by the Research Council and submitted to the American Standards Association through the ASA Sectional Committee on Motion Pictures, for consideration for formal standardization by the ASA:

(*1*) Lenses of $f/2.0$ and $f/1.9$ focal ratios are of particular interest to the industry at the present time. Everything possible should be done to produce lenses of these speeds whose performance is satisfactory for background projection. All possible development should be made on $f/1.6$ projection lenses from 4″ to 6″ focal lengths. There

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*NOTE: The relay condenser system, because it does not focus the crater of the arc on the aperture, gives a smoother illumination. Furthermore, this system is not limited by as many uncontrollable items as is the mirror system, such as the increase of heat, increase of size of lamphouse, etc., associated with increased speed of the mirror.

Experiments have proven that it is possible to diaphragm certain types of projection lenses used in process work without having the diaphragm actually in the lens.

This diaphragm is located just in front of the front element. Tests with Bausch and Super-Cinephor lenses show that perfectly uniform light control is obtained with no trace of increase of existing vignetting or hotspot due to stopping down of the diaphragm at this position. The definition of the image improves greatly when the iris is stopped down. Further tests with other types of lenses must be made to be certain that this method can be applied to all types.

will be a demand for this series when it is produced with sufficient correction to permit its use in background projection work.

(2) Studios will use $f/2.0$ and $f/1.9$ lenses up to and including 4″ focal length with the diameters that are adopted by the manufacturers as standard for theater use. It is strongly urged, however, that the diameters of the $f/2.0$ and $f/1.9$ lenses be kept as consistent as possible and with as few changes in shell diameter throughout the series as is practical. The latter restriction applies also to any $f/1.6$ lenses that may be developed.

(3) For lenses of longer focal lengths, the standard lengths shall be 5″, 6″, 7″, and 8″. All other focal lengths will be in the nature of special requirements, to be supplied upon individual studio order.

(4) Lenses of the $f/2.0$, $f/1.9$, or $f/1.6$ series with focal lengths of 5″, 6″, 7″, and 8″ will maintain an outside barrel diameter of $4^1/_2$″.

(5) Lenses of an $f/1.6$ speed will be in focal lengths of 4″ to 6″, inclusive. Lenses with focal lengths longer than 6″ should maintain a constant lens diameter up to the 8″ focal length at which point the speed of this group will converge upon the $f/2.0$ series.*

Light Control

Light Control Diaphragm (*Basic*): A heat-resisting diaphragm light control shall be provided at a suitable point in the relay condenser system to control the intensity of the light output. This diaphragm must not affect the flatness of field.

This diaphragm control in the relay type condenser system will allow carbons to be burned at their correct amperage and thus give the maximum efficiency and maximum steadiness in light output. In an equipment provided with this control, it is recommended that the carbons be burned within ±5 amperes of their rated current, as shown by the following list.

RECOMMENDED OPTIMUM CURRENTS FOR CARBONS:
(*Submitted by the National Carbon Co., Inc.*)

	Amperes
13.6 mm × 22 Positive Carbon	
7/16″ × 9 Orotip Negative	125
13.6 mm × 22 Super H. I. Positive Carbon	
1/2″ × 9 Heavy Duty Orotip Negative	175
16 mm × 20 M. P. Studio Positive Carbon	
1/2″ × 9 Regular Orotip Negative	150
16 mm × 22 Super H. I. Positive Carbon	
1/2″ × 9 Heavy Duty Orotip Negative	195

*NOTE: Since these two lenses operate in such close conjunction with the projection movement, it is recommended that lens manufacturers contact the studios to determine necessary allowances in the lens barrel to clear the projection movement employed. It is the hope of the Committee that one type of projection movement will eventually be adopted as standard by the industry, thus alleviating the necessity for several styles of mountings. (See "Aperture.")

(***Submitted by the Noris Carbon Co., Inc.***)

16 mm × 20 Positive Carbon—Type A		**200**
13 mm × 9 Negative	**Type B**	**225**
13.6 mm × 22 Positive Carbon		
7/16″ × 9 Negative		**175**

Lining Up Method (*Basic*): The design should include a means of projecting a single frame for lining up purposes, permitting as much light as possible to pass through the aperture without damage to the stationary film.*

PART VI

Grids

Capacity (*Basic*): Grids shall be designed for mirror type lamps to have a capacity of from 75 to 150 amperes. For condenser type lamps, the grid capacity shall be from 100 to 250 amperes. Both types are to be provided with 5 ampere steps and with a uniform resistance at each step throughout the whole range.

Capacity (*Auxiliary*): It has been suggested that the above conditions can be met by providing 10 ampere steps with auxiliary controls of 5 amperes to fulfill the Basic Recommendation above.

Temperature Rise (*Basic*): Grids shall be designed of such material and of a type giving a minimum resultant temperature resistance coefficient. (See "Light Variation.")

Construction (*Basic*): Grids shall be built solidly and be compact yet easily portable.

Line Switch Control (*Basic*): A remote control operating from the control panel of the projector, to open and close the power supply switch, shall be provided.

Starting Resistance (*Basic*): Grids shall be so designed that when used in conjunction with a mirror lamp a maximum starting current of 75 amperes will be provided and when used in conjunction with a condenser type lamp a maximum starting current of 100 amperes will be provided. This current should be held steadily for a minimum of 30 seconds, at which time the grid should provide an easily operated means for raising the current to its proper predetermined operating value. (See "Light Control.")

Starting Resistance (*Auxiliary*): The use of a switch arranged to first provide the proper starting or heating current and then by one switching operation the proper operating current, has been suggested as one method of meeting the above Basic Recommendation. Such a pre-

* NOTE: An auxiliary light source of sufficient intensity to permit lining up should be provided.

heating arrangement would aid in the most effective use of the grid during the start of operation. (See "Line Switch Control," above.)

Contact (*Basic*): The contacts of the grid shall be so designed that the grid will give an easily operated method of resistance change and provide good electrical contacts, the efficiency of which will not vary over a period of time.

Contacts (*Auxiliary*): For grids designed to be used in conjunction with a projector equipped with a light control diaphragm (see "Light Control"), the inclusion of a locking device has been suggested which, after a resistance change is made, gives a positive contact, rather than a contact of the rheostat or potentiometer type.

PART VII

The Film Gate and Projector Head

Normal Speed Projector Head

Aperture (*Basic*): The projector head shall be so designed that an *f*/1.6 cone of light can be accommodated through the aperture and fill an *f*/1.6 projection lens from all parts of the picture, necessitating that the opening behind the aperture be of sufficient angle to allow the above cones of light to reach all parts of the aperture. The projector head should be designed to accommodate *f*/1.6 lenses (when such fast lenses are satisfactorily developed), and permit lenses of large diameter* to come close enough to the aperture and not interfere with the operation or steadiness of the movement to obtain a proper focus on any length of set-up. A full screen aperture, 0.950″ by 0.723″, shall be provided.

Shutter Opening (*Basic*): The projector head should be designed for a maximum shutter opening of 240°, this to mean that the film shall be at rest and the shutter to fully clear the aperture for this period of time.**

Synchronizing (*Basic*): A readily accessible synchronizing device which is quick and positive in operation shall be incorporated in this design. This device shall synchronize the projector and camera shutters to a tolerance of ±2°.

Motor Drive Systems (*Basic*): Provision shall be made in the design of the projector head motor drive so that the projector can be interlocked with the camera and recorder motor drive system, and so that it will maintain the tolerances as given above under the Basic Recommendation "Synchronizing."

Cooling Device (*Basic*): A cooling device shall be provided in the optical system or incorporated in the aperture design. It has been sug-

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*NOTE: See "Standards of Lens Mount Diameters."

** NOTE: It is understood that all equipments shall be equipped with rear shutters. It has been further suggested that a 240° shutter be developed for the camera.

gested that a stream of air, striking the film from the projection lens side and away from the light source, be employed. Such a device, if within the specifications given under "Noise Level," would also help to meet the recommendations given under "Position of the Film During Exposure," as a means of holding the film in the aperture during exposure.

For the mirror or straight condenser type of lamphouse, the design shall also include a means, located between the gate and light source, to eliminate from the film aperture assembly that portion of spill light not actually used in the aperture. This device should be interchangeable to accept an $f/1.6$ to $f/2.3$ cone of light. The development of such means or device is recommended primarily to decrease the amount of heat on the film trap assembly with no loss of light in an $f/1.6$ system.

In the relay system such a device may not be necessary as the amount of spilled light is practically nil. However, provision should be made for such a device should it be found necessary.

Registration and Registering Pins (*Basic*): Inasmuch as steadiness of picture is the *basic and primary requisite* of a background projector equipment, the design shall be such as to include pilot pins providing rock-steady registration. These pilot pins may be either moving or stationary, providing the above specified registration is obtained and the pins stand up reasonably well under projection conditions.*

Adjustment Control of Registration (*Basic*): Adjustment control means shall be provided in registration to accommodate a maximum film shrinkage of 0.030″ per foot, this adjustment to be calibrated against the vertical adjustment of the aperture.

Registration—Film Reversed (*Accessory*): *If possible, means should be provided to reverse the registering pilot pins to give good registration to a background print when it is necessary to turn the background print over for projection purposes.*

Clearance (*Basic*): Sufficient clearance, that is, space between the aperture and lens, shall be left in the design to accommodate a projector head giving the steadiness required in the above specifications. (See "Aperture.")

Forward and Backward Operation of the Projector Head (Two-Directional Movement) (*Basic*): The projector head shall be so designed as to have the ability to run either forward or backward with perfect registration with a take-up designed to take care of this two-way operation. This should be accomplished with no damage to the film as specified under "Operating Speed of Projector Head." This type of two-directional projector head also fulfills the function of projecting a back-cranked scene with the camera running forward and the projector running backward, both shutters operating in synchronism.

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*NOTE: The pilot pins of the projector should engage the same perforations as the camera and printer.

This Recommendation is made after consideration of observations and comments made by those members of the Committee who have worked with this type of equipment. The resultant saving of production time will far more than offset any added difficulties encountered in securing such design.

Forward and Backward Operation of the Projector Head (Two-Directional Movement) (*Accessory*): *It has been suggested that the design of the two-directional movement be such that the background print can be rewound without taking the film from the projector head, by disengaging the synchronous motor from the distributor and operating independently.*

Position of the Film During Exposure (*Auxiliary*): A method is desired in the design which will aid in holding the film as near as possible in the same exact plane during each exposure period under any heating or operating condition. (See "Cooling Device.")

Rotation of the Projector Head (*Accessory*): *The projector head should be so designed as to rotate 90° either to the right or left about the optical axis, making a total circular coverage of 180°.*

Rotation of the Projector Head (*Accessory*): *It has been suggested that for the purposes of rigidity and registration in the equipment an attachment or device be designed to rotate the projected image 90° to the right or to the left, making a total circular coverage of 180°, rather than rotate the projector head. This might be accomplished through the use of prisms, first surface mirrors, or adaptor plates used in conjunction with a separate head.*

Focusing Control (*Basic*): **The design shall include a remote control for focusing, operating from the camera position.**

Focusing Control (*Auxiliary*): It has been suggested that the above focusing control be provided with a rheostat and be operated by a universal motor to give a variation in the speed of focusing. This focusing device should be easily released for manual focusing.

Fire Shutter (*Basic*): **The design shall include a fire shutter with a device to secure positive full opening when the machine is running. If of the centrifugal force opening type, an indicator should be incorporated so that the operator can at all times tell that the fire shutter is fully opened. This fire shutter should not open until the projector has reached the speed of 1200 rpm., and should close by the time the projector has slowed down to that speed. This opening and closing speed should be adjustable to meet special conditions where an operating speed of less than 1200 rpm. is necessary.* An auxiliary control should be included so**

*NOTE: The amount of this adjustment to meet special conditions shall be determined by the intensity of the light source, degree of shutter opening, and speed of operation.

that the light can be flashed without the necessity of running the machine.

Film Breakage (*Basic*): A positive operating buckle-trip device shall be included which will stop the mechanism under conditions of film breakage, loss of loop, or take-up failure. (See "Forward and Backward Operation of the Projector Head.")

Film Breakage (*Auxiliary*): A contact breaker or mechanism to disengage the drive system has been suggested as a means of meeting the above Basic Recommendation.

Noise Level (*Basic*): The noise level of the projector head in operation shall be 3 db below the noise level specification given for the whole equipment in that part ("Noise Level") of these Recommendations. This Recommendation is to be met without the use of a booth or cumbersome blimp.

Magazines (*Basic*): The magazines shall be so designed as to be adaptable to reel or spool (optional) take-off and take-up and shall accommodate up to 1000 ft. reels.

Lens Mount (*Basic*): A sturdy lens mount of sufficient size shall be provided to permit the use of all specified focal length lenses, with a speed of *f*/1.6 (see "Standards of Lens Mount Diameters"). Proper stability should be provided to eliminate movement and vibration and to keep the lens always in its proper focal position. The lens must accurately rack in and out along its horizontal optical axis and not revolve while focusing.

High-Speed Projector Head

Operating Speed of Projector Head (*Basic*): A high-speed projector head shall be provided which will operate at a speed of 120 frames per second with perfect registration, giving a minimum amount of abrasion to the film. The high-speed projector head shall fulfill the recommendations given under *"Normal Speed Projector Head"* with the exception that the noise level specification may be disregarded. However, additional specifications as given below must be met.

High-Speed Projector Head for Miniatures (*Basic*): In the event that by substituting the *High-Speed Projector Head* for the *Normal-Speed Projector Head*, the above speed requirement cannot be adequately accomplished or reconciled with steadiness, it has been suggested that separate heads for high speed be developed. Special high-power motors will be required and shall be designed to adequately operate the projector at a speed of 120 frames per second.

Shutter Control (*Basic*): A positive synchronizing shutter system shall be provided to eliminate the possibility of shutter slippage. (See "Synchronizing.")

PART VIII

Noise Level

Maximum Noise Level (*Basic*): Considering noise measurements made at 45° positions about the projector and at a distance of 6′ from the projector, using a meter which employs a 40 db ear loudness weighing characteristic and calibrated with respect to the standard reference noise level of 10^{-16} watts per square centimeter, the maximum allowable noise level from the whole equipment shall be 34 db.

PART IX

The Translucent Screen

Base Composition (*Basic*): All screens shall be made with a SAFETY-TYPE base—cellulose acetate or an equivalent *comparable to clear base acetate film*—this base to be of such quality that no discernible color change is noticeable over a two-year operation period. When a diffusion surface is applied to the base, this surface should be readily removable so that the screen may be easily refinished in the event the surface is damaged.

Light Transmission, Field, Definition (*Basic*): The screen, over its entire area, shall be so designed as to provide: (*1*) optimum transmission (see above paragraph); (*2*) optimum diffusion, diffraction, or refraction characteristics; (*3*) as flat a field as possible; and (*4*) uniform definition.

Standard Screen Sizes (*Basic*): The Committee recommends that motion picture producing companies, manufacturers, and commercial organizations engaged in process and miniature work standardize upon the following screen sizes (specified as usable inside area, exclusive of binding):

Height		*Width*	*Height*		*Width*
5′	×	7′	16′	×	21′
8′	×	10′	18′	×	24′
11′	×	14′	24′	×	30′
14′	×	18′	27′	×	36′

PART X

Screen Illumination

Standard Method of Measuring Screen Illumination (*Basic*): The following method of measuring the amount of light falling on a screen is recommended: The full screen aperture of the projection machine is flashed with the shutter open and stationary. Nine readings of the light intensity are taken at different points on the projection side of the screen —the four corners, the middle of the top and bottom and the two sides and the exact center of the image. The measurements at the corners and edges are made by placing the center of the cell in from the edge 5% of the total width and in from the top and bottom 5% of the total height of the projected image. The exact height and width of the projected image

is measured and the area of the image computed in square feet. The number of square feet of the image is multiplied by the average of the nine foot-candle readings. The result is the number of lumens delivered to the screen by the light and optical system in question.

Type of Meter (*Basic*): It is recommended that measurements of screen brightness be made with the Weston foot-candle meter, Model 603, with the cells filtered by means of the Weston Viscor filter which approximates the color sensitivity of the human eye.

Calibration of Meters (*Basic*): It is recommended that all meters used in the measurement of screen brightness be calibrated at least twice a year against known standards. It is further recommended that this calibrating be done by an organization properly equipped and authorized by the Weston Laboratories to adjust and calibrate Weston Foot-candle Meters.*

Minimum Light Intensity of Screen. It has been suggested that the minimum intensity of illumination at the screen, considering the speed of the lens system used, be as follows: The minimum output of a conventional condenser system, using an $f/2.3$ system be 12,000 lumens, an $f/2.0$ relay type system, 16,000 lumens, and an $f/1.6$ relay type system, 25,000 lumens.

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* NOTE: The Weston Meter, Model 603, is recognized as Standard in Hollywood. Meters which do not have proper care and protection from rough handling may require calibration oftener than twice per year.

REPORT ON RECENT ACTIVITIES OF THE RESEARCH COUNCIL

COMMITTEE ON

STANDARDIZATION OF THEATER SOUND PROJECTION EQUIPMENT CHARACTERISTICS*

JOHN K. HILLIARD**

Summary.—*The early history of the standardization of electrical characteristics and the preparation of the first version of the Research Council Theater Sound Test Reel is detailed. Performance specifications and methods for using the various types of Standard Multi-Frequency Test Reels, Warble Frequency Reels, Buzz Track, Scanning Illumination Test Track, Standard 7000 and Standard 9000-Cycle Film, and Balancing Films are enumerated.*

Current activities of the Committee on Standardization of Theater Sound Projection Equipment Characteristics, including current investigations toward specifying a Standard Electrical Characteristic for the Simplex 4-Star Sound Systems, are outlined. General recommendations for adjustment of theater sound equipment, in the light of the Committee's experience, are recounted, and in conclusion, the coöperation of the theater service and equipment groups in commenting upon the Committee's Theater Standardization activities and submitting suggestions for further consideration is requested.

Many members of the Society of Motion Picture Engineers are familiar in general with the theater standardization work of the Academy Research Council, from direct contacts with the Council and the Committee and from previous reports and publications detailing our activities, so this paper will cover only very briefly the phases of our program which are already well known, and concentrate more upon those activities upon which there has been little or no previous publication.

A great deal of our effort during the past year has been devoted to the preparation of various types of test films for use in the field, so a

* Presented at the 1939 Spring Meeting at Hollywood, Calif.; received April 24, 1939.

** Chairman.

brief outline of some of the difficulties encountered and the problems which had to be solved before we were able even to approach our ultimate aims along these lines will undoubtedly be of interest.

When this Committee was set up by the Research Council early in 1937, our first step was to recommend Standard Electrical Characteristics for the common types of theater reproducing equipment, in order that the studios would be able to record for the best possible reproduction on these standard systems.

The Standard Electrical Characteristics were arrived at by visiting various representative theaters in the local district, and conducting a great number of listening tests at various settings of the electrical characteristic in each theater. Immediately at the start of this work a need was recognized for a test reel containing representative sound recordings from all the studios. Such a reel was made up and through its use the Committee was able to correlate the listening tests conducted in the various theaters.

This test reel was so useful to the Committee that it was later decided to make prints available to those in the field who might have need for such a reel—that is, equipment manufacturers, servicing organizations, theater circuits, *etc.* During the past year or so a great many prints of the reel, known as the Research Council Theater Sound Test Reel, have been distributed throughout the United States, and prints have been sent to Canada, Holland, Belgium, Italy, Germany, Sweden, France, England, Australia, Switzerland, Czechoslovakia, Brazil, and South Africa.

However, for purposes of checking theater reproducing equipment in the field, the reel was considered to be somewhat too long, so the Committee has recently made up a new Theater Sound Test Reel. Because of its shorter length, approximately 1000 feet, this reel should be of considerably more value for every-day theater service use.

Containing representative examples of recording from current product from each of the eight studios participating in the Research Council coöperative technical program, this test reel furnishes a quick and immediate check of the overall sound quality of an auditorium with the type of product played regularly in the theater.

The reel contains both sound and picture, with dialog and music recording so chosen that the assembled reel contains a representative example of sound as currently recorded by each studio. One of these recordings is a "Hi-Range" print which serves as a check on the amplifier capacity in relation to the volume of the auditorium which is under consideration.

The reel contains also an excerpt of piano and other musical instrument recording, included for the purpose of furnishing a more critical flutter test.

For setting theater sound reproducing equipment to the Standard Electrical Characteristic, the Theater Sound Test Reel furnishes a tool by which an optimum setting for presence and intelligibility, combined with a natural balance between the high and low frequencies, may be obtained for all current product.

The use of this reel demonstrates the inadvisability of having too much low-frequency electrical response which brings out noise reduction bumps, footsteps, and parisitic low-frequency noises present on the set.

We might point out that judgment is required in the use of the Theater Sound Test Reel as the product must be evaluated in terms of the material at hand, that is, crowd noises and people talking in a loud voice or excited manner should not be expected to have the same quality and chest tones which are present in conversational dialog in a quiet, intimate scene.

The Council and the Committee have always felt that electrical and acoustical curves furnish valuable means of setting equipment, but that the final criteria should be a listening test of the equipment. For this reason all our Standards to date have been set up on the basis of listening tests correlated with engineering data.

One of the purposes of the Standard Electrical Characteristic is to provide a basis for an eventual standard recording characteristic. We believe that the new Theater Sound Test Reel demonstrates the fact that the recording characteristics of the various studios are very much closer together than they were a year or two ago.

The material contained in the reel is not a sample of the best recording available, but is typical of the average.

The Committe also realizes that it is necessary to keep the samples of recording from the various studios in the reel up-to-date and for this reason a procedure has been set up whereby individual studios will, from time to time, submit new samples for inclusion in the Theater Sound Test Reel of approximately the same length as the sample already included in the reel. All users of the Theater Sound Test Reels will be notified of these substitute samples as they are available, and will be given the opportunity of purchasing individual new samples to be spliced into their print. By rotating and spacing this "substitution of samples" procedure, prints of the reel will be kept up-to-date at a minimum of cost to the users, and the new samples will replace deteriorated prints. This will thus furnish an inexpensive means of replacing the reel as well as keeping it representative of up-to-date recording.

In the Committee's work in setting up the Standard Electrical Characteristics, the need for a good standard multi-frequency reel was very evident as this type of reel provides the only tool to evaluate the listening tests in terms of electrical characteristics.

Previously, two general types of frequency reels had been in use. One of these was a toe-recorded negative in which the printing process had been eliminated to obtain steadiness of level in each frequency, a good frequency response, and freedom from printer trouble. This method proved quite satisfactory from a technical standpoint, but the negative was costly to make and its life in the field was short in comparison to the life of a print.

The other was prints of either variable-density or variable-area recording. Prints of frequency reels were subject to several sources of variation, some of which follow:

(*1*) Weave trouble in recording and reproducing.

(*2*) Bad flutter content at both high and low frequencies.

(*3*) Variation in printer slippage, which causes non-uniform, high-frequency response.

(*4*) Non-uniformity of emulsion during drying process and manufacture, causing periodic changes in density and gamma, which in turn create a variation in output of as much as 1 db.

In considering this matter, the Committee found (in the opinion of users of this type reel) that some of the available reels contained too few frequencies, while others contained too many frequencies. In the one case the number of points would be insufficient to determine electrical characteristics properly, and in the other case would consume too much of the serviceman's time for every-day use.

After a consideration of the critical points in the electrical characteristics and the necessity for particular frequencies, it was decided to make available two specifically different frequency reels.

The first, termed the Secondary Standard Multi-Frequency Test Reel, for the purpose of the routine checking of theater characteristics, contains the following frequencies:

1000	500	4000
40	1000	5000
70	2000	6000
100	2500	7000
300	3000	8000
	3500	

The second, called a Primary Standard Multi-Frequency Test Reel, is intended for use in installation of new equipment or for the complete check of an electrical characteristic by equipment manufacturers, servicing organizations, or studios. The Primary Standard Reel should also be used for those particular cases when more points on the curve are to be investigated than might be necessary in a routine check. The following frequencies are included in the Primary Standard Reel:

1000	400	4000
40	500	5000
55	700	6000
70	1000	7000
100	1500	8000
150	2000	9000
200	2500	10000
300	3000	1000

Announcements are included before each frequency in both the Primary and Secondary Standard Reels to facilitate use of the reels.

To overcome the difficulties with the then current frequency reels—that is, the fact that in some cases negatives were used, which were expensive and had a short life, or, in the case of prints, it was found that many prints did not agree when subjected to field tests—the Committee laid out the following specifications for a Standard Multi-Frequency Reel for field use:

First, the reel must be accurate, that is, the level response within each frequency must be held to within $^1/_4$ db up to 9000 cycles.

Second, the print must be reproducible, that is, a method of individual calibration must be set up so that prints from the same as well as different negatives will give the same electrical characteristics on the same equipment within at least 1 db, and

Third, the reel should be relatively inexpensive in comparison with the reels then in existence and prints should be provided in order to give a longer life and consequently reduced cost.

With a method of individual calibration and as long as the variation within any one frequency in one reel is a maximum of $^1/_4$ db, the variation of the electrical film level or of the correction factors from one reel to another is of relative unimportance.

In order to achieve widespread use, it was recognized that the cost of the reels should be kept as low as possible consistent with quality and the previously determined tolerances, and could be controlled by limiting the number of frequencies, the length of each frequency, and

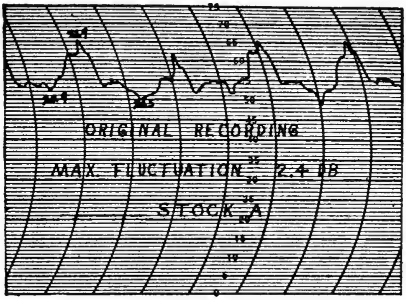

FIG. 1. Variation in output from a print of an original negative of the conventional type.

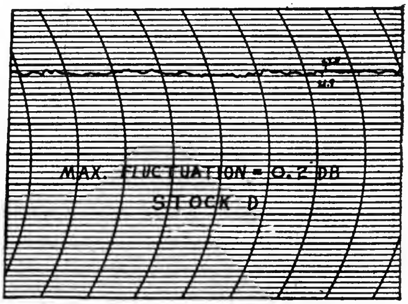

FIG. 2. Variation in output from a print from continuously dried stock.

by comparatively large quantity production of prints calibrated by a relatively simple, yet accurate, method.

In the preparation of the variable-density reel the first problem encountered was the non-uniformity of the emulsion resulting from the use of the conventional drying process. This non-uniformity appeared as a periodic fluctuation in gamma along the length of the film, which in turn created a variation in output by as much as 1 db from prints off the original negative. Figs. 1 and 2 are taken from graphs obtained from a continuous level recorder which clearly show the fluctuation present in a stock dried in the then conventional way, as well as the constant output from the continuously dried stock.

Fig. 1 shows the variation in output from a print of an original negative of the conventional type. The fluctuations of 2.4 db are somewhat above average, but the periodic variation in output is clearly indicated. The time scale, that is, the scale in the horizontal direction, is approximately 5.4 feet of film for each division on the graph.

The horizontal scale is a log scale and the lowest output point is 20.5 db and the highest output level is 22.9 db. The regularity of the fluctuation should be noted.

Fig. 2 illustrates the exceptionally constant output of a print from the new continuously dried stock. It will be noted that there are no periodic fluctuations and that the average level is maintained within a range of 0.2 of a db.

It might be pointed out that when the usual re-recording methods are employed, the fluctuation (as shown in Fig. 1) in the conventional type stock may amount to as much as 3.5 or 4 db when the fluctuation in the original and the re-recorded negatives fall in phase.

By using this type stock for all frequency reels, periodic fluctuations in the print arising from stick marks in the film drying process have been eliminated.

The next question was the method of calibration. After the frequency reel negative had been made several prints were struck off and run on the continuous level recorder. As each print was run the continuous level recorder tape, as well as a volume indicator meter, was carefully watched for variations in output level in each frequency. From this group of prints the one with the best level response was selected as a calibrating print. This print was then projected on the screen and inspected for scratches, oil, dirt, or any irregularity of the track which might affect the output. If no such irregularities were indicated, this particular print was then calibrated on a recording microdensitometer.

This instrument has as its function the production of a continuous detailed record of the transmission (where density = log 1/transmission) of the sound-track. That is, the transmission of each small section of track is measured and automatically recorded on film. (Transmission of the film is defined as the ratio of the light transmitted by the film to the light incident upon the film.) Means are provided for slowly scanning the film at a constant velocity so that a continuous record is produced.

Light from a very steady source is focused upon the sound-track in a fine line by an optical slit system. The transmitted light is collected by a photoelectric cell and the resulting current is amplified and measured. Because of the difficulties involved in the amplification of direct current, a 400-cycle chopper is introduced into the optical system so that the light is interrupted at a frequency much greater than any to be encountered in density variations of the film, traveling at the scanning speed used in the instrument. This carrier is amplified, rectified, and the resulting direct current, which is proportional to the transmission of the sample, actuates an oscillograph.

Since the output is controlled by the transmission of the sound-track under study, and since the recording speed is much greater than the analyzer speed, the record is a much elongated and amplified variable area record of the original track. Sufficient energy is available to give a deflection of 1 inch, making possible the measurement of small modulations as well as small changes in density.

Inasmuch as a $^1/_4$-mil slit is employed, there is no appreciable slit correction needed up to 10,000 cycles, and since only 400 cycles are passed by the amplifier the system needs no frequency correction.

Approximately 20 to 30 per cent of each frequency on the calibrating print is run through the microdensitometer, portions being chosen which the volume indicator shows to be the most constant level, and the average of the modulation on the microdensitometer record is used as a basis for calculating the electrical film level of that frequency.

Inasmuch as the microdensitometer sees very small changes in the output of the film, it is necessary to take a great number of measurements in order to arrive at a good average.

Another method which we have successfully used is to wind the film rapidly over the scale, thus averaging the modulation on the microdensitometer record.

The film can then be rated on an absolute basis without regard to a reproducing system. The level of a film modulated 100 per cent and having a peak transmission of 100 per cent is used as a reference level; that is, $\Delta T'$, its change in transmission, is 100 per cent.

The densitometric level is then equal to

$$20 \log \frac{K \Delta T}{K \Delta T'} = -40 + 20 \log \Delta T$$

where ΔT is the change in transmission over a cycle in the test track.

In order to use this film to determine the gain in reproducing systems in terms of this film, an electrical film level is supplied with each print. This level is obtained by the same method used to determine the electrical film level of the ERPI *ED-20* test film. For this reason, a cross calibration between any *ED-20* film and our Standard Multi-Frequency Test Reels can be easily obtained by noting the difference in levels.

This electrical film level is expressed in terms of the level produced by this film with respect to 6 milliwatts at the output of some standard photocell pick-up system. In the case of the *ED-20* reel this system was an average *3A* cell and 10 megohms' internal impedance working into a 10-megohm load. The illumination is supplied by an average $8^1/_2$-volt, 4-ampere exciter lamp operated at 3.7 volts through a lens system having an optical transmission equal to the ERPI *KS-6470* lens tube assembly corrected for zero slit width.

Such a set-up described above experimentally yields a level of 37.8 db less than the densitometric level obtained from the formula given above. Hence the electrical film level in db is equal to $-40 + 20 \log \Delta T - 37.8 = -77.8 + 20 \log \Delta T$.

All frequencies are rated in terms of the 1000-cycle level and the "deviation from 1000-cycle level" for each of the other frequencies, with the signs of all values reversed, are given as correction factors for testing. Corrections are used rather than deviations in output level so as to conform with field use where direct addition is used in making out field test reports.

For example, if a test film has an output level of 3 db lower at 8000 cycles than at 1000, it is necessary to add 3 db to the output level to compensate for this loss. The correction factor for 8000 under this condition would then be given as +3 db and the sign of the correction factor is therefore reversed in sign from the true characteristic of the film.

After the microdensitometer or electrical film level of this calibrating print has been established, individual prints are calibrated by comparing each print with this calibrating print on a sound reproducing system. We have been employing a conventional theater sound-head with a particularly steady film movement used in conjunction with an amplifier working into the continuous level recorder. This continuous level recorder gives a complete graphic record of the output of the film, and by comparing these graphs to the one secured from the calibrating print, the electrical film level at each frequency of the reel being calibrated is found, and from these values are found the correction factors.

In recording these frequency reel negatives, several practical problems were encountered. The variable-area negatives are recorded at 50 per cent modulation throughout the frequency range, while in the case of the density negatives the rise of the valve is allowed to compensate for the film loss up to within about 1 db of overload. Practically, this means that the modulation increases from 50 per cent at 1000 cycles to about 90 per cent at 6000 cycles. From this point on the modulation is controlled so that no overload is present.

In order that there should be no splices, and consequently no flutter or printer troubles such as would be contributed by splices, the negatives for all our multi-frequency reels are made in one piece. Thus, in recording it is necessary at each frequency in the reel to make an announcement, change the frequency, adjust the level, and throw the keys from the microphone to the oscillator in less than three seconds.

After the negatives had been made, the next problem was that of printing. Tests on several types of printers were made for variation in level, flutter, and frequency response. It was found in general that a printer giving the best test on one of these factors did not necessarily give the best test on the others, and for this reason a printer giving the best level response with a minimum of flutter was chosen.

Test prints made on the non-slip printer indicated that the level response was considerably improved on the first and last frequencies on the reel by using long head and tail leaders.

It was found also that a slightly increased pressure between the print and negative appreciably improved the level response. It is possible to do this when printing sound-track only, and at the present time all our prints are made in this manner.

In calibrating the prints, the reproducing equipment must necessarily be carefully checked for overload, scanning, focusing, hum, and voltage regulation, and in addition, each print must be checked for track placement.

After the above problems had been solved, a Variable-Area and Variable-Density Secondary Standard print was sent to each studio participating in the Research Council program. These prints were carefully checked in each studio and compared to test reels already in use, and it was found that these Research Council Standard Multi-

Frequency Reels agreed, in general, with those already in use and that most deviations which were present could be traced to deficiencies in the other reels.

Figs. 3, 4, and 5 show the level response of our variable-density and variable-area calibrating reels. Fig. 3 shows the response of the first 1000-cycle tone on these reels from which it should be noted that the variation is a *maximum* of less than 0.2 db.

Fig. 4 shows the level response of several frequencies of a variable-area reel and it should again be noted that the variation is very

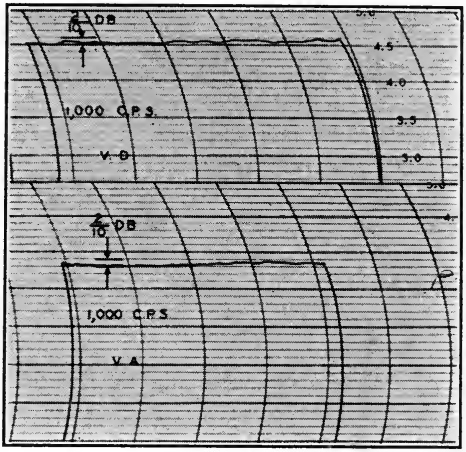

FIG. 3. Variation in level of the first 1000-cycle frequency of the Academy Research Council Variable-Area and Variable-Density Multi-Frequency Test Reels.

small. However, the gain at these high frequencies has been increased and the frequency response of the reel is not of this order. This particular figure has been prepared in this way for the purpose of showing the level response at these high frequencies at a point on the graph where the scale is large.

Fig. 5 illustrates the level response on the density calibrating reel, with the particular frequencies illustrated shown on the graph. The vertical scale shows the amount of the variation in level response.

Fig. 6 shows the Electrical Characteristic of our test reel calibrating reproducing system. The full line is the characteristic as given by the Primary Variable-Area Multi-Frequency Test Reel Calibrating Print and the broken line is the characteristic as given by the Primary Variable-Density Multi-Frequency Calibrating Print.

It should be pointed out that the vertical scale giving the relative response of the system is somewhat exaggerated. Normally the division given here as 2 db is 5 db. However, this scale has been used to illustrate the small difference in response on the same system of our two Primary Calibrating Prints.

The maximum deviation between the 2 prints appears between 150 and 300 cycles and is a maximum of 0.6 db at this point.

Our experience in checking all types of different test reels indicates that this agreement is well within present practice in the measurement of electrical characteristics of reproducing equipment.

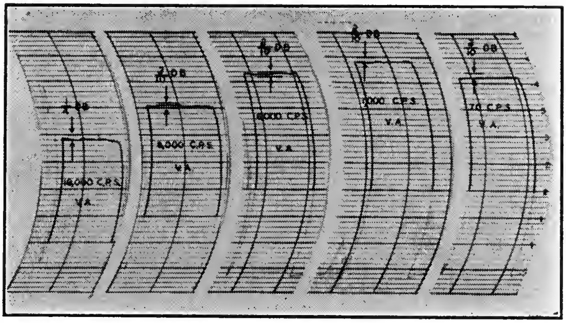

FIG. 4. Variation in output of a few frequencies of the Standard Variable-Area Multi-Frequency Test Reel.

For the purpose of determining the acoustic response of the horn systems and of the auditorium we have made up Standard Warble-Tone Test Reels. As in the Multi-Frequency Test Reels, Primary and Secondary Standard prints are available, in both variable-area and variable-density, each containing approximately the same frequencies as are included in the multi-frequency reels.

Each frequency in the Warble-Tone Test Reels has a warble of ±5 per cent on all frequencies, this degree of warble having been chosen so that standing waves will be minimized in the auditorium.

Through the use of a microphone in conjunction with an amplifier system and a sound level meter, the acoustic response of the sound system and auditorium at the various frequencies can be determined. Under normal conditions at least five different microphone positions in the auditorium are used, and the readings are averaged to give the acoustic curve for the auditorium.

To determine the acoustic response of the speakers, the conventional method of measurement involves the averaging of five or more readings made with the microphone close to the speakers. However, in making these measurements care must be taken to select microphone positions which will not favor the response of either the high or the low-frequency units.

These warble-tone prints are calibrated exactly as are the multifrequency test reels; that is, against the same calibrating reel and on the same equipment set-up.

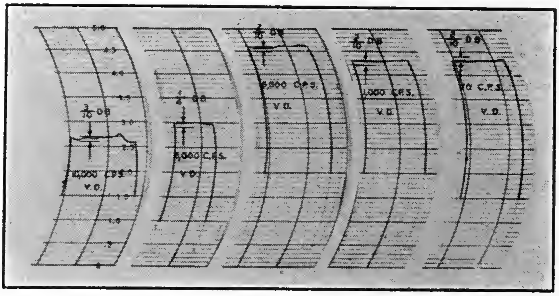

FIG. 5. Variation in output of a few frequencies of the Standard Variable-Density Multi-Frequency Test Reel.

To check the lateral alignment of the scanning slit we have a Standard Buzz Track (Fig. 7). The opaque track is 86 mils wide. On the picture side of the track there is a 300-cycle tone and on the sprocket side a 1000-cycle tone. These tracks are so spaced that if the scanning slit is properly placed and of the correct dimension, no tone will be heard from the reproducer, but if the scanning slit is improperly placed toward the picture side the 300-cycle tone will be heard, and if misplaced toward the sprocket side the 1000-cycle tone will be heard.

A loop prepared from this track is run in the equipment and the scanning slit laterally adjusted until no tone is heard. In making up these prints we hold the track placement to within ±2 mils of the correct position. This track thus provides a means of adjustment of the position of the scanning slit to the current positioning tolerances.

After the scanning slit has been checked for proper dimension and placement, it is, of course, necessary to check the uniformity of illumination across the scanning slit, and for this purpose we have made available a Standard Scanning Illumination Test Track, which contains seventeen 1000-cycle tracks, approximately equally spaced, each with an amplitude of 6.8 mils ± 1.6 per cent (Fig. 8).

If the illumination on each track is constant, the output as measured with a volume indicator meter will be constant, but if the illumination varies the amount of this variation may be read directly on the VI meter measuring the output.

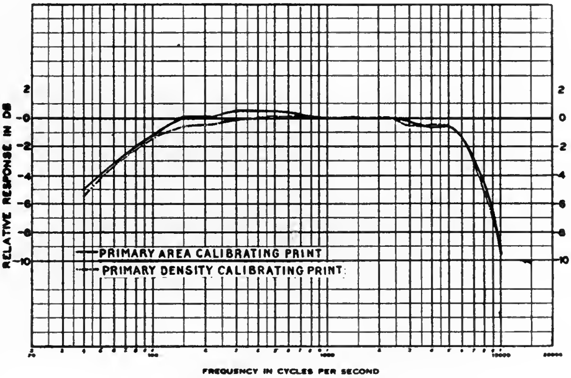

FIG. 6. Electrical characteristic of test reel calibrating reproducing system from primary variable-area and primary variable-density calibrating prints, showing agreement between prints.

Of the seventeen different tracks, the outside two and the inside two fall outside a correctly positioned 84-mil slit. Therefore, with correct scanning illumination only tracks 3 to 15, inclusive, will be reproduced at full output. The maximum allowable variation in output level is 3 db, that is, a tolerance of ±1.5 db.

After this track has been run and the readings plotted against the track position, the graph so secured indicates any necessity for correcting non-uniformity of the illumination. This correction should be by adjusting the exciter lamp rather than by changing the lateral adjustment of the slit.

For the adjustment of rear scanning sound-heads, that is, the ERPI *TA7400*, we have what is termed a rear scanning adjustment track, which consists of an opaque 84-mil sound-track whose center is ±2 mils from the nominal center line of 243 mils from the guided edge of the film.

Our Standard 7000-Cycle Film contains a 7000-cycle variable-density recording at 2 db below 100 per cent modulation, in which the film response level varies less than ±$^1/_4$ db. This film is available to be used as a test film to adjust the focus and azimuth of reproducer optical systems.

The Committee recommends the use of 7000 rather than an 8000- or 9000-cycle track because of the fact that in most theater reproducing systems the low-pass filter greatly attenuates these higher frequencies. When using either 8000- or 9000-cycle tones for adjustment it is usually necessary to remove the low-pass filter. However, at the request of a number of groups in the field who have been

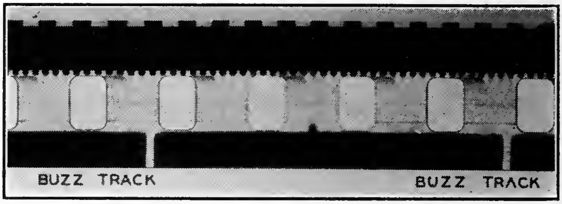

FIG. 7. Section of Academy Research Council Standard Buzz Track.

coöperating in the work of the Committee, Standard 9000-cycle film with a response level varying less than ±$^1/_4$ db is also available for special purposes.

These various test reels have been made available as a result of tours of investigation covering the entire country made by different members of the Committee during the past year. Visits to hundreds of theaters indicate in most cases a lack of sufficient test film for the projectionists and servicemen to provide even routine adjustment of equipment. For this reason, the Committee and the Council believe that in making these test reels available at a minimum cost through one centralized distributing agency, we are performing a service to the entire industry.

All these reels are available through the Research Council upon a cost price basis which, in most cases, includes no negative or recording time costs, as these items have been furnished by one or another of the studios at no cost to the Committee or the Council.

These tours of investigation by individual members of the Committee mentioned above also brought forcibly to our attention the fact that many theaters had no means of balancing their projection machines for output level. For this reason, it was decided to make available to theaters an easily used Balancing Film at a reasonable cost and with sufficient instructional information to enable the projectionist to check the volume level balance between machines as part of his daily routine. Hundreds of these loops have been

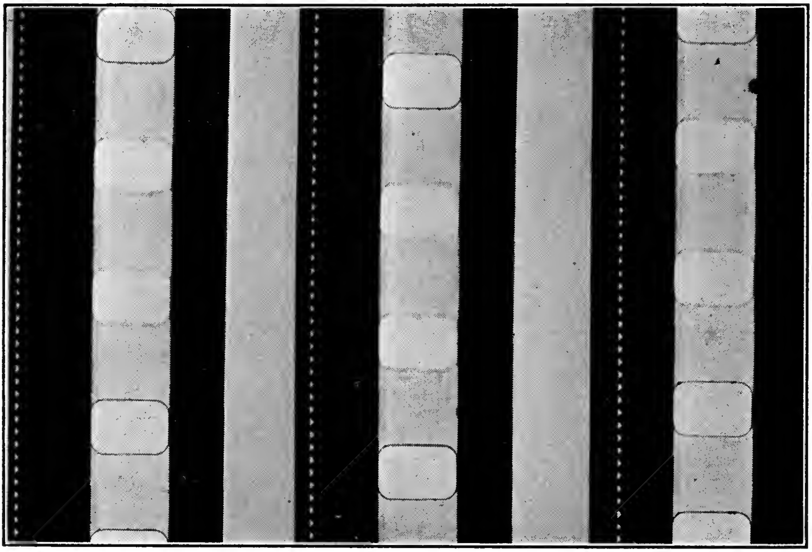

FIG. 8. Sections of three of the seventeen differently positioned 1000-cycle increment tracks of the Academy Research Council Standard Scanning Track.

distributed to the field and we believe their use represents a great step forward in the standardization of theater sound projection.

Data assembled by the Committee on the various types of equipment commonly installed in the theater indicated that the longest loop necessary in any equipment would be slightly shorter than 7 feet. The Balancing Films were therefore made up to consist of sufficient film for two such loops. An instruction folder sent with each set of Balancing Films shows the proper method of threading the loops into each of the common types of reproducing equipment, and outlines the proper method of checking the volume level balance between the two machines.

Figs. 9, 10, and 11 illustrate the method of threading Balancing Films into various common types and makes of equipment.

After the loops have been properly threaded, the machines are started and the volume output is compared by means of a meter or

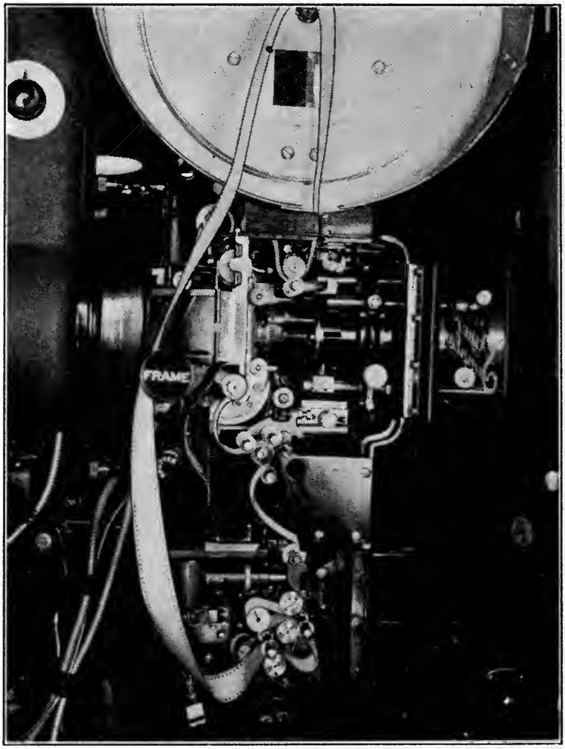

FIG. 9. Method of threading applying to all types and makes of equipment other than the exceptions illustrated in Figs. 10 and 11. Loop length, 81 inches.

by ear. The machines are then balanced for equal loudness at identical fader settings by adjustments normally provided in the equipment.

In addition to the preparation of the test reels outlined above, the Committee has been active on a number of other projects. Listening tests have been conducted at several theaters recently equipped with the Simplex 4-Star System, and we intend in the very near future to issue a supplement to our Bulletin on the Standard Electrical Characteristics to specify characteristics for the Simplex Systems similar to those previously specified for the various ERPI and RCA equipments.

Recent investigations indicate that only approximately 25 per cent of the existing two-way installations have been set on the Standard Electrical Characteristic. We believe several reasons for this situation exist. Acoustically defective auditoriums are in most cases not given the proper acoustic corrections, and an attempt is

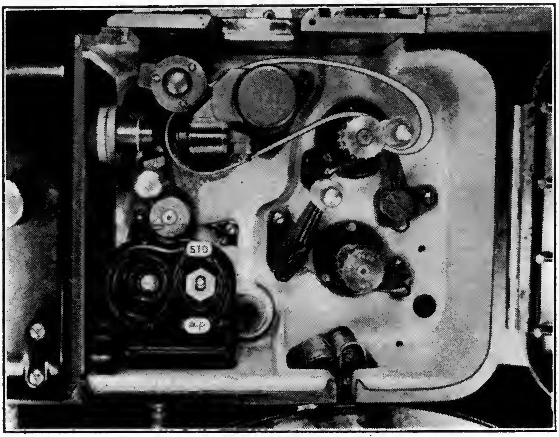

FIG. 10. Method of threading applying to RCA *PS-24* and other later similar type sound heads, used in conjunction with any make of picture head. Loop length, $15^1/_4$ inches.

made to compensate for the defective acoustic condition by electrical adjustments intended to make up for these deficiencies. Under such conditions it is, at best, difficult to compensate electrically for acoustic deficiencies. A great deal of time and effort must be spent to obtain a satisfactory electrical characteristic for such a theater, and in general it is not possible to put forth such effort. The result is that even if the house is set so that the sound is passable, not all concerned with the theater are satisfied with it, and further efforts are made to compensate for the acoustic deficiencies by a continual juggling of the electrical characteristic. We believe that far more satisfactory results would be obtained, and in the end less time and money would be expended, if acoustic defects were originally remedied by acoustic treatment of the auditorium.

We have had some comment from the field regarding volume variation between different reels in the same release print or between different sequences within the same reel, requiring fader changes in the theater during the show. Some of these comments have been referred to the Council's Sound Recording Committee, under the Chairmanship of E. H. Hansen of 20th Century-Fox Studio. Tests conducted by this Committee indicate that recordings balanced for

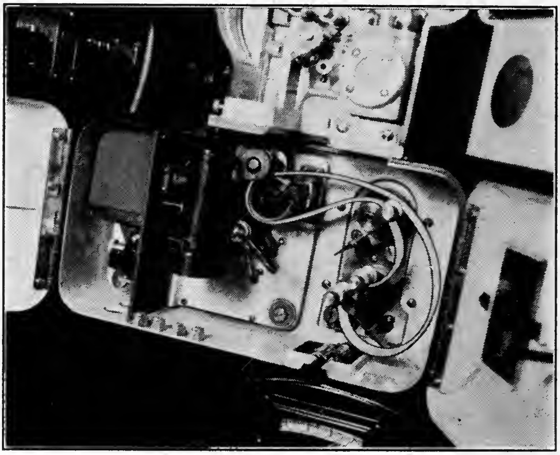

FIG. 11. Method of threading applying to Simplex 4-Star sound heads, used in conjunction with any type of picture head. Loop length, 26 inches.

reproduction on an equipment set to the Standard Electrical Characteristic will invariably require fader changes when played in a theater adjusted to a non-standard electrical characteristic. Consequently we believe that a great deal of the volume variation encountered in the field is a result of reproduction of product originally recorded for the Standard Characteristic, but which is played upon equipment set to a non-standard characteristic.

Listening tests have been conducted in a sufficient number of acoustically average auditoriums to convince the Committee firmly that present-day recordings are sufficiently alike to reproduce satisfactorily on an equipment set to the Standard Electrical Characteristic.

However, the adoption of the Standard Electrical Characteristics has not been as widespread as would be expected, possibly through a lack of appreciation of the intent behind the Committee's work—that is, our aim in setting up a Standard Reproducing Characteristic so that the studios might in turn set up a standard recording characteristic.

While there have been no radical changes in recording or reproducing in the last year, there has been gradual improvement in both branches of the field. We believe that during the last year the idea as to what constitutes good sound may have changed within the industry. A theater considered to have good sound a year ago *may* not be so considered at the present time. As a consequence, it is possible that more recent installations have been set to the Standard Electrical Characteristic and that a 25 per cent estimate may be low.

We also realize that we in Hollywood may not always fully understand the problems of the manufacturers and service groups as encountered in the field. We have recently sent a letter to the sound supervisors of several hundred theater circuits explaining that our recommended Standards have not received as widespread use as was hoped; that in some cases they have been modified and in some cases they have been completely disregarded, and that the Committee and the Council would be very much interested in knowing the reason for this condition. Experience of the men in the field has undoubtedly given them many valuable ideas on theater reproduction, and we would appreciate receiving comments or suggestions on the Committee's work as well as on the use of our Standards to date.

We also realize that we in Hollywood are not without fault, so we have asked at the same time for criticisms from the field on current studio recording. To mix metaphors for the moment, we are not throwing rocks at glass reproducing systems, and we are attempting to clean up our own back yard at the same time. Our entire aim, in fact, is devoted to improve the overall and reproduced quality of sound motion pictures.

Accomplishments achieved so far have been the result of the coöperation of a large group representing all the various interests in the industry. If each of these groups had had to work separately no one would have been able to accomplish alone even a small proportion of what has been accomplished to date. Needless to say, for our future efforts we are counting upon the continued interest and coöperation of all who have been participating in this work.

We welcome any comments or suggestions or criticisms at any time, and all will be given careful consideration by the Council and the Committee. Whether or not we have communicated directly, we would appreciate comment from anyone in the field who may have information concerning field conditions which would be of interest or assistance to us in our work.

APPENDIX

Prints of all the Test Reels described in the foregoing paper or information regarding prices, *etc.*, are available at the offices of the Research Council of the Academy of Motion Picture Arts and Sciences.*

Code numbers have been devised for each type of reel, as indicated, for convenience in designating the particular type desired. Prices are based upon cost and are f. o. b. Hollywood, Calif.

Reel	Code No.
Theater Sound Test Reel	*ASTR-2*
Primary Standard, Multi-Frequency Variable-Area	*APFA-1*
Primary Standard, Multi-Frequency Variable-Density	*APFD-1*
Secondary Standard, Multi-Frequency Variable-Area	*ASFA-1*
Secondary Standard, Multi-Frequency Variable-Density	*ASFD-1*
Primary Standard, Warble Frequency Variable-Area	*APWA-1*
Primary Standard, Warble Frequency Variable-Density	*APWD-1*
Secondary Standard, Warble Frequency Variable-Area	*ASWA-1*
Secondary Standard, Warble Frequency Variable-Density	*ASWD-1*
Standard Buzz (Lateral Alignment) Track	*ABzT-1*
Standard Scanning Illumination Test Track	*A17P-1*
Standard 7000-Cycle Film	*A7KC-1*
Standard 9000-Cycle Film	*A9KC-1*
Rear Scanning Adjustment Track	*ARS-1*
Standard 1000-Cycle Balancing Film	*ABL-1*

Inasmuch as no extensive stock of Test Films is carried on hand, a period of from five to ten days should be allowed for preparation, calibration, *etc.*, of prints.

* 1217 Taft Building, Hollywood, Calif.

SOUND PICTURE RECORDING AND REPRODUCING CHARACTERISTICS*

D. P. LOYE AND K. F. MORGAN**

Summary.—*In the improvement of sound motion pictures, the trend has been to make the response of all parts of the recording and reproducing circuits as nearly "flat" as possible. In some cases, however, this has resulted in unnatural sound, and therefore certain empirical practices have been adopted in the studios and theaters to make pictures sound best.*

This paper describes the results of a study the purpose of which has been to evaluate the factors which effect the quality of speech as recorded and reproduced, from the vocal cords of the actor on the sound-stage to the brain of the listener in the theater. The characteristics of the various factors have been determined and combined with dialog, voice effort, and other equalizers designed to produce an overall characteristic "subjectively flat" at the brain of the theater patron. These factors, as well as others which are now in the process of being studied, are presented in this paper.

One of the most important characteristics studied is that of the change in voice quality with a change in the effort on the part of the speaker. This is described in detail in this paper. The stage and set acoustic characteristics, microphone characteristic, and dialog equalization to compensate principally for the hearing characteristic of the average theater listener, are among the factors described herein.

Sound pictures in the final analysis represent a form of mass entertainment, intended to produce a subjective result to please millions of persons, and thereby return box-office dollars. Dramatically a good sound picture usually runs the gamut of human emotions, and technically it strives to attain either such perfection or illusion that the theater patron is not conscious of limitations. In achieving the desired results, it is considered not only proper but also entirely ethical to resort to various dramatic and technological tricks to produce the intended subjective result. What theater goer, for instance, has fewer thrills out of seeing someone fall from a tall building when he learns that it was actually a photographic trick? Rather he admires the technicians' ingenuity, and if the picture is dramatically good, he gets just as big a thrill as if the fall had actually occurred and the photography had been real.

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

Sound has been steadily improving during the last ten years, but there are still definite limitations that make it necessary for the sound engineer to take liberties directed toward giving pleasure to the theater patron. In our every-day life, we are accustomed to binaural hearing with a wide frequency range, which with the aid of our two eyes, assists us in localizing a source of sound, as well as discriminating against extraneous noises. The sound picture is a one-eyed, one-eared medium with a somewhat restricted frequency and volume range. These restrictions are minimized in many ways by the sound engineer, and the result when well done is quite acceptable to the theater patron.

Before describing reasons for some of the practices established by sound engineers, it is desirable to consider the sound picture with reference to our real life experiences, and use the real life conditions as the standard for improving recording and reproduction. In our every-day existence, we do a great deal of talking under varying conditions of acoustics and noise. We unconsciously strive to express ourselves in such a way that the listener can intelligibly and comfortably understand what we are saying. This holds true for an average room, a boiler factory, or a funeral parlor. One may be virtually screaming in one case and whispering in another without any astonishment on the part of the listener, because it is what he expects; but try whispering in a boiler factory or screaming in a funeral parlor and see what happens. The sound engineer strives to deliver sound to the theater listener's brain in such a way as to produce the same results that would be experienced under real-life conditions. This is a high goal, the approach to which necessitates many additional improvements in sound recording and reproduction.

General.—When talking pictures were first produced, emphasis was placed upon recording acceptable dialog. The studios were not concerned primarily with obtaining high quality, emphasis being placed upon intelligibility. Even if high-quality recordings had been made, the theaters at that time were not capable of reproducing them faithfully. The time and energies of the studios were required for producing, as fast as possible, the new and novel sound pictures in order to satisfy theater demands in all localities.

As soon as the installation rush was over and the novelty began to wear off, the question was asked, "What can be done to make recorded sound more natural?" In recent years, the trend has been toward the improvement of the low and high-frequency response characteristics. The recording and reproducing frequency ranges have been widened, the effort being directed toward making the overall response characteristic as nearly "flat" as possible. However, it has not been found possible to record and reproduce the best dialog with systems having overall "flat" characteristics.

It was early recognized that voices became more natural when the low frequencies were attenuated either by microphones with suitable characteristics or with equalizers which provided this attenuation. They became known as dialog equalizers. The reasons for the need of them were not completely known, however. One of the reasons assigned, and one that is a partial explanation for the use of dialog equalization, was that stages were more reverberant at the low frequencies than at the high, and therefore these frequencies were accentuated in the recording. Another explanation, which also contains part of the truth, was that the microphones used for pick-up purposes were more directional at the high frequencies than at the low, and therefore the reverberation picked up was made still more prominent. As these reasons were recognized, corrective measures were taken which improved recordings but did not eliminate the use of certain equalizers. It has been necessary to continue to use dialog equalizers in recording, and to suppress the high frequencies in reproduction, and until recently the need for such equalization has not been explained adequately.

About two years ago, there was begun a fundamental study of the chain of events occurring in recording and reproduction, which contribute to best dialog quality in the theater. In making this study the generally accepted ideas that the recording and reproducing system should have an overall "flat" frequency characteristic were cast aside, and all the steps which go to make the final sound reproduction in the brain of the listener most natural and pleasing were investigated. In short, it was the purpose of the investigation to determine how sound can best be recorded and reproduced to make the overall response, including everything, most natural, or "subjectively flat." In other words, how can dialog be made most natural and pleasing to the brain of the theater patron? In this investigation, the important phases of sound production, recording, reproduction, and the physiology and psychology of hearing were considered.

An overall appreciation of the problems involved can be obtained by considering the aims of the producer of a motion picture, which of course are to please an audience both technically and dramatically. In general he attempts to make you observe a sequence of events as if you were present, or at a convenient place to view and hear these happenings. It is obvious that this is a difficult thing to accomplish. In the first place, for commercial reasons a large number of persons must be included as observers in large auditoriums. This means that instead of reproducing life-size figures on a screen, they must be made sufficiently large so that for a person viewing them from an average position in the audience, they will cover as nearly as possible the same visual angle of observation as they would if they were being viewed under real life conditions. If, for instance, a conference of bankers is being depicted as part of a motion picture, it very naturally might be desired by the producer to picture the conference in such a way as to give the effect that each member of the audience was seated in the conference room at a convenient position from which to observe the actions of the members and readily hear what they are saying. To do this for each member of an audience of one thousand persons means that each banker must be enlarged approximately ten times his natural size on the screen.

In addition to this visual enlargement, the bankers must speak more loudly than normal in order to fill the auditorium. They must speak loudly enough also to override ventilator, street, and audience noises existing in the theater. Also, the sound quality as reproduced must fit in with the listener's memory of real-life conditions such as are being depicted. The picture has an important bearing upon the illusions produced by the sound, and therefore studies of sound for motion pictures must necessarily be considered in combination with the picture.

In the case of the bankers' conference under consideration, street noises entering through windows and doors, and noises from ventilators, fans, typewriters, and other sources determine the speaking effort required to be readily understood. These conditions have an important bearing upon our memory of the real life conditions.

The conditions on the motion picture studio stage, where the recording is done, are generally different. On the stage, every precaution is taken to exclude and reduce all noises, both external and internal. The modern stage is so constructed that the normal airplane and traffic noise is not heard. Very quiet conditions prevail during takes, the only noises being those incidental to the action being depicted. Background noises usually are dubbed into the picture during re-recording and therefore are not present during the takes. Under these conditions, the actors unconsciously tend to lower their voices because of the fact that it is unnecessary for them to override extraneous noises. This is a natural tendency, as will be realized by anyone who recalls that in conversing when walking along a quiet residential street, it is natural to speak only loudly enough to be heard readily; and when walking along a busy street it is necessary to raise the voice appreciably in order to be heard. This is done automatically in order to avoid the necessity of repeating phrases.

The facts that actors generally speak more softly on the recording stage than is natural, and that a higher reproduced level is required

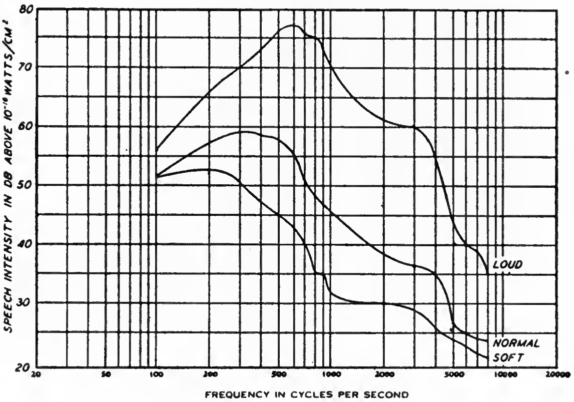

FIG. 1. Average voice characteristics, men and women.

in the theater than is produced by the speaker under real-life conditions, lead to two important effects, one in recording and one in reproducing, which will now be considered in detail.

Voice Effort Characteristics.—When a person speaks in a low, confidential tone, the low and high frequencies are relatively prominent as compared to the voice characteristic of normal or declamatory intensity. When the voice is raised to a normal conversational level, the low and high-frequency tones increase only slightly, but the intensity of the middle frequency tones increases to an appreciably greater extent. When the voice is raised to a declamatory level, the intensity increase of the low and high-frequency tones is relatively small, but again the increase of the middle frequency tones is relatively great. This is illustrated by the curves of voice quality for various degrees of speaking intensity shown on Fig. 1. These data, which are in general agreement with the fundamental measurements made by Sivian of the Bell Telephone Laboratories,[1] were obtained by measuring the voice qualities of men and women. The voice characteristics of the men and women have been plotted separately in the curves of Figs. 2 and 3, respectively.

This information was obtained by the use of the crystal band-frequency analyzer and sound-level meter developed by the Bell Telephone Laboratories.[2] The measurements were made by the use of a microphone connected to the sound-level meter and analyzer, the former being placed within 3 feet of the speaker. The phrase

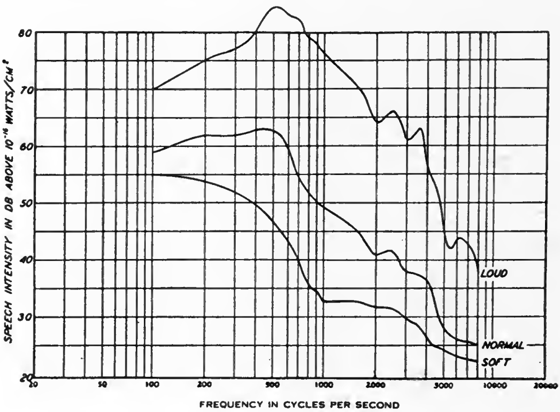

FIG. 2. Average male voice characteristics.

"Joe took father's shoe bench out" was repeated again and again during the time the measurements were being made. The 200-cycle band-filter of the analyzer was used, the measurements being made at 100-cycle intervals below 1000 cycles. Above 1000 cycles the measurements were made at 500-cycle intervals, which was sufficient for indicating the quality trend.

It was necessary during these measurements to make sure that the loudness of the speech did not change during the course of the measurements made at each intensity level. To accomplish this, a separate microphone connected to a separate sound meter was used, the latter being placed in such a position that the speaker could readily observe the deflections caused by his or her speech. The speaker was instructed to watch this meter and repeat the phrase in such a manner as to keep the deflections of the sound meter the same each time.

Fig. 1 contains the average results of measurements of men's and women's voices. From these curves, however, it is not readily possible to visualize the increase in the intensity of the tones in the middle frequencies, as compared to the low and high-frequency range when a greater amount of effort is put forth on the part of the speaker. In order to make the change in quality evident, the soft and loud speech intensity characteristics have been plotted relatively to the normal speech intensity. The characteristics plotted in this way are shown on Fig. 4.

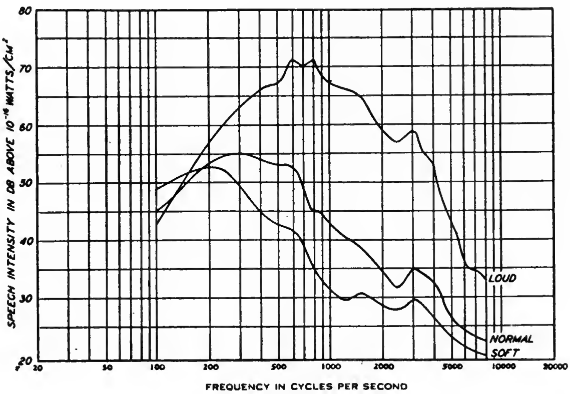

FIG. 3. Average feminine voice characteristics.

From these data the change in speech quality resulting from a reduction in the overall speech intensity of 5 db has been derived and plotted as shown by the curve on Fig. 5. This curve has been plotted relatively to the 1000-cycle value. It indicates the extent to which the low and high-frequency components are accentuated, compared to the 1000-cycle tone, when the voice intensity is lowered 5 db.

From a study of this information, it is evident that the effort exerted by the speaker has a very important bearing on the quality of his speech. It follows that if, during recording, an actor speaks in a lower tone of voice than is normal for the action being depicted, the quality will be unnatural. The low and high-frequency tones of his voice will be accentuated, and therefore, in order to make his voice natural as heard in the theater, it will be necessary to attenuate these frequency components. This accounts for a greater amount of dialog equalization than has been explained in the past.

Different amounts of effort equalization (included as part of the dialog equalization) are required by each studio. This is evident from the data obtained regarding their dialog equalization practices. The reasons for this are that in some studios the actors are permitted to speak in low tones of voice as they would naturally be inclined to do under quiet conditions, whereas in other studios they are requested to speak up. Whenever an actor is loaned by one of the former studios to one of the latter, for instance, he is likely to find

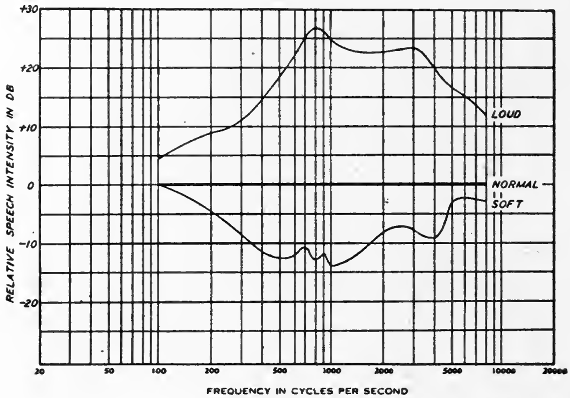

FIG. 4. Average voice characteristics relative to normal speech intensity.

that his habit of speaking in a low tone of voice does not fit in with the recording practices of the latter studio. He is requested, therefore, to speak more loudly. It is necessary to use appreciably more dialog equalization in the former studios, which is to be expected from the voice-quality curves described above.

As a guide for recording uses, the attenuation characteristics of voice-effort equalizers for various differences between sound intensity on the recording stage and under real-life conditions, have been plotted as shown in Fig. 6. These curves are derived from the fundamental measurements shown in Fig. 1. The small irregularities of the curves in this figure have been smoothed in order to provide for equalizer characteristics which it is readily possible to build. The family of equalizer curves has been plotted in 3-db steps, and any intermediate values desired can readily be interpolated.

From the data described in a later section of this article regarding the average theater intensity of soft, normal, and declamatory speech at the ear of the average listener, and from data relating these intensities to real-life values, it would be possible to determine the amount of effort equalization required for each recording by measuring the intensity of the actor's voice on the set during rehearsals. In making such a measurement, the microphone connected to the sound-level meter should be placed at the correct position for viewing the action in proper perspective. This is approximately at the place where a camera equipped with a 2-inch focal-length lens would be placed for photographing the action.

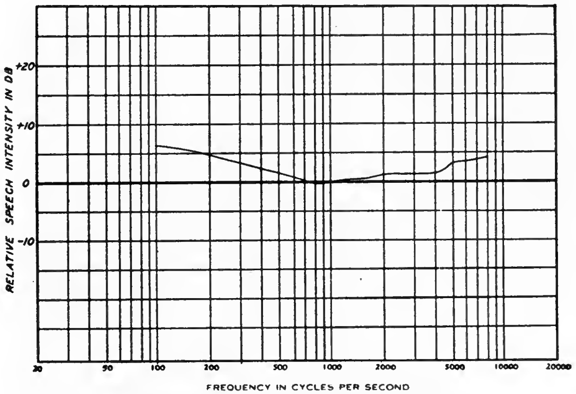

FIG. 5. Relative speech characteristic change produced by lowering voice 5 db, plotted relative to 1000-cycle value.

Hearing Characteristics.—In reproduction, the hearing characteristic of the average listener further accentuates the low frequencies, due to the reproduction of the speech in the theater at a greater intensity than normal, in order to override theater noises. This can be best understood by referring to the curves prepared under the direction of Fletcher of the Bell Telephone Laboratories.[3] These are shown on Fig. 7. They represent equal loudness contours over the hearing frequency range. Each of these contour curves represents the various sound intensities required to produce a constant loudness throughout the audible frequency range. For instance, in order to produce a loudness of 60 db of a 100-cycle tone, a sound-intensity of 72 db is required. Loudness is a measure of what the ear hears, whereas intensity is a physical quantity which may be measured by means of a microphone and sound meter. For a 1000-cycle tone, the loudness and the intensity required to produce that loudness have the same numerical value.

When the dialog intensity is 5 db higher in the theater than in real life, the low-frequency tones will be accentuated by the average ear. For instance, if the loudness of a 100-cycle tone under actual conditions is 60 db above reference level, the intensity required to produce it will be 72 db. If this intensity is increased 5 db, from

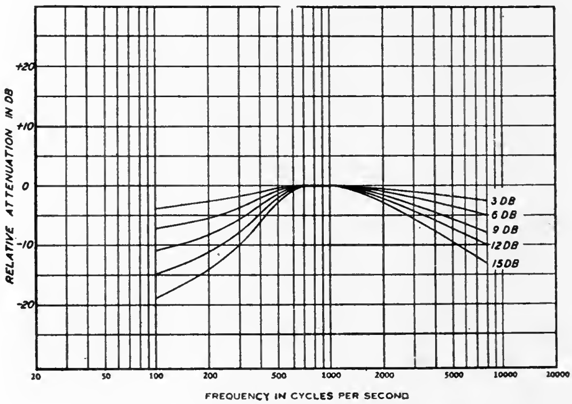

FIG. 6. Voice effort equalization.

72 to 77 db, in the theater in order to overcome noise as has been explained above, the loudness produced will be 69 db. In this case, therefore, the 5-db increase in sound intensity results in a loudness increase of 9 db, or in other words the loudness is accentuated 4 db by the non-linear hearing characteristic of the average ear. This, therefore, is another factor which determines the amount of dialog equalization required for satisfactory recordings.

Stage and Theater Dialog Intensities.—In 1932 a study was made to determine the difference in dialog intensity in the theater and on the recording stage. An automatic level recorder was used for recording the intensities of various takes of a United Artists' picture. The microphone connected to this recorder was placed at a position where a person would stand in order to view the action in proper perspective. To be more specific, it was placed at the position where a camera equipped with a 2-inch lens would be placed for photographing the action. If the camera were equipped with a 4-inch lens, the microphone would be placed half as far from the actor as the camera. If, on the other hand, the camera were equipped with a 1-inch lens, the microphone would be placed twice as far from the action as the camera. When the dailies were reproduced in the review room, corresponding automatic level recorder charts were made with the microphone at the average audience position. Still later, after the picture had been completed, automatic level recorder

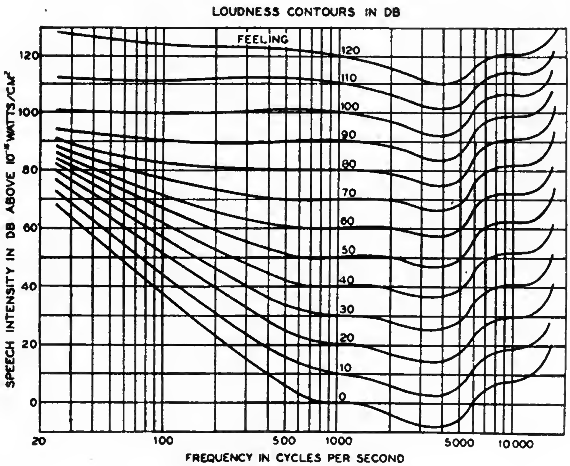

FIG. 7. Equal loudness hearing contours.

charts were made in the theater at the average audience position. The results of these measurements of *Kid from Spain*, starring Eddie Cantor, indicated that the average intensity difference between theater and recording stage was approximately 5 db. Mr. Cantor spoke loudly enough during recordings so that he could be heard readily by observers on the stage.

During March, 1937, similar measurements were made of Paramount test recordings. Actors were provided by the studio, and several takes were made. In order to illustrate to best advantage the effect of various amounts of voice effort equalization, the actors whispered, spoke in low tones, in medium tones, and declaimed. For these takes, the required amounts of dialog equalization were provided in accordance with calculations based on the data of Fig. 1. Prior to hearing the results, studio personnel expressed the opinion that recordings of whispering would be entirely unsatisfactory. They were, however, surprisingly good.

To check the differences in dialog loudness on the set and in the review room, a sound meter was used with the microphone attached to it placed at the correct position for viewing the action in proper perspective. When the takes were reproduced in the review room the next day, the sound meter was again used, the microphone being placed in a representative audience position. The average of all the takes shows that the reproduction level was 5 db higher than the speech intensity on the stage. Excluding the close-up scenes, however, the average was increased to 9 db. Inasmuch as the theater is generally noisier than the studio review room, the theater reproduction level would be somewhat higher and therefore the above differences would be greater.

About this same time, measurements were made of sound reproduction in three of the important Hollywood preview theaters. During an entire program in each of these theaters, the sound intensities were measured at a representative audience position. The results are shown in Table I, which indicates that, for confidential and close-up dialog, the average intimate and close-up intensity in these three theaters was 59 db, normal and medium shot 63 db, and declamatory and long shot 66 db. The average of all the dialog in these theaters was 63 db. The above figures have been taken as normal dialog intensities in the theater, but it would be desirable to obtain more complete data in a greater number of theaters throughout the country, for use as a basis for determining the voice effort and dialog equalizations which should be used in recording.

TABLE I

Theater Dialog Reproduction

	Pantages	Ritz	Fox Wilshire	Average
Intimate and close-up	59	64	55	59
Normal and medium shot	64	66	59	63
Declamatory and long shot	66	69	63	66
		Overall average		63

Note: The values in this table are decibels above 10^{-16} watts/cm.^{2} They were obtained with a sound meter having a 70-db ear-weighting characteristic.

SUMMARY OF RECORDING AND REPRODUCING CHARACTERISTICS

Recording Characteristics.—Two factors which have an important bearing on the overall quality of dialog, have been discussed in the preceding paragraphs. A summary of all the factors which should

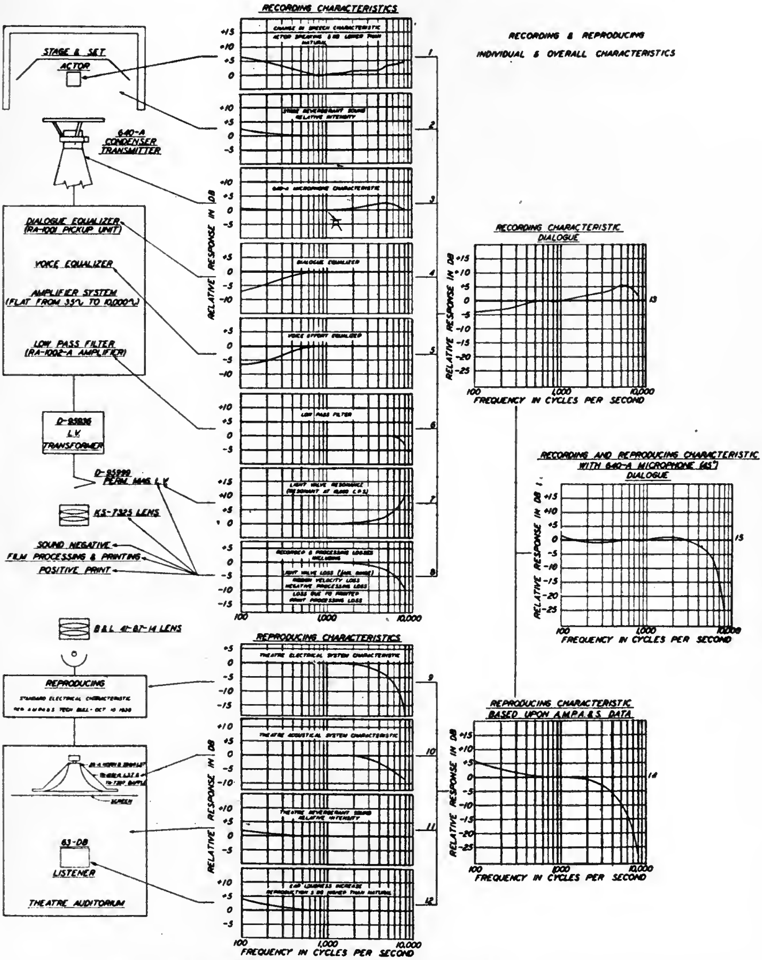

FIG. 8. Recording and reproducing individual and overall characteristics.

be considered as affecting dialog quality, from the vocal organs of the speaker to the brain of the listener, will now be described with reference to Fig. 8.

Curve *1* at the top of this figure represents the accentuation of the low and high frequencies of the voice due to the actor's speaking 5 db lower than is natural. It will be noted from this curve that the intensity of the 100-cycle tone is accentuated approximately 7 db, and the intensity of 8000 cycles approximately 5 db. Inasmuch as the reasons for this accentuation have been described in the preceding paragraphs, no further explanation is required here.

The next factor affecting recorded quality involves the recording stage and set. Due to the fact that the reverberation time of the average stage is longer at the low frequencies than at the high, the reverberant sound accentuates the low frequencies in a characteristic manner as shown by Curve *2*.

The characteristic of the microphone plays an important part in recorded quality. The response of a new microphone for sound recording purposes, the Western Electric miniature condenser (*640-A*) at an angle of 45 degrees is given as Curve *3*. This microphone, as the sketch indicates, contains a screen for making it essentially nondirectional. If it is used without the screen, the high frequencies are accentuated, the maximum response being at approximately 8000 cycles.

The dialog equalization characteristic, shown as Curve *4*, is required for attenuating the low frequencies primarily in order to compensate for their accentuation occurring at the ear of the listener when the dialog intensity in the theater is 5 db louder than normal, in order to override audience and other extraneous noises. Stage and set low-frequency reverberation is also compensated for by this equalization. This is a form of pre-equalization for an effect occurring in reproduction. It has been described in detail above, and therefore need not be discussed further here.

Curve *5* shows the characteristic of the voice-effort equalizer, required to overcome the low-frequency accentuation occurring below 1000 cycles, as illustrated by Curve *1*. The accentuation of the high frequencies is not corrected by the proposed voice-effort equalizer for practical reasons. This is done in reproduction and constitutes another step in pre-equalization.

The low-pass filter, Curve *6*, which begins to cut off at approximately 6000 cycles, is required in order to eliminate high-frequency noises which are objectionable as reproduced in the average theater.

The response characteristic of the light-valve used in recording, which is tuned to have a resonant frequency of 10,000 cycles, is shown on Curve *7*. The increased response of the high frequencies caused by the light-valve is adjusted to compensate for the recording and processing losses, shown in Curve *8*. The latter curve, as is indicated on the chart, includes the losses inherent in light-valve operation as well as the negative processing, printer, and print processing losses.

The eight individual recording characteristics which have been described in the preceding paragraphs, add together to make a recording characteristic as shown by Curve *13*. It is evident from an inspection of this curve, that the response is approximately 10 db greater at 5000 cycles than at 100 cycles. This effectively is pre-equalization which is valuable for overcoming noise.

Reproducing Characteristics.—The electrical characteristic of the theater reproducing system, which has been proposed by the Research Council of the Academy of Motion Picture Arts and Sciences, is shown as Curve *9*. It will be noted that the attenuation specified at 8000 cycles by the Committee of the Academy appointed to make theater reproduction sound best, is approximately 18 db. The Committee came to the conclusion that such a characteristic is desirable only after a long and careful study involving a series of tests in which representatives of the major studios of Hollywood participated. Their report[4] describes their findings in detail, and it is therefore beyond the scope of this paper to discuss them further.

The acoustical response of a typical high-quality two-way horn system, also described in the reports of the Academy of Motion Picture Arts and Sciences is shown in Curve *10*. It is evident from this and the preceding curve that the response of the overall electrical and horn system of the theater is down approximately 26 db at 8000 cycles.

The theater reverberation characteristic, shown in Curve *11*, accentuates the low frequencies in reproduction in a manner similar to that described with respect to Curve *2* in recording.

The ear of the listener and the approximately 5 db higher-than-normal sound intensity required in the theater to overcome audience and other extraneous noises, is responsible for the accentuation of the low frequencies as shown in Curve *12*. This and the stage reverberation effect of Curve *2*, which have been described above, are the principal ones which are compensated for by the dialog equalizer Curve *4*.

Adding these four curves (*9* to *12*, inclusive) together, results in Curve *14*, which represents the overall reproducing characteristic of a normal, good theater.

Overall Subjectively Flat Recording and Reproduction Characteristic.—The overall recording and reproducing characteristics (Curves *13* and *14*) combine to give Curve *15*. Inspection of this curve indicates that it is practically flat to 4000 cycles. It is "subjectively flat," inasmuch as it includes not only the acoustical, mechanical, and electrical elements of the recording and reproduction system, but also the voice quality of the actor and the ear of the listener. It is interesting to note that the rise in the overall recording characteristic is almost exactly compensated for by the droop in the reproduction characteristic. This provides effective pre- and post-equalization, which reduces the reproduction noise in the theater. It is interesting to note that the dialog equalization practices which have grown up in the studios, and which have been found necessary to make the recording and reproduction quality sound natural, are in accordance with the results of this preliminary study. These practices which have been determined empirically, have largely been explained above.

In the preceding paragraph, it was mentioned that this study was a preliminary one. Plans have been made for carrying it further. A survey is contemplated of music as well as dialog, recorded and reproduced both in the regular manner and stereophonically. This latter factor is a very important one requiring careful consideration. It is evident from the results that have been obtained so far, in the demonstrations conducted in 1933 by Fletcher and Stokowski in Philadelphia and Washington,[5] and again in 1936 in the Hollywood Bowl, that a marked improvement in quality and illusion will be obtained when speech and music are recorded and reproduced stereophonically. It appears also from a comparison of stereophonic and monaural tests recorded and reproduced both ways, that in order to produce more natural sound than is recorded and reproduced by the present methods, it will be necessary to modify the present response characteristics.

The authors wish to acknowledge their appreciation for valuable assistance contributed by their associates and studio engineers, including L. L. Ryder, H. C. Silent, and H. G. Tasker.

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DISCUSSION

MR. TROOP: How did you obtain the curves shown in the illustrations?

MR. LOYE: A sound meter, together with a frequency analyzer containing a 200-cycle wide crystal band-filter, was used. With this analyzer it is possible to select and measure separately the intensity of a 200-cycle band of speech energy at any portion of the speech frequency spectrum. Data obtained in this way were used in plotting the voice intensity *vs.* frequency characteristic curves shown in the illustrations.

DR. MILLER: Can you demonstrate the effect here this evening?

MR. LOYE: You are familiar with the quality of my voice as I have been speaking from my present position in presenting the paper. The intensity of my voice has been and now is between normal and declamatory. Now I approach the microphone, and at the same time reduce the intensity of my voice to a "confidential" level. If the amplification of the public address system is unchanged, my voice will be reinforced more as I approach the microphone, thereby overcoming the reduction in intensity of my speaking. (*Demonstrating*) I am now speaking in a low, confidential manner, and am depending upon the amplifier system to provide the same loudness at your ears as when I was farther from the microphone and speaking in a declamatory manner.

DR. MILLER: There exists some evidence that indicates that the apparent intelligibility of recordings may be changed to a considerable degree by the presence of more or less high-frequency distortion. Have you any data that would indicate the degree of that effect?

MR. LOYE: No, we do not. As I indicated, the study is quite incomplete.

ANALYSIS AND MEASUREMENT OF DISTORTION IN VARIABLE-DENSITY RECORDING*

J. G. FRAYNE AND R. R. SCOVILLE**

***Summary.**—Several types of non-linear distortion in variable-density recording are discussed and methods of measurement outlined. The two-frequency intermodulation method is described. Mathematical and experimental relationships between per cent intermodulation and per cent harmonic distortion are established. The intermodulation method is applied to film processing for the determination of optimal negative and positive densities and overall gamma. Variance of these parameters from those indicated by classical sensitometry are traced to halation in the emulsion and to processing irregularities. The use of special anti-halation emulsions appear to reduce residual distortion effects and tend to bridge the gap between intermodulation and sensitometric control values.*

The variable-density type of sound-record, in common with other recording media, usually contains a certain amount of distortion, the degree of which will vary with the operating technic of the recording system and the accuracy of the controls applied to the processing of the film. The type of variable-density track that forms the basis of this paper is that made by the well known Western Electric light-valve, and while some of the distortions analyzed may be found in this type of modulator, the bulk of the paper is devoted to a study of distortion inherent in any variable-density record made by any type of modulator.

The distortion peculiar to the light-valve has previously been discussed in the JOURNAL of the Society[1] by Shea, Herriot, and Goehner. These authors have shown, for example, that due to what is known as "ribbon velocity" effect, there is considerable harmonic generation at high frequencies in a variable-density film when fully modulated by a double-ribbon type of valve having a 0.5-mil mean image height. They have further shown that the magnitude of this effect is markedly dependent on the mean valve spacing and that reduction of this to one-third of the usual value of 0.5 practically eliminates this source

* Presented at the 1939 Spring Meeting at Hollywood, Calif.; received April 13, 1939.

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

of harmonic distortion. These authors have also shown that the amplitude of the fundamental frequency falls off with increasing frequency, and that the loss at any high frequency is markedly dependent on the height of the recording image.

The combined effect of film processing and light-valve distortions has been treated in detail by Miller.[2] Using the framework of the paper previously described, he calculates on a theoretical basis the total harmonic content to be expected from light-valve recordings for other than optimal processing conditions. Miller also made experimental determinations of the harmonics generated and found general agreement between the values thus determined and the theoretical computations.

Sandvik and Hall[3] have made extensive harmonic analyses of variable-density recordings and have analyzed the effect of varying negative and positive density, as well as negative gamma on the harmonic

FIG. 1. Oscillogram of film recorded with 500 cycles and 8000 cycles superimposed. Excessive image height produces marked "ribbon-velocity effect."

content. They have reported that lower negative and positive densities give less harmonic content than is obtained with the higher values of negative and positive densities in current use.

Chief emphasis is laid by these authors on the generation of harmonics and consequent reduction of fundamental as the primary distortions to be encountered in the variable-density recordings made by the light-valve. Coexistent with these and directly depending on them is the type of distortion that is the chief basis of this paper. This is known as intermodulation, or the modulation of the amplitude of one frequency component by another frequency component simultaneously impressed on the modulating device. This type of distortion is encountered in the light-valve records particularly when a low-amplitude high-frequency signal is impressed on a high-amplitude low-frequency signal. This may be explained as follows. Since the amplitude of the high frequency, say, 8000 cycles, is dependent on the mean valve spacing, it will be seen that the 8000-cycle amplitude will vary continuously as the mean valve spacing is changed by an impressed low frequency of, say, 500 cycles. This is illustrated in Fig. 1

which shows an oscillogram of a recorded wave having the frequencies mentioned. It is customary to use the term "per cent intermodulation" as a measure of the distortion. This may be defined as the average deviation of the amplitude of the higher-frequency wave above and below the mean value. For a one-mil spacing of the valve ribbons, reduced to 0.5-mil image of the film, the amplitude of the

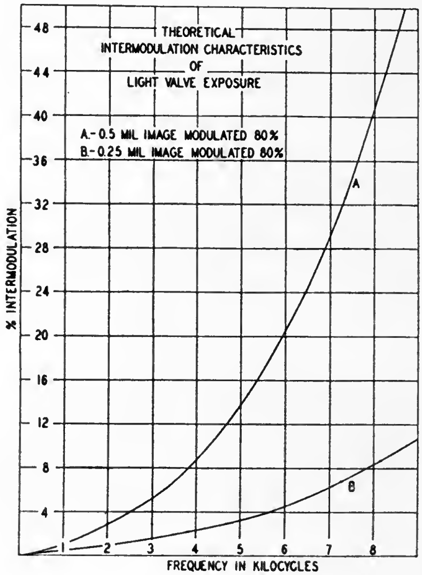

FIG. 2. Computed intermodulation due to the ribbon-velocity effect when two frequencies are simultaneously recorded. Lower frequency fixed at 60 cps with amplitude 4X that of higher frequency.

higher-frequency component will be a minimum when the valve spacing approaches the 2-mil value, and will be a maximum when the ribbons approach the zero-spacing condition. Thus we see that the higher-frequency tone is modulated at the lower-frequency rate; in the example given, the impressed 8000-cycle tone has added to it certain side-frequencies at 8500 and 7500 cycles plus higher-order modulation products of diminishing intensity. In Fig. 2 is shown the theoretical relationship between percentage intermodulation of a fixed low frequency and various high frequencies for two values of image height at the film: namely, 0.5 mil and 0.25 mil. The peak amplitude of the modulation of the combined low and high frequencies is limited to 80 per cent, and the high-frequency amplitude is one-fourth that of the low frequency. It will be noted that there is a marked reduction in the intermodulation when the image height is reduced to the 0.25-mil value, the latter value corresponding to the image height obtained from the one-mil spaced light-valve and the 4:1 reduction objective lens which is in use on a considerable number of Western Electric recording machines. The reduction of this type of

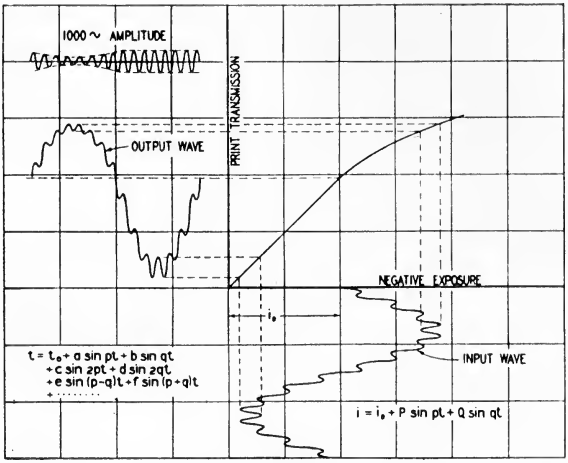

FIG. 3. Analysis of intermodulation when non-linearity exists at only one end of the film characteristic (test signal 60 and 1000 cycles superimposed).

distortion probably contributes more to improved quality in the high-frequency tones than the reduction of harmonics as such, the existence of which has been emphasized by other investigators.[1,2,3]

In the processing of the variable-density film it has been shown by MacKenzie[4] that under certain sensitometric conditions of processing of the negative and positive sound-tracks, a linear relationship may be found between print transmission and negative exposure, thus obtaining a distortionless reproduction of the exposure wave-form originally impressed on the negative. However, MacKenzie points out that, while under ideal conditions, a maximum of 90 per cent modulation may thus be reproduced without distortion, any departure of the projected overall gamma from unity reduces the range of undistorted modulation. He further points out that incorrect choice of negative or printing exposure will result in further non-linear relationships between print transmission and negative exposure. Under these conditions, intermodulation will exist between any pair of superimposed frequencies, irrespective of where they may lie in the frequency spectrum. A suitable test signal for processing irregularities is the combination of 60 cycles and 1000 cycles, the latter having one-fourth the amplitude of the former. Two types of intermodulation distortion may be introduced in the processing by incorrect choice of negative

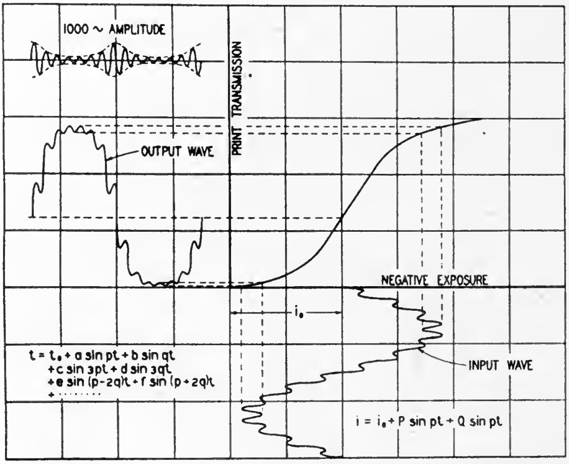

FIG. 4. Analysis of intermodulation when non-linearity exists at both ends of the film characteristic (test signal 60 and 1000 cycles superimposed).

or print exposure. The first type is illustrated in Fig. 3, where due to a choice of either too light a print or too dark a negative, the operation is too close to the shoulder of the overall characteristic curve. This produces an unsymmetrical distortion which results in an intermodulation, as shown in the same figure. A similar sort of distortion would be obtained if excessive curvature existed in the toe of the overall characteristic which would be caused by too dark a print or too light a negative or both. The second type of distortion is shown in Fig. 4, where both negative and print exposures are too low, resulting in an overall curve having excessive curvature at both ends. Here it will be noted that the higher frequency is modulated at a rate equal to twice the low-frequency rate. This is in contrast to the intermodulation of Fig. 3, where the modulation rate of the high frequency is primarily that of the low-frequency signal.

Fig. 5 shows the wave-shapes in the analyzing process. Oscillogram *a* indicates a typical appearance of the wave after passing through a system having distortion at one end of its characteristic, as was previously described in connection with Fig. 3. Thus, on the negative half of the low-frequency cycle the amplitudes of the 1000-(or 7000) cycle loops are reduced compared to those on the positive half. This is apparent in oscillogram *b* wherein the 60-cycle signal has been eliminated and the resultant wave has been amplified. Had there been no distortion, oscillogram *b* would have had a constant amplitude. In order to measure the percentage modulation of *b*, the wave is first rectified as in *c*, then passed through a 200-cycle low-pass filter which removes the ripples, leaving a wave appearing as in *d*. This is impressed on a transformer which passes the a-c component, and this is then measured on a volume indicator calibrated with reference to the average amplitudes and with a scale indicating percentage amplitude modulation (R/S x 100).

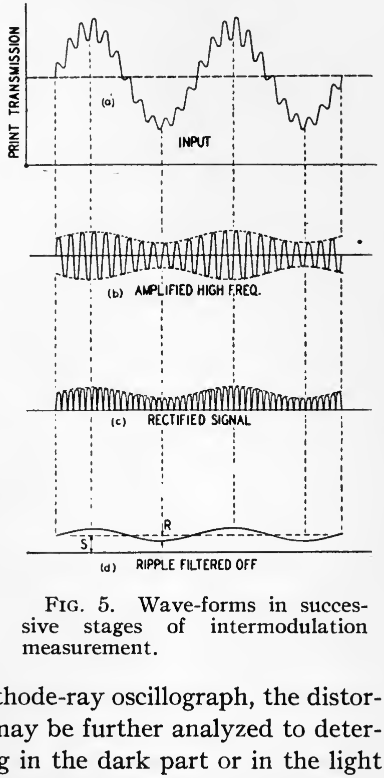

FIG. 5. Wave-forms in successive stages of intermodulation measurement.

By using a phase detector or a cathode-ray oscillograph, the distortion of the higher-frequency wave may be further analyzed to determine whether distortion is occurring in the dark part or in the light part of the film. With the harmonic analysis method, on the other hand, no indication is given as to whether the distortion measured is caused by printing too dark or too light.

THEORY OF DISTORTION MEASUREMENT

The measurement of distortion by the intermodulation method has a close relationship to the harmonic measurement method. If in any system the harmonic generation could be measured, both as to order and percentage amplitude of the extraneous components for the complete range of frequencies at which the system functions, there would be no need for any further measurements of intermodulation. This is because the same distortion factors that produce harmonics also produce intermodulation, and if one effect is completely determined, the other may be mathematically deduced therefrom. Thus, it would seem that both types of tests are not required. However, in systems having a limited frequency characteristic and a limited signal-to-noise ratio, there is difficulty in satisfactorily measuring harmonics, particularly with the higher frequencies. This is especially true of film recording where noise due to graininess interferes with the accuracy of

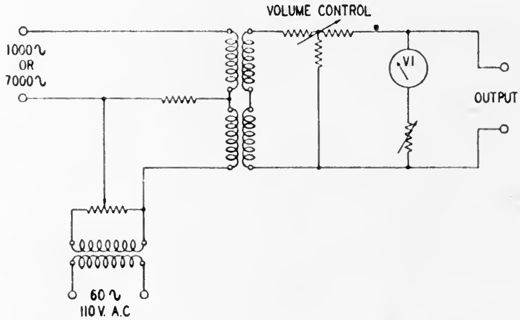

FIG. 6. Two-frequency mixing unit for intermodulation testing.

measurement. Consequently, intermodulation tests have been devised to measure specific types of distortion in a manner which eliminates the noise difficulty.

The mathematical relation between the readings of percentage intermodulation as defined herein and percentage harmonic generation is readily derived providing certain assumptions are made as to the nature of the distortion process. For the first case the assumption is made that the distortion products produced are of the second order. That is to say, the output current y has the following relation to the input current x:

$$y = x + ax^2 + \ldots.$$

Upon substituting the expressions for the two superimposed frequencies in this equation the ratio of the intermodulation component to the fundamental higher-frequency signal may be determined as shown in the appendix. Similarly the amplitude of the second harmonic as related to the fundamental may be derived and it is then found that

$$\frac{\% \text{ Intermodulation}}{\% \text{ 2nd Harmonics}} = \frac{4m_1}{m_1 + m_2}$$

where m_1 = amplitude of the lower-frequency tone
m_2 = amplitude of the higher-frequency tone.

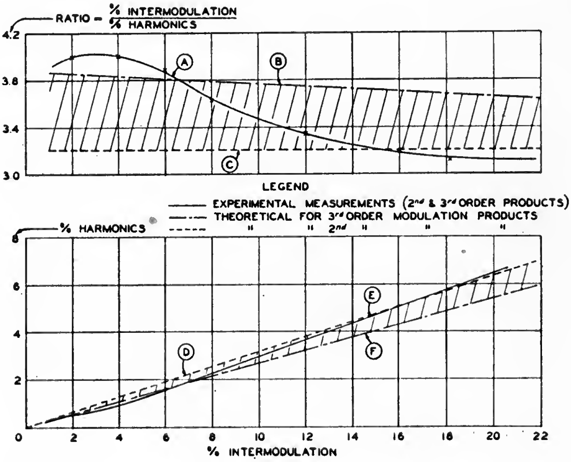

FIG. 7. Relation of intermodulation to harmonic generation.
Curves A, E—Comparative readings of intermodulation analyzer and general radio type 732-A distortion meter.
Curves B, F—Calculated relation for distortion producing only 3rd-order modulation products.
Curves C, D—Calculated relation for distortion producing only 2nd-order modulation products.

Thus when m_2 is small compared to m_1 the ratio is 4. Actually m_2 is made $^1/_4$ of m_1 in these tests, so that in this case the theoretical intermodulation percentage is 3.2 times that of the percentage 2nd harmonics.

However, many cases arise wherein the distortion products generated are of the third order. The derivation in this case is based upon the assumption that the output y has the form:

$$y = x + bx^3 + \ldots.$$

Upon substituting the expressions for signal currents as before (see appendix), a new value is obtained for the ratio:

$$\frac{\%\ \text{Intermodulation}}{\%\ \text{3rd Harmonics}} = \frac{6m_1^2\,[4 + (3b)(m_1 + m_2)^2]}{(m_1 + m_2)^2\,(4 + 6bm_1^2)}$$

Where the distortion factor b is small the expression becomes

$$\frac{\%\ \text{Intermodulation}}{\%\ \text{3rd Harmonics}} = \frac{6m_1^2}{(m_1 + m_2)^2}$$

Where $m_1 = 4m_2$ as in these tests the ratio becomes 3.84, that is, intermodulation percentages are 3.84 times the corresponding 3rd harmonic percentages. The ratio falls off for high values of distor-

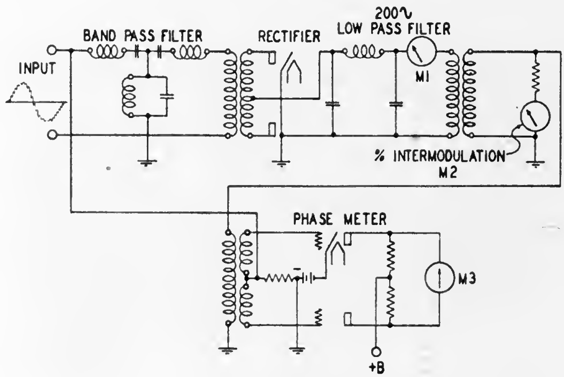

FIG. 8. Intermodulation analyzing circuit.

tion as indicated in Curve *B* of Fig. 7 which ratio is derived from the more exact equation (see also appendix). In the lower half of the diagram the relation of harmonics to intermodulation is shown. Curve *D* is the calculated relation for 2nd-order distortion; Curve *F* is for 3rd-order distortion calculated for the more exact expression mentioned above. Curve *E* gives an experimental measurement comparing the readings of the intermodulation analyzer with the indications of a General Radio Type *732A* distortion meter. Here measurements were made on a light-valve to photocell monitor circuit at various inputs, and readings were made on each unit at corresponding peak signal amplitudes. For high values of distortion which correspond to light-valve clash producing mainly 2nd-order distortion the experimental curve closely approximates the 2nd-order theoretical while for lower amplitudes the experimental is nearer to the theoretical value for 3rd-order distortion. Thus it may be concluded that for an average distortion condition the true relation between harmonics and intermodulation will lie somewhere within the cross-hatched region of the diagram dependent upon what form of distortion is present. The upper diagram of the figure expresses the same information as the lower except that the numerical ratio is given between intermodulation and harmonics. It would appear from this data that the ratio in question varies between 3.2 and 4. This ratio should always be kept in mind in considering the intermodulation tests which follow.

The type of intermodulation test concerned herein is thus fully qualified to measure any type of distortion which a total harmonic

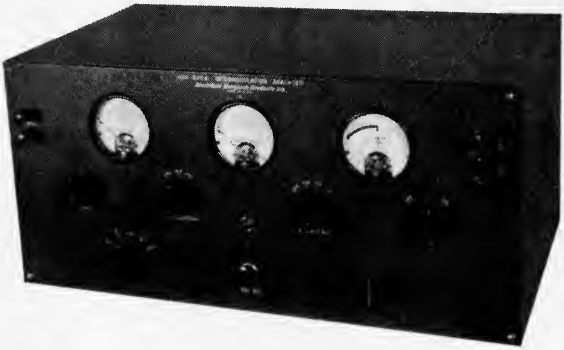

FIG. 9. Intermodulation analyzer unit.

method would measure and is superior where noise is a factor. In this respect the test differs from another type of intermodulation test now widely used in variable-area recording. This is the rectification test described by Baker and Robinson[5] and widely used for variable-area records. Here, a 9000-cycle signal is amplitude-modulated at a 400-cycle rate and recorded. When "fill in" between the wave tips occurs, a rectification is obtained so that a 400-cycle component is generated. Distortion of a type producing even harmonics is readily indicated by this type of test. It will not, however, indicate the type of distortion producing odd order harmonics, since in this case there is no rectification. With variable-area recording, the test is reliable only for the high frequencies where odd harmonics, when generated, are not reproduced. At lower frequencies the increased wavelength insures that the harmonics, due to image spreading, will be reduced, but odd orders from the modulator are present at all frequencies and are not indicated by the test. With variable-density recording nonlinear distortion may be present due to processing irregularities at low frequencies as well as at high. Consequently the rectification test method is not adequate for variable-density analysis.

The so-called "Delta-db Test," described by Albin,[6] has been used for many years in variable-density work to perhaps a greater extent than the harmonic method. In this test a low-amplitude signal 18–24 db below overload is recorded at several biased values of light-valve spacings, for example, 30, 100, and 150 per cent of the normal spacing. The test print is later measured by means of a volume indicator and the decibel difference in response between the various mean spacings is observed. In the ideal case all tests would have the same response and the departure from this condition then becomes a measure of distortion. This method, though favored at some studios, is considered inconvenient to use at others. It also requires a greater length of film than does the intermodulation type of test. The intermodulation measurement method resembles the "Delta-db" method, except that a low-frequency signal replaces the static bias. By so doing a single short recording test, involving usually about 10 feet of film, furnishes an indication of the total distortion for the particular recording and processing conditions involved.

INTERMODULATION TEST EQUIPMENT

(*A*) *Test Generating Set.*—A simple method of providing two frequencies superimposed for use in intermodulation tests, is as shown in Fig. 6. A hybrid coil is used to combine the output of an external oscillator which may be set to 1000 cycles or 7000 cycles, as desired, with a 60-cycle line frequency. Volume controls are provided so that the relative amplitudes of the two frequencies may be adjusted and measured on the volume indicator. The regular practice thus far has been to set the higher of the two frequencies at 12 db less amplitude than the lower of the two frequencies.

(*B*) *Analyzing Equipment.*—Fig. 8 is a block diagram of the circuit used in the analyzer, the elements of which have already been discussed above. The band-pass filter in the input circuit has a pass range between 800 and 1200 cycles per second where the 60/1000-cycle test is used or for the 60/7000-cycle test the filter passes only frequencies above 6500 cycles. The rectifier is a duo-diode type of vacuum tube and the volume indicator is one of the more sensitive types of copper-oxide a-c microammeters. A useful accessory in the form of a phase meter, which has also been called a "pinch" detector, is employed which, by the deflection of a meter to the right or to the left of center, indicates whether the compression of the analyzed wave occurs in the dark or in the light part of the print. This phase-measuring circuit compares the 60-cycle signal of the input with the wave envelope which comes through to the volume indicator M_2. The relative phases of these two waves will be additive for one condition of distortion and substractive for a different condition of distortion, or if different rates are being compared there will be little or no phase effect so that the needle will remain in the center of the scale. This condition occurs when a symmetrical type of distortion is obtained as in Fig. 4. Thus the final demodulated signal is primarily of 120 per second rate as compared to the 60-cycle input signal. This device has operated quite satisfactorily to indicate phase conditions. It is necessary when setting up the equipment to determine the proper polarity of the input signal which may be done by running a film known to be too dark or too light, as the case may be, and making sure that the meter reads in the designated direction. Any subsequent turn-over of polarity in the reproducing circuit would, of course, reverse the deflection of the phase meter.

(*C*) *Use of Cathode-Ray Oscillograph.*—A cathode-ray oscillograph provides a desirable but not indispensable adjunct to the intermodulation measuring equipment. The sweep circuit of the oscillograph is triggered by the 60-cycle input signal, so that for a given set-up the sweep always begins at the same point in the input signal, that is, commencing with the light portion of the print, according to the present arrangement. The vertical plates may be connected (*a*) to the envelope wave coming out of the final transformer (Curve *d*, Fig. 5); (*b*) to the output of the first filter (Curve *b*, Fig. 5); or (*c*) to the compound input signal (Curve *a*, Fig. 5). The position of any point along the horizontal axis is related to the relative light-valve opening. Thus in Fig. 5, the position of compression occurs in the "dark" portion of the intermodulation cycle as determined by preliminary calibration. Useful information may be gained as to the nature of any distortion condition from examination of the oscillograms.

Fig. 9 shows the general appearance of the analyzing unit. It is intended to work out of a 500-ohm circuit at an input of approximately 0.006 watt. The percentage-indicating meter has three sensitivity ranges: namely, 10, 30, and 100 per cent full scale. There is also an *off* position and a position labeled *Noise Test*, which will be described later. Binding posts are provided for connection to an external oscillograph, and a switch is mounted on the panel to enable observations to be made on any of the three positions described previously.

In addition to the intermodulation measuring and "pinch" indicating functions described, the analyzer will also measure the percentage

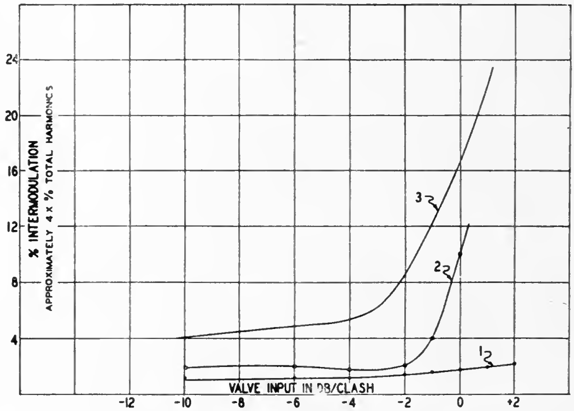

FIG. 10. 60/1000-cycle intermodulation as related to valve clash input.
Curve *1*—System amplifiers.
Curve *2*—Measured through light-valve, photocell monitor, and system amplifiers.
Curve *3*—Recorded film measured with standard reproducer. Optimal processing conditions, standard film and processing.

ratio of noise amplitude to signal (*a*) as weighted by the ear characteristic at the 40-db sensation level, or (*b*) for low-frequency noise passed by a 200-cycle low-pass filter. The latter test is frequently useful in measuring the 96-cycle "sprocket modulation" which occurs due to processing troubles. In such tests an unmodulated track is reproduced following a reference signal of known amplitude used to set the input control.

A further useful function of the instrument is in measuring the amplitude modulation of high-frequency records which may be caused by faulty printer operation. Here a 9000-cycle film is recorded and printed. The reproduced output is measured just as a 60/7000-cycle intermodulation test would be.

The choice of 60 cycles for the lower rate in the intermodulation method is based only on the requirement that it be as low as it is convenient to make it. By using 60 cycles, a simplification of the oscillator test equipment is made possible through the employment of the ordinary a-c line frequency. Harmonics in the latter, unless extremely high, do not seem to be a source of errors.

When testing amplifiers the measured percentage intermodulation for a given condition of distortion is the same whether the 60- and 1000-cycle or the 60- and 7000-cycle test is used. However, when film is recorded the percentage measured is generally different in the two cases due to the ribbon-velocity effect of the light-valve, or to other factors which cause a varying high-frequency response when the mean ribbon spacing is changed.

A given percentage of intermodulation may not always represent the same quality degradation since such a reading is proportional only to the average deviation and not to the form of the distortion. Thus, of two different measurements having the same percentage reading, one might have mainly a 2nd-order distortion due to non-linearity only at one end of the scale as, for instance, due to the toe of the negative characteristic; whereas the other might have a 3rd-order distortion due to curvature at both ends of the overall characteristic. The phase-meter would indicate on the dark side for the first example and neutral in the second. However, the same situation exists in respect to harmonic distortion, wherein the degree of quality degradation depends on the order as well as on the magnitude of the harmonic components present.

ANALYSIS OF DISTORTION COMPONENTS

In high-quality amplifiers of the modern type, particularly those employing stablized feedback, the measured intermodulation seldom exceeds 1.5 per cent, which corresponds to a total harmonic content of $^1/_2$ of 1 per cent, or less, which may be considered negligible.

There is a possibility of non-linear distortion when using gaseous type caesium photocells, due to ionization effects. Extensive tests have indicated that with the illumination intensities generally used with reproducing equipment the distortion contributed by the cell is only slightly greater than that of the amplifier with which the photocell is normally associated. The photocell coupling circuits used in Western Electric reproducers are designed to further reduce the effects of non-linear cell characteristics. The chief remaining sources of non-linear distortion, excluding microphones and loud speakers, which are beyond the scope of this paper, are the light modulators and the film medium.

The light-valve will be discussed from two standpoints: first, purely as a light modulator, the operation of which is interpreted by a photocell and associated amplifier; and, second, as a photographic device for exposing film.

(*1*) *The Light-Valve as a Modulating Device.*—When distortion measurements are made through the light-valve and an associated photocell monitor unit, a negligible amount of distortion is indicated, being only very slightly greater than that of the amplifier itself, as may be seen from Curve *2* of Fig. 10. As the "clash" value is approached, the distortion increases rapidly, as would be expected. Since clash first occurs in the center of the ribbon span, the overload point is not as abrupt as would otherwise be expected. In these and in subsequent tests the valve overload point has been considered to be where an intermodulation value of 10 per cent is measured (or approximately $2^1/_2$ per cent on the harmonic basis).

(*2*) *The Light-Valve as a Photographic Device.*—Due to deficiencies of currently available film emulsions, the translation of the motion of the light-valve to the film image at relatively low frequencies is accomplished with the introduction of a moderate amount of distortion when present standard methods of processing are used. Curve *3*, Fig. 10, shows a film intermodulation test using 60 and 1000 cycles as the test pair, when processed in the optimum manner. For a signal two decibels below clash the 60/1000-cycle intermodulation is 2 per cent when measured at the valve through photocell monitor but is 8 per cent when the recorded film is measured. In terms of total harmonics this means a change from about 0.5 to 2.0 per cent. Though the latter value is not serious, it is significant that all tests conclusively show that the increase must be attributed to the characteristics of the film, and not to the physical components in the recording link.

If 60 and 7000 cycles are used instead of 60 and 1000 cycles in recording through the light-valve, a different result is usually obtained, because of increased intermodulation due primarily to the ribbon-velocity effect. This phenomenon is most marked where the mean image height in the recorder is relatively great. Thus in systems using mean image heights at the film of 0.0005 inch, the 60/7000-cycle intermodulation effect is considerable. Fig. 11 shows the relative magnitude of this effect.

Curve *1* is the 60/1000-cycle test, indicating minimum distortion of about 8 per cent with a print density of about 0.6 (using a negative density of 0.45). There is practically no difference on this test whether the image height is 0.0005 or 0.00025 inch. For the same mean film densities, an intermodulation of 18 per cent is obtained on the 60/7000-cycle test, using a mean image height of 0.0005 inch,

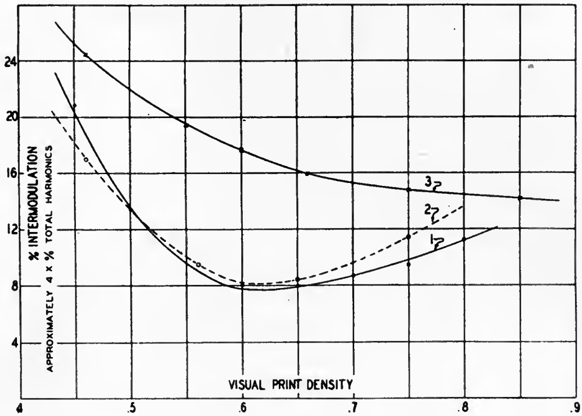

FIG. 11. Comparison of 60/1000-cycle and 60/7000-cycle types of intermodulation as related to print density ($D_n = 0.45$).
Curve *1*—60/1000 cycles using mean image height of 0.00025 inch or 0.0005 inch.
Curve *2*—60/7000 cycles using image height of 0.00025 inch.
Curve *3*—60/7000 cycles using image height of 0.0005 inch.

shown in Curve *3*. Here the distortion is occurring in the lightest portions of the print due to the fact that the 7000-cycle signal is attenuated when the mean spacing of the valve is at the widest value (due to the ribbon-velocity effect). This is somewhat less than the theoretical amount to be expected from the ribbon-velocity effect indicated in Fig. 2, which is probably due to the introduction of other factors related to the formation of the film image. However, with recording systems having $^1/_4$-mil mean image height, or less, as when 4:1 reduction optical equipment is used, the high-frequency intermodulation effect is greatly reduced. Curve *2* of Fig. 11 shows the

60/7000-cycle test, and, as indicated, there is practically no contribution evident from the ribbon-velocity effect.

DISTORTION CHARACTERISTICS OF FILM AND FILM PROCESSING

An analysis of the effect of varying negative and positive unmodulated track densities, as well as overall gamma, is made in this paper using the intermodulation method of distortion measurement. Under some conditions it has been found that the optimum values of negative and positive density are not in agreement with values that might be predicted from the classical sensitometric analysis outlined by

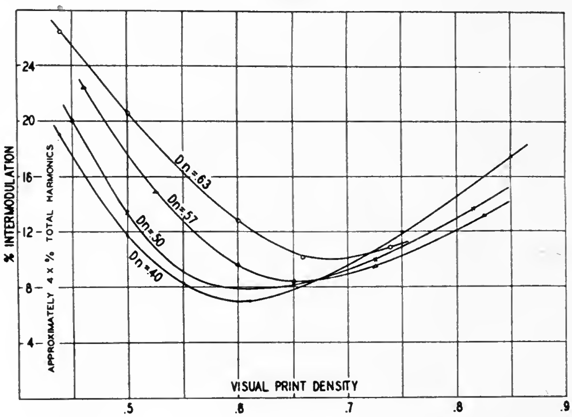

FIG. 12. Intermodulation family typical of Studio *A*. Overall gamma approximately unity.

MacKenzie.[4] It is possible, however, to reconcile the conditions when there is taken into consideration sources of distortion such as dispersion of the recording image by the emulsion and irregularities of wave-form caused by directional effects in development. These do not enter into the sensitometric analysis where relatively large areas of the film are exposed, such as in the standard Eastman II*B* type of sensitometer. It has been found that when the image definition is improved by the use of fine-grain films or absorbing dyes in standard films, the optimum conditions for processing indicated by the distortion method of analysis correlate quite closely with those indicated by the sensitometric method.

In order to determine optimum processing conditions, in a comprehensive manner intermodulation tests are made as follows: First, the light-valve overload is measured with the 60- and 1000-cycle intermodulation signal impressed. The overload point as previously defined is taken at a 10-per cent reading of intermodulation, measured through the photocell monitor. The input is then reduced 2 db from the overload value and recordings are made at each of three or four lamp current values, ranging above and below the correct ones. The negative is developed to a gamma such that when printed in the manner desired, an overall projected gamma of nearly unity will be obtained. In some cases a gamma greater than unity is preferred as will be discussed later, but generally the optimum results are obtained

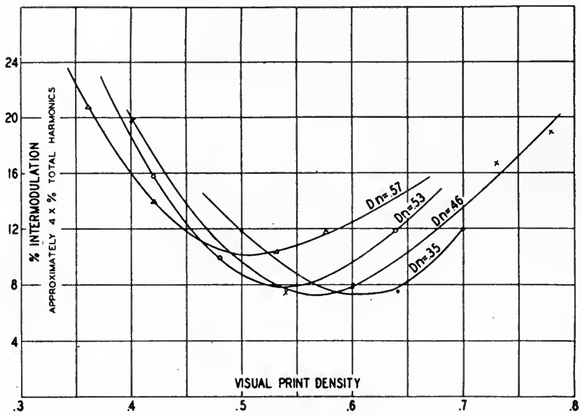

FIG. 13. Intermodulation family typical of Studio *B*. Overall gamma approximately 1.15.

with the unity condition as determined by the present sensitometric methods. After the negative is developed it is printed several times each at a different printer light intensity. The print is developed usually in the standard manner determined by picture requirements, or otherwise, if special conditions prevail, provided the restrictions as to overall gamma are met. The film is reproduced and measured on the intermodulation analyzer and from the data, so obtained, curves are plotted similar to those of Figs. 12 and 13, from which the optimum negative and print densities may be readily observed. Usually this type of test indicates optimum negative and print densities which differ somewhat from the corresponding values determined by sensitometric methods. For example, average negative, as well as print, densities appear to be appreciably lower in these tests for best results than is indicated by classical sensitometry. In fact for certain types of laboratory processing, setting the mean print density on the print toe break point produces optimum results, a condition obtained usually with an overall gamma somewhat greater than unity. One is not to assume from this that present sensitometric methods are in error, but only that other factors enter which are not included in the sensitometry. For instance, a number of blurring effects are known to exist which are more pronounced in regions of heavy density than in low density. One of these is a side-image effect, as illustrated in Fig. 14. On each side of the primary image of a still exposure on film there is found to be a secondary image which is due to the reflection of the primary rays which strike the far side of the base at angles greater than the critical angle. The side images thus produced, though faint, have a definite effect on the film record. For instance, when frequency films are recorded and reproduced in the normal manner, it is found that frequencies in the vicinity of 100 cycles come through 1 to 2 db higher in amplitude than frequencies of around 1000 cycles per second. This can not be attributed to any abnormality of the system frequency characteristic. The explanation is that the side images are in the additive phase at 100 cycles, but at 1000 cycles they are in the subtractive phase. That this is true is indicated when antihalation films are used and equal response is obtained at 100 cycles and 1000 cycles. Definite reductions of intermodulation are also observed by using films of this type. In addition to the side-image effects there are other halation effects. These appear to act as if a fogging exposure were delivered to the film only during the periods where the exposure is heaviest. By reducing exposure the effect is minimized. Where blurring effects are strongest in the negative, the intermodulation tests show a shift toward greater print densities and where the blurring effect is greatest in the print, the shift is toward lighter prints than is indicated by classical sensitometry.

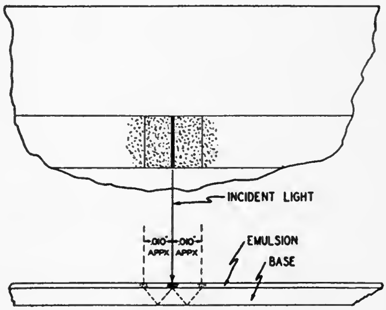

FIG. 14. Production of side images by reflection from back side of film base.

When blurring effects are reduced, as by the use of an emulsion containing an absorbing yellow dye, it is found that not only are the side-images eliminated, but the intermodulation test indicates reduced distortion and the optimum negative and print densities obtained correspond more closely with the values which would be expected from the sensitometry. Use of some of the fine-grain duplicating stocks also appears to be effective in reducing the blurring effects.

The intermodulation recording tests show that although an overall gamma of unity as determined by sensitometric methods is generally desirable, there may be considerable deviations from unity without serious detriment, and in some cases there may be definite advantages in using an overall gamma as much as 20 per cent higher than unity. Where relatively light prints are desired, the overall gamma should be greater than unity, and where darker prints are wanted the gamma should be lowered. As between an overall gamma of 1.01 and 1.16 the minimum distortion readings were respectively 7.5 and 8.5 per cent provided the optimum densities were selected in each case. If gamma were the only distortion factor, the intermodulation percentage as calculated would be 13.6 per cent, to which should be added 1.8 per cent for the PEC-amplifier light-valve, making a total of about 15.4 per cent for the gamma 1.16 case instead of the 8.5 per cent actually obtained. One reason a lower figure is obtained in that the print toe characteristic is compensating the opposite curvature of high gamma.

Fortunately the required negative and print densities for optimum results are not very critical. The tolerance for the negative is generally considerably greater than for the print, which is as would be expected from sensitometric considerations. The intermodulation test indicates minor differences in the distortion characteristics between the work of the various processing laboratories in Hollywood, even where the same types of films are used. For instance, the optimum printing densities are frequently appreciably lighter at one studio than at another. Fig. 12 shows a typical intermodulation test recorded and processed at Studio *A* in the customary manner used at the studio. Fig. 13 shows a similar test made at Studio *B*. The overall gamma was about 15 per cent higher in the latter case than in the former.

The desirability of maintaining intermodulation percentages as low as possible in the original recordings is stressed because nearly all original recordings must be subsequently re-recorded. This process in many cases doubles the percentage distortion over the original value. However by careful adjustment of all the stages in the processing including the most suitable "poling" of the re-recording light-valve an overall result may be obtained showing only slightly greater intermodulation than did the original.

EFFECT OF PUSH-PULL RECORDING

The use of two adjacent class-*A* sound-tracks 180 degrees of phase in the so-called push-pull relationship affords a much broader intermodulation characteristic than is the case with the usual single-track

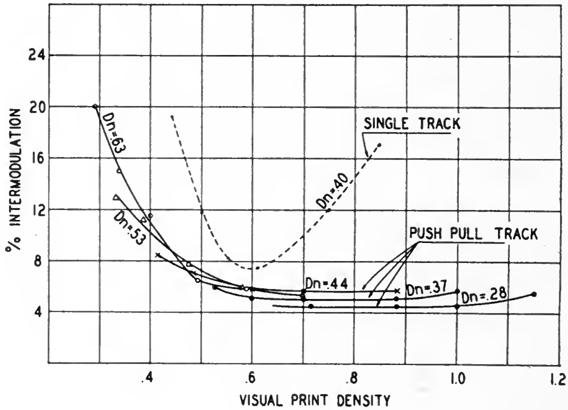

FIG. 15. Typical 60/1000-cycle intermodulation test made with push-pull system.

record. Fig. 15 shows a push-pull intermodulation test. Here the intermodulation percentage is practically constant for print densities between 0.5 and 1.0 and for negative densities between 0.3 and 0.6. However, one may not assume from this that all densities between these limits are equally suitable for push-pull recording use. One reason is that noise-reduction bias current acts in the same phase on both tracks. Consequently certain distortion products generated by the bias action will not be balanced out by the push-pull relation. Therefore it is preferable to determine the processing parameters by the use of single-track recordings even though push-pull recording is contemplated. This may be accomplished by measuring only one of the two tracks. Another point of interest is that the signal-to-noise ratio is not constant over the very wide range of densities shown.

Strictly speaking, the operating condition should be one affording both a maximum signal-to-noise ratio and a minimum intermodulation percentage. In general the ratio does not change appreciably for visual print densities between 0.5 and 0.7, so that it should not be necessary to measure it frequently. For comparison a single-track intermodulation curve is shown with dotted lines in the figure. The difference in latitude between the two systems is quite apparent.

EFFECT OF NOISE REDUCTION

The application of noise-reduction bias currents to light-valves does not appear to increase intermodulation distortion appreciably, provided optimum parameters are used. Where prints are darker than optimum, as determined by the intermodulation test, the application of noise-reduction contributes relatively more distortion than where prints are lighter than normal, because the bias currents are continually working the signal into the denser regions of the print which contribute distortion.

CONCLUSION

The analyses of distortion described in this paper may be summarized as follows:

(*1*) The mechanical vibration of the light-valve is relatively free of intermodulation effects, provided 100-per cent modulation is not exceeded at any point of the ribbon span.

(*2*) The ribbon-velocity type of intermodulation introduced in exposing film by a light-valve is negligible if the mean image height is reduced to 0.00025 inch or less.

(*3*) With standard films used for negative and positive the intermodulation distortion due to non-linearity of the overall print transmission *vs.* negative exposure characteristic can be held to 10 per cent or less, which corresponds to $2^1/_2$ per cent harmonics or less.

(*4*) Further reduction of intermodulation depends on obtaining further improvement in the definition of negative and positive film images. This may be accomplished by the use of improved film stocks in which yellow dye or fine-grain emulsions, or both may be incorporated.

(*5*) Sensitometry, though useful for processing controls, can not always be completely relied on as a measure of overall conditions in film recording. Consequently a dynamic check on overall results such as is supplied by the intermodulation type of test is needed.

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APPENDIX

Derivation of Relation between Intermodulation and Harmonic Generation

Case 1. 2nd-Order Distortion Analysis:

Assume
$$y = x + ax^2 \quad (1)$$

where
y = output current of system
x = input current of system

For the two frequency intermodulation test:

$$x = m_1 \sin \omega_1 t + m_2 \sin \omega_2 t \quad (2)$$

Where m_1 = amplitude of lower impressed frequency, ω_1
m_2 = amplitude of higher impressed frequency, ω_2

$$\begin{aligned} y = {} & m_1 \sin \omega_1 t + m_2 \sin \omega_2 t \\ & + am_1^2 \sin^2 \omega_1 t + am_2^2 \sin^2 \omega_2 t \\ & + 2am_1 m_2 (\sin \omega_1 t)(\sin \omega_2 t) \end{aligned} \quad (3)$$

The intermodulation test measures the ratio

$$\frac{2am_1m_2}{m_2} = 2am_1 \quad (4)$$

For the single-frequency harmonic test:

$$y = (m_1 + m_2) \sin \omega_1 t \quad (5)$$

When substituted in (*1*) and simplified

$$y = (m_1 + m_2) \sin \omega_1 t - a \frac{(m_1 + m_2)^2}{2} \cos 2\omega_1 t + etc. \quad (6)$$

Ratio 2nd-harmonic to fundamental:

$$= \frac{a(m_1 + m_2)}{2} \quad (7)$$

Ratio of (*4*) to (*7*) expresses relation of intermodulation to 2nd-harmonics and is:

$$\frac{4m_1}{m_1 + m_2} \quad (8)$$

Case 2. 3rd-Order Distortion Analysis:

Assume $$y = x + bx^3 \tag{9}$$

Substituting (*2*) in (*9*) and simplifying

$$y = m_1 \sin \omega_1 t \left(1 + \frac{3}{4} bm_1^2 + \frac{3}{2} bm_2^2\right) + m_2 \sin \omega_2 t \left(1 + \frac{3}{4} bm_2^2 + \frac{3}{2} bm_1^2\right) \tag{10}$$

$$-{}^3/_2 bm_2^2\, m_1 (\sin \omega_1 t) \cos (2\omega_2 t)$$
$$-{}^3/_2 bm_1^2\, m_2 (\sin \omega_2 t) (\cos 2\omega_1 t)$$
$${}^1/_4 bm_2^3 \sin 3\omega_2 t - {}^1/_4 bm_1^3 \sin 3\omega_1 t$$

The intermodulation component measured is the amplitude of $(\sin \omega_2 t)(\cos 2\omega_1 t)$ and the ratio of this to the amplitude of $\sin \omega_2 t$ is

$$\frac{\frac{3}{2} bm_1^2\, m_2}{m_2\left(1 + \frac{3bm_2^2}{4} + \frac{3}{2} bm_1^2\right)} \tag{11}$$

Which reduces to

$$\frac{6bm_1^2}{4 + 3bm_2^2 + 6bm_1^2} \tag{12}$$

Since $3\, bm_2^2$ is small it may be neglected so that:

$$\%\ \text{Intermodulation} = \frac{6bm_1^2}{4 + 6\, bm_1^2} \times 100 \tag{13}$$

For the single-frequency case of third-harmonic generation (*5*) is substituted in (*9*) and after simplifying:

$$y = (m_1 + m_2) \sin \omega_1 t + \frac{3b}{4}(m_1 + m_2)^3 \sin \omega_1 t - \frac{b}{4}(m_1 + m_2)^3 \sin 3\omega_1 t \tag{14}$$

The ratio of third harmonic to fundamental is:

$$\frac{\frac{b}{4}(m_1 + m_2)^3}{(m_1 + m_2) + \frac{3}{4} b(m_1 + m_2)^3} \tag{15}$$

which reduces to

$$\%\ \text{3rd Harmonics} = \frac{b\,(m_1 + m_2)^2}{4 + 3b\,(m_1 + m_2)^2} \times 100 \tag{16}$$

The ratio of the intermodulation percentage to the harmonic percentage is the ratio of (*13*) to (*16*) or

$$\frac{6m_1^2\,[4 + 3b\,(m_1 + m_2)^2]}{(m_1 + m_2)^2\,(4 + 6b\, m_1^2)}$$

Where the distortion is low, terms involving b may be neglected, so that for that case the ratio is

$$\frac{6m_1^2}{(m_1 + m_2)^2}$$

In the curves shown in Fig. 7, values for b were assumed from about 0.01 to 0.3 and calculations were made of intermodulation and harmonic generation for the cases of 2nd- and 3rd-order distortion, respectively, from which the ratios were computed and plotted using percentage intermodulation as the independent variable. Acknowledgment is due Mr. C. R. Keith for many valuable suggestions made in the course of this work.

DISCUSSION

MEMBER: Has developing at the time of processing any effect upon distortion in variable-density sound?

MR. SCOVILLE: Any change in processing that affects either the negative or the print characteristic will have an effect upon the overall linearity and consequently the total distortion. The objective in variable-density recording is to obtain an overall characteristic with a straight-line relationship between negative exposure and print transmission over as long a range as possible, and certainly this is affected by the developing conditions.

MR. KELLOGG: One of your illustrations shows the curves of intermodulation, one with 0.5-mil and one with 1-mil slit image width. The latter gave considerably less intermodulation. Does that mean that distortion went down with reduced exposure, or was the exposure maintained the same?

MR. SCOVILLE: For the 0.5-mil image a two to one optical reduction was used and for the other case a four to one reduction was obtained. The spacing of the light-valve was 1 mil in both cases and the actual exposure to the film was also the same. Usually it is not desirable to reduce the light-valve spacing much below 1 mil because of the mechanical-optical considerations.

DR. FRAYNE: Mr. Kellogg's question can be answered by saying that it is usual to raise the lamp current due to lower efficiency of the optical system, for the case of the 0.25-mil image.

MR. KELLOGG: I do not know, unless it was due to ribbon-velocity effect, why it should make any difference to cut down the recording image light. What two frequencies were involved?

MR. SCOVILLE: The high frequencies involved in Fig. 2 were from 1000 to 9000 cycles. The low frequency may be any value less than about 10 per cent of the higher frequency.

The reason why a reduced image height becomes important is that at high frequencies the film is moving at a velocity comparable to that of the light-valve ribbon image. One ribbon is moving in the same direction as the film; the other ribbon is moving in a direction opposite to that of the film with the result that an irregular exposure is obtained by the film at high frequencies.

DR. DAILY: The data as presented apply primarily to high-level recording. In practical operations, it is important that the signal be as free as possible from intermodulation effects, not only at high levels but also at low levels where the action of the noise-reduction permits operation on a different portion of the film characteristic. This dynamic method of distortion analysis aids in the selection of an optimum processing point under both conditions. For a given overall gamma, it aids in the determination of a minimum of distortion that is practical to handle commercially with all the variations that are normally encountered.

MEMBER: Does the intermodulation meter convey enough information to estimate what the total distortion would be due to re-recording process?

MR. SCOVILLE: When the intermodulation percentage is the minimum amount, the phase-meter indicates neutral; that is, it shows that the signal is swinging equally between the two extremities of the characteristic. If the re-recording is made in like manner so that optimum processing is obtained, then the total distortion will be $1^1/_2$ to 2 times as great as that in the original. Usually it is not possible to maintain optimum processing conditions in both the original and re-recording films. The final results are dependent upon how the distortion phases add, and the total may be either slightly greater than the original intermodulation, or, in the worst case, double.

MR. SOLOW: For some years film processing has been subjected to examination by the delta-db tests at the United Artists Studios. Are the intermodulation tests you have been describing superior, or do they reveal more?

MR. SCOVILLE: The intermodulation type of test is closely related to the delta-db test. In the delta-db test a low-amplitude signal is recorded several times, each at a different mean spacing of the light-valve, a bias current being used to change the spacing. In the intermodulation test one of the test signals is the same as in the delta-db test, but instead of the static bias there is a low-frequency signal which is constantly swinging the mean valve spacing open and closed. The advantage of this method is that there is a uniform change of mean valve spacing so that one recording swings the test signal over the entire characteristic. One reading gives the total effective distortion. The delta-db tests, on the other hand, give a set of readings which, if properly interpreted, lead to similar conclusions, but are rather inconvenient for reference. The delta-db tests usually take three or more separate recordings, whereas the intermodulation test for a particular condition requires only one involving about ten feet of film. Where many conditions are to be investigated, the intermodulation test thus saves film, reduces the number of readings, and simplifies the plotting of curves.

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.

American Cinematographer

20 (Apr., 1939), No. 4

A. S. C. Men Turn Out to Discuss Meters (pp. 151–152)

Randolph Clardy Makes First 8 Mm. Talker (pp. 164, 189) — W. Stull

3-Way Microphone Announced by R. C. A. (p. 180)

Cinecolor Formally Opens Big New Plant (p. 185)

British Journal of Photography

86 (Mar. 3, 1939), No. 4113

Progress in Colour (p. 135)

86 (Mar. 10, 1939), No. 4114

Progress in Colour (pp. 147–149)

86 (Mar. 17, 1939), No. 4115

Progress in Colour (pp. 168–170)

Communications

19 (Mar., 1939), No. 3

Frequency Response Characteristic of Amplifiers Employing Negative Feedback (pp. 5–7, 42, 44, 45)

Television Economics, Pt. II (pp. 17–19, 27, 49) — A. N. Goldsmith

Practical Aspects of Wideband Television Amplifier Design (pp. 21–22, 24, 38, 39, 48, 49) — F. A. Everest

Radio Transmission Considerations. Sound vs. Picture (pp. 30–32) — T. A. Smith

Cine-Technician

4 (Jan.-Feb., 1939), No. 19

Three Thousand Pictures a Second (pp. 148–149) — D. H. Geary

Electronics

12 (Mar., 1939), No. 3

Television Receivers in Production (pp. 23–25, 78–81)

Television Transmitters (pp. 26–29, 47)

A Television Formulary (pp. 33–35) — D. G. Fink

Institute of Radio Engineers, Proceedings

27 (Mar., 1939), No. 3

Lateral Disk Recording for Immediate Playback with Extended Frequency and Volume Range (pp. 184–187) — H. J. HASBROUCK

Oscillograph Design Considerations (pp. 192–198) — G. R. MEZGER

An Improvement in Constant-Frequency Oscillators (pp. 199–201) — G. F. LAMPKIN

International Photographer

11 (Mar., 1939), No. 2

New York Technical Facilities O. K. (pp. 5–6) — H. MOHR

New P & H Developing Process (pp. 7–9)

Fundamental Photographic Physics (pp. 10–13) — D. HOOPER

Fog Effect Filters (p. 13) — G. SCHEIBE

First Rear Projection Specifications (pp. 21–24)

International Projectionist

14 (Mar., 1939), No. 3

An Analysis of Brush Operation on Commutating Equipment. Pt. II. (pp. 7–10) — ENGINEERING DIVISION, NATIONAL CARBON COMPANY

New Forms for Electrical Data (pp. 12–15) — A. NADELL

Ohm's Law and Its Application to Some Projection Problems (pp. 18–19) — J. H. HERTNER

Kinematograph Weekly

265 (Mar. 23, 1939), No. 1666

The Vinten-Built Printer for Dufaycolor (pp. 53, 54A)

Kinotechnik

21 (Feb., 1939), No. 2

Photographie und Kinotechnik bei der Luftfahrt und Luftwasse. (Photography and Motion Pictures in Aeronautics and Aerial Warfare) (pp. 29–33) — C. ASCHENBRENNER

Neuzeitliche Verstarkereinrichtungen für das Tonfilm-Forschungslaboratorium. (Recent Amplifying Arrangements for the Sound Film Research Laboratory) (pp. 33–38) — A. NARATH AND K. H. R. WEBER

Die Farbenphotographie mit Mehrschichtenmaterial. (Multiple Layer Color Photography) (pp. 38–41) — W. MATTHAES

Kopiekurve und Hochintensitatsprojektion. (Printing Curves and High Intensity Projection) (p. 42) — E. M. HOFER AND R. SCHMIDT

Bildprojektion mit Quecksilber-Hochdrucklampen. (Projection with Mercury High Pressure Lamps) (pp. 43–45) — W. HEGMANN

Kathodenstrahloszillograph als Aussteuerungsinstrument. (Cathode Ray Oscillograph as a Modulator) (pp. 45–57) — H. ORLICH AND E. WALTER

HIGHLIGHTS OF THE SPRING CONVENTION

HOLLYWOOD-ROOSEVELT HOTEL, HOLLYWOOD, CALIF.
APRIL 17-21, 1939

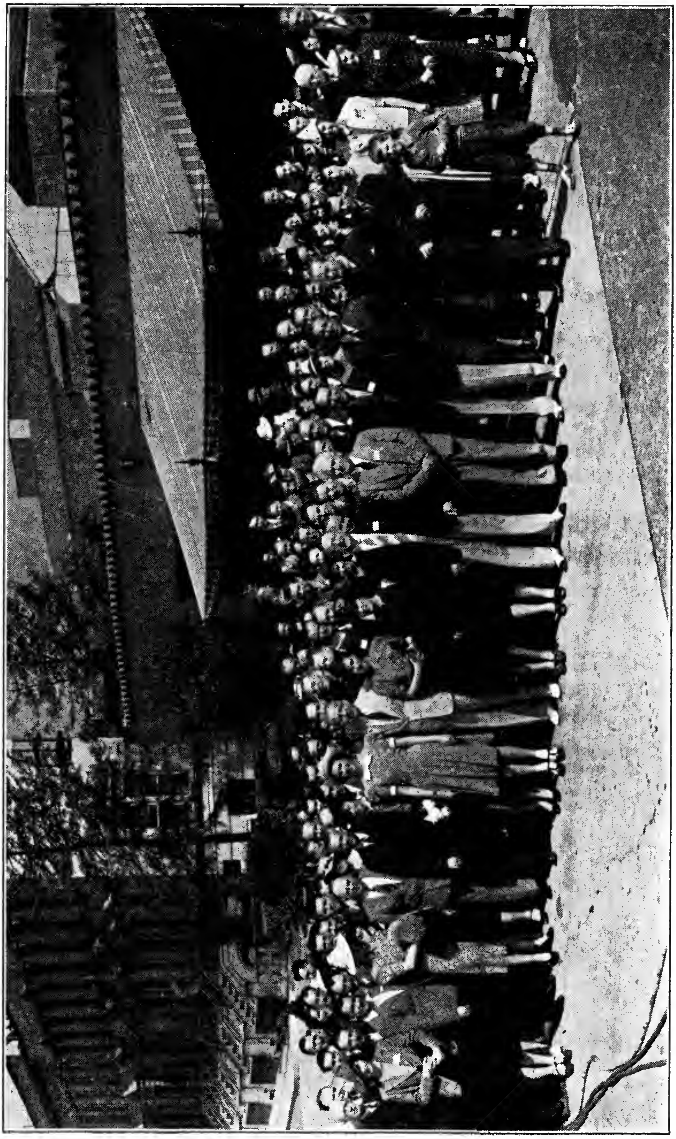
A number of outstanding features marked the 1939 Spring Convention of the Society just ended at Hollywood, among which was the notable fact that at not one of the ten sessions did the attendance fall below approximately 150. This is all the more remarkable because of the fact that the program for the five days was very crowded with technical material requiring close attention and concentration. At the last session of the Convention, on Friday, April 21st, devoted to a television symposium, the attendance was close to 500 persons.

The Convention opened at 10 A.M., Monday, April 17th, under the Chairmanship of Mr. Loren L. Ryder, who welcomed the delegates to the Convention on behalf of the Pacific Coast Section of the Society and its Board of Managers, of which Mr. Ryder is Chairman. Following several committee reports, the meeting was turned over to President E. A. Williford, who delivered a brief address of welcome to the delegates from the East and an invitation to all those engaged in motion picture pursuits in Hollywood to attend the various sessions of the Convention and to make themselves welcome. Perhaps the most outstanding paper of the Monday morning session was the "Review of Foreign Film Markets" by N. D. Golden, of the Motion Picture Division of the United States Department of Foreign and Domestic Commerce, the keynote of which was that, despite the fact that American motion pictures were still enjoying fairly wide distribution in Europe and had a very promising market in Latin America, it behooves the American producers to send abroad only their very best films in order to be sure of retaining those markets.

At noon of the opening day, the usual Informal Get-Together Luncheon was held in the Florentine Room of the Hotel. An address of welcome to Los Angeles was made by the Honorable Fletcher Bowron, Mayor of the City of Los Angeles, and as guests at the speakers' table were Mr. Lester Cowan, producer, of Universal Studios; Mr. Sinclair Lewis, author; Mr. James Hilton, writer, of Warner Bros.-First National Studio; and Mr. W. K. Howard, director. Seated at the speakers' table also were Messrs. W. C. Kunzmann, *Convention Vice-President;* J. I. Crabtree, *Editorial Vice-President;* M. C. Batsel, *Governor;* and President E. A. Williford.

Mr. Cowan, in a brief address, referred to the imminence of television and indicated that he planned to conduct "television tests" instead of the customary screen tests in selecting "Angela" for the film version of Sinclair Lewis' play, *Angela Is 22.*

Mr. Hilton stated that he believed more brains—certainly more good-will—go into making even the worst Hollywood picture than is found around the average



Photograph of Convention group, taken at Warner Bros.-First National Studios, Burbank, Calif., April 20, 1939.

European round-table, and Mr. Howard paid tribute to the valuable contribution of sound experts and other technicians to the progress of motion pictures. Mr. Williford acted as Master of Ceremonies.

The afternoon session of Monday included an interesting discussion by A. L. Williams on "Further Improvements in Light-Weight Record Reproducers, and Theoretical Considerations Entering into Their Design." The session concluded with an interesting paper on "The Time Telescope" by C. R. Veber, a new highly automatic mechanism for making time-lapse pictures.

Mr. K. F. Morgan presided at the Photographic Session held on the evening of Monday, April 17th, which opened with a discussion of the new fluorescent lamps and their application to motion picture studio lighting, by G. E. Inmann and W. H. Robinson. These lamps are finding wide application in industrial and domestic uses and are now being applied to motion picture stage lighting. A paper by L. D. Grignon discussed the controversial question of "Flicker in Motion Pictures," and contained a qualitative review of the now prevailing sources of flicker, presenting some new concepts, and emphasizing the sources of major importance at the present time. The paper evoked considerable discussion from the floor.

Tuesday morning, April 18th, was devoted to a Projection Session, under the Chairmanship of H. W. Remerschied, and contained the reports of the Projection Practice and Exchange Practice Committees, in addition to an extensive discussion of "Lamps and Optical Systems for Sound Reproduction," by F. E. Carlson, in which the problem of uniformity of sound-slit illumination was discussed.

Tuesday afternoon was devoted to a visit to Paramount Studios, under the direction of Mr. Loren L. Ryder, Director of Recording. The visit included a demonstration of projection background shooting and inspection of the stages where special effects and miniature work are carried out. Visits were made also to the Sound Department, Dubbing Department, and the Production Stages, where feature shooting was witnessed.

In demonstrating the projection background process, a scene of the forthcoming picture *Union Pacific* was shot by Mr. Cecil B. deMille, Director. In the Review Room, scenes from *Spawn of the North* were projected without sound, in order to show the various background sequences in the scene, which were pointed out by Mr. A. F. Edouart, in charge of the Paramount Transparency Department. The same scene was later shown with the sound effects added.

The Tuesday evening session was held at the Filmarte Theater under the Chairmanship of Mr. B. F. Miller. One of the interesting presentations of the evening was a paper on "The Present Technical Status of 16-Mm. Sound-on-Film," by J. A. Maurer. Mr. Maurer's entire presentation had previously been recorded on 16-mm. film by the processes described in the paper, and instead of making the presentation orally, Mr. Maurer allowed the film reproducer to make it for him, including in the reproduction various samples of music and speech. The presentation was notable for the excellence of the reproduction. A paper by K. F. Morgan and D. P. Loye discussed in considerable detail the various amounts of dialog equalization required in recording and reproducing, tracing these requirements from the voice of the actor on the stage to the brain of the auditor in the theater subjectively receiving the reproduced sounds. An interesting phase of the presentation was the demonstration by Mr. Loye of the manner in which the quality of the voice changes with changes of level in speaking and in reproduction from the film.

The morning of Wednesday, April 19th, was devoted to sound, under the Chairmanship of Mr. J. O. Aalberg. An interesting paper by G. M. Best described a new sound-track projection microscope by means of which sound-track records can be examined with great speed and precision and effects in recording, such as transients due to printer sprockets, weave, and the like, discovered and analyzed with great dispatch.

On Wednesday evening Mr. R. M. Townsend was the Chairman of the Sound Session, held at the Filmarte Theater. A new "Direct Positive System of Sound Recording" was described by G. L. Dimmick and A. C. Blaney, and an interesting "Report on Recent Activities of the Research Council Committee on Standardization of Theater Sound Projection Equipment Characteristics" was presented by J. K. Hilliard, Chairman of the Committee. The demonstration included the projection of the new Academy sound test films, which included a series of fixed frequency records, buzz track, and recordings of outstanding scenes from the major studios.

A demonstration was given by N. B. Neeley and W. V. Stancil of "Modern Instantaneous Recording and Its Reproduction Technic," which included the reproduction of remarks made by President Williford on the day before, and recorded on disk unknown to the audience. In exemplification of the improvements that have been made in disk recording, several records recorded in 1906 were reproduced as a matter of contrast with some modern recordings recently produced. In addition, an example of stereophonic reproduction was given in which the recording had been done with two microphones and two cutting heads, the reproduction being accomplished by two reproducing heads running in synchronism on two separate sound-tracks on the disk.

The evening closed with the projection of one reel of Bluebeard's *Eighth Wife*, dubbed in French, the purpose being to demonstrate the exact synchronism attainable nowadays in preparing foreign-language versions of films originally recorded in English.

The Photographic and Laboratory Session, held on the morning of Thursday, April 20th, under the Chairmanship of D. E. Hyndman, contained several interesting papers, among which was the description of "An Instrument for the Absolute Measurement of the Graininess of Photographic Emulsions," by A. Goetz, W. O. Gould, and A. Dember, and a paper by J. R. Alburger describing the new "RCA Aluminate Developers." Mr. Alburger's paper evoked considerable discussion, including the question of whether similar effects could not be achieved with other materials.

A visit to the Warner Bros.-First National Studio, under the direction of Major Nathan Levinson, Executive Vice-President of the Society, occupied the afternoon. First the delegates were the guests of the Studio at luncheon in the commissary, after which they were conducted on a tour through the Wardrobe and Property Departments and also to the new unit of the Crafts Building. An opportunity was also afforded to visit the new laboratory, in addition to a general sight-seeing tour of the lot, and an inspection of the outdoor stages.

The Semi-Annual Banquet ofthe Society was held in the Blossom Room of the Hotel in the evening (April 20th). About 400 persons attended the banquet and after introducing the officers and governors present, President Williford addressed a few words of appreciation to all the studios and individuals who had contributed their time and effort to making the convention so successful. He then introduced Bob Hope, motion picture and radio comedian, who acted as Master of Ceremonies. Present at the speakers' table were Mr. and Mrs. Frank McHugh, Mr. and Mrs. Pat O'Brien, Mr. and Mrs. Edward G. Robinson, Mr. and Mrs. E. A. Williford, Major and Mrs. Nathan Levinson, Rudy Vallee, Miss Marjory Weaver, and Mr. Lucian Hubbard.

A half hour of entertainment was provided by Bob Hope, Rudy Vallee, Miss Ella Logan, and Jerry Cologna, after which the evening concluded with dancing.

Although not scheduled as part of the Convention program, members of the Society witnessed a demonstration by Mr. J. G. Capstaff, at the Grauman's Chinese Theater, of the effect of providing around the screen picture projected borders of various shades of gray. The demonstration was witnessed by quite a large gathering of persons, and an interesting discussion followed.

Friday afternoon (April 21st) was devoted to a Studio Practice Session under the Chairmanship of Mr. H. Griffin. S. J. Begun demonstrated "A New Magnetic Recorder," developed according to principles described in papers presented at previous conventions, and a paper by R. N. Marshall and W. R. Harry described very completely the new "Cardioid Directional Microphone" recently developed by the Bell Telephone Laboratories.

The climax of the Convention occurred on Friday evening, when the Television Session was held in the Blossom Room of the Hotel under the Chairmanship of Professor S. MacKeown of the California Institute of Technology.

This symposium on a subject of such vital importance at this time to the motion picture industry, has been described as the most outstanding collection of presentations on the subject of television as related to motion pictures so far held at one time, and covered the various phases from television stage production to the applications of film to television, and television studio technic, lighting, and equipment. Included in the symposium was the report of the SMPE Television Committee, the theme of which was the expressed hope of avoiding conflicting standards or practices in the motion picture and television arts, and to guard against misunderstanding, misstatements, and unnecessary conflicts of aims or opinions. Partial reports of the Sub-Committees on Production Technic and Film Processing were included.

EXHIBITS

An exhibit of new equipment was held throughout the entire convention under the Chairmanship of Dr. J. G. Frayne, and it was generally conceded that this exhibit was one of the finest yet held and commanded the greatest amount of interest. The exhibitors were as follows:

The Ampro Corporation
Electrical Research Products, Inc.
International Projector Corporation
The Kalart Company
Lansing Manufacturing Company
Moviola Company
Newman Brothers, Inc.
RCA Manufacturing Company
The Strong Electric Corporation
Eastman Kodak Company
Golde Manufacturing Co.
D. G. Jones & H. G. Tasker
Mole-Richardson Company
Neumade Products Corp.
Norman B. Neely Radio Enterprises
Universal Microphone Co., Ltd.

The exhibit covered broadly the field of production and reproduction of motion pictures in both the professional and amateur fields. ERPI and RCA had very interesting exhibits of microphones, while International Projector, Lansing, and RCA displayed their most recent projection equipment. The Norman B. Neely Company and the Universal Microphone Company both had exhibits of direct recording and playback equipment.

On Thursday and Friday nights of the Convention, the Hollywood Television Society, under the leadership of Mr. Richard Baird and Mr. Thornton Chew, gave an interesting demonstration of television reception, the broadcast being received from the Don Lee Broadcasting Station W6XAO. This demonstration was particularly timely as it rounded out the papers program devoted to television.

Also during the entire convention an exhibit of approximately 150 color-stills was held on the mezzanine of the Hotel. This exhibit was particularly outstanding with respect to the quality of the exhibits both from the photographic and artistic points of view, and the Society extends much appreciation to all those who contributed in making this exhibit such an outstanding success. Following is a list of the exhibitors. Mr. O. O. Ceccarini was Chairman of the Exhibit.

E. W. BENSON
North Hackensack, N. J.

CHARLES W. BURGESS
Minneapolis, Minn.

WHITING-FELLOWS
New York, N. Y.

PAGANO, INC.
New York, N. Y.

PAUL A. HESSE STUDIOS
New York, N. Y.

VICTOR KEPPLER
New York, N. Y.

E. L. LETTEN
Toronto, Canada

GOESTA P. G. LJUNGDAHL STUDIOS
New York, N. Y.

NICKOLAS MURAY AND ASSOCIATES
New York, N. Y.

JAMES PICKARDS, II
New Haven, Conn.

CHESTER A. PLEADWELL
Flint, Mich.

DEFENDER PHOTO SUPPLY CO., INC.
Rochester, N. Y.

SHIGETA-WRIGHT, INC.
Chicago, Ill.

WILLIAM STEVENSON
Cleveland, Ohio

WALDEMAR G. HANSEN
Los Angeles, Calif.

VAN DAMM STUDIO
New York, N. Y.

W. G. HOUSKEEPER
South Orange, N. J.

WILFRED H. WOLFS
New York, N. Y.

MAX HIRSCH, JR.
Long Island, N. Y.

S. G. HALL
Rochester, N. Y.

JAMES N. DOOLITTLE
Los Angeles, Calif.

NICOLL-PRATT CORP.
Los Angeles, Calif.

R. T. DOONER
Philadelphia, Pa.

CHARLES H. MILLER
Chicago, Ill.

K. L. HENDERSON
Rochester, N. Y.

RALPH BOYLE
Philadelphia, Pa.

O. O. CECCARINI
Hollywood, Calif.

H. I. WILLIAMS STUDIO
New York, N. Y.

HARRIS B. TUTTLE
Rochester, N. Y.

WYNN RICHARDS
New York, N. Y.

FRANK MILLER

EVERETT MOSES
Chicago, Ill.

ACKNOWLEDGMENTS

The Society wishes to acknowledge its gratitude to the large number of persons and companies who collaborated in providing the various facilities of the Convention and in fact making the Convention possible. The general facilities of the

Convention were arranged by Mr. W. C. Kunzmann, *Convention Vice-President;* Major Nathan Levinson, *Executive Vice-President;* Mr. J. I. Crabtree, *Editorial Vice-President;* Mr. L. L. Ryder, chairman of the Pacific Coast Section; Mr. H. G. Tasker, Chairman of the Local Arrangements Committee; and Mr. Julius Haber, Chairman of the Publicity Committee. Mr. L. A. Aicholtz was Chairman of the Pacific Coast Papers Committee and Mr. L. D. Grignon assisted in arranging the television symposium.

Thanks are due to Dr. J. G. Frayne for his work in arranging an outstanding exhibit of new motion picture equipment, and to Mr. O. O. Ceccarini, who was Chairman of the Color Still Exhibit.

Messrs. H. Griffin, C. N. Batsel, C. R. Sawyer, and W. V. Stancil are all to be thanked for their efforts and labor in providing the projection and sound reproducing equipment used at the Filmarte Theater and the public address system used in the Blossom Room as well as at the theater.

The society extends its thanks also to the Research Council of the Academy of Motion Picture Arts & Sciences, and to Mr. Gordon S. Mitchell, for their kind assistance; to the members and chairmen of the various SMPE local committees; and to the Walt Disney Studio for making the Filmarte Theater available to the Society for the two evening sessions held there.

The Society is indebted also to Mrs. Nathan Levinson, Chairman of the Ladies Committee, for her efforts in arranging an interesting program for the ladies attending the Convention.

Among the companies who contributed in equipment and service to the Convention were the following: RCA Manufacturing Company; Electrical Research Products, Inc.; Lansing Manufacturing Company; International Projector Corporation; National Carbon Company; General Electric Company; Bausch & Lomb Optical Company; Eastman Kodak Company; Mole-Richardson, Inc.; Bell & Howell Co.; and National Theater Supply Company.

Thanks are due also to the members and officers of Los Angeles Projectionists Local No. 150 IATSE for providing the projectionists for the Convention.

The Society is indebted to the Paramount Studios and Warner Bros.-First National Studio for the visits arranged for the Tuesday and Thursday afternoon sessions and to Fox West Coast Theaters, Inc., Warner Bros. Theaters, Inc., and Rodney Pantages, Inc., for passes issued to the delegates to the Convention for the following theaters: Grauman's Chinese and Egyptian Theaters, Warner's Hollywood Theater, and Pantages' Hollywood Theater; also to the Hollywood Chamber of Commerce and the staff and management of the Hollywood-Roosevelt Hotel.

PROGRAM*

MONDAY, APRIL 17TH

General and Business Session; L. L. Ryder, *Chairman.*

10:00 a.m. Report of the Convention Committee; W. C. Kunzmann, *Convention Vice-President.*

Report of the Membership and Subscription Committee; E. R. Geib, *Chairman.*

Welcome by the President; E. A. Williford, *President.*

Society Business; E. A. Williford, *Chairman.*

Report of the Progress Committee; J. G. Frayne, *Chairman.*

"Safekeeping the Picture Industry;" K. W. Keene, Underwriters' Laboratories, San Francisco, Calif.

"Review of Foreign Film Markets;" N. D. Golden, Motion Picture Division, Department of Commerce, Washington, D. C.

12:30 p.m. **Informal Get-Together Luncheon;** E. A. Williford, *Chairman.*

Address of Welcome by the Honorable Fletcher Bowron, Mayor of the City of Los Angeles.

Guests: Mr. Lester Cowan, Producer, Universal Studios; Mr. Sinclair Lewis, Author; Mr. James Hilton, Writer, Warner Bros.-First National Studios; Mr. W. K. Howard, Director.

General Session; J. I. Crabtree, *Chairman.*

2:00 p.m. "The Polyrhetor—a 150-Channel Film Reproducer;" G. T. Stanton, Electrical Research Products, Inc., and F. R. Marion and D. V. Water, Western Electric Co., New York, N. Y.

"Technicolor Field Service;" G. Giroux, Technicolor Motion Picture Corp., Hollywood, Calif.

"Further Improvements in Light-Weight Record Reproducers, and Theoretical Considerations Entering into Their Design;" A. L. Williams, The Brush Development Co., Cleveland, Ohio.

"New Frontiers for the Documentary Film;" A. A. Mercey, United States Film Service, National Emergency Council, Washington, D. C.

"The Time Telescope;" C. R. Veber, Department of Biophotography, Rutgers University, New Brunswick, N. J.

"The Preservation of History in the Crypt of Civilization;" T. K. Peters, Oglethorpe University, Ga.

Photographic Session; K. F. Morgan, *Chairman.*

8:00 p.m. "The Fluorescent Lamp and Its Application to Motion Picture Studio Lighting;" G. E. Inman and W. H. Robinson, Jr., General Electric Co., Los Angeles, Calif.

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* As actually followed at the meetings.

"Mobile Photography by the Technicolor Method;" G. Cave, Technicolor Motion Picture Corp., Hollywood, Calif.

"Recent Improvements in Carbons for Motion Picture Set Lighting;" D. B. Joy, W. W. Lozier, and R. J. Zavesky, National Carbon Co., Fostoria, Ohio.

Report of the Studio Lighting Committee; C. W. Handley, *Chairman.*

"Remarks on the Work of the Research Council Process Projection Equipment Committee;" F. Edouart, Paramount Publix Corp., Hollywood, Calif.

"Carbons for Rear Projection Motion Picture Studios;" D. B. Joy, W. W. Lozier, and M. R. Null, National Carbon Co., Fostoria, Ohio.

"Twentieth Century Silent Camera;" G. Laube, Twentieth Century-Fox Film Corp., Hollywood, Calif.

"Flicker in Motion Pictures;" L. D. Grignon, Paramount Productions, Inc., Hollywood, Calif.

TUESDAY, APRIL 18TH

Projection Session; H. W. Remerschied, *Chairman.*

10:00 a.m. "Screen Color and Brightness;" W. C. Harcus, Technicolor Motion Picture Corp., Hollywood, Calif.

Report of the Projection Practice Committee; H. Rubin, *Chairman.*

Report of the Exchange Practice Committee; A. L. Schwalberg, *Chairman.*

"The Motion Picture in Education;" A. Shapiro, Ampro Corp., Chicago, Ill.

"Lamps and Optical Systems for Sound Reproduction;" F. E. Carlson, General Electric Co., Cleveland, Ohio.

"The Status of Lens Making in America;" W. B. Rayton.

"Technicolor Field Service;" G. Giroux, Technicolor Motion Picture Corp., Hollywood, Calif.

2:30 p.m. **Visit to Paramount Publix Studios;** under the direction of Mr. Loren L. Ryder, Director of Recording. The visit included an opportunity of viewing projection background shooting and visiting the stages where special effects and miniature work are carried out. Visits were made also to the Sound Department, Dubbing Department, and the Production Stages where picture shooting was witnessed.

Sound Session; B. F. Miller, *Chairman.*

8:00 p.m. "Methods of Using and Coordinating Photoelectric Exposure Meters at the 20th Century-Fox Studio;" D. B. Clark, 20th Century-Fox Corp., Hollywood, Calif.

"The Present Technical Status of 16-Mm. Sound-on-Film;" J. A. Maurer, Berndt-Maurer Corp., New York, N. Y.

"Recording and Reproducing Characteristics;" K. F. Morgan and D. P. Loye, Electrical Research Products, Inc., Hollywood, Calif.

"Analysis and Measurement of Distortion in Variable-Density

Recording;" J. G. Frayne and R. R. Scoville, Electrical Research Products, Inc., Hollywood, Calif.

"A New Film Playback;" D. G. Jones, Hollywood, Calif.

WEDNESDAY, APRIL 19TH

Sound Session; J. O. Aalberg, *Chairman.*

10:00 a.m. "A Sound-Track Projection Microscope;" G. M. Best, Warner Bros.-First National Studios, Burbank, Calif.

"Controlled Sound Reflection in Review Rooms and Theaters;" C. M. Mugler, Acoustical Engineering Co , Los Angeles, Calif.

"Acoustic Condition Factors;" M. Rettinger, RCA Manufacturing Co., Hollywood, Calif.

"Push-Pull Audio Transformer Design for Minimum Amplifier Distortion and Intermodulation;" B. F. Miller, Warner Bros.-First National Studios, Burbank, Calif.

"Use of an A.-C. Polarized Photoelectric Cell for Light Valve Bias Current Determination;" C. R. Daily, Paramount Productions, Hollywood, Calif.

"A Densitometric Method of Checking the Quality of Variable-Area Prints;" C. R. Daily and I. M. Chambers, Paramount Productions, Hollywood Calif.

"A New Mobile Film Recording System;" B. Kreuzer, RCA Manufacturing Co., Los Angeles, Calif., and C. L. Lootens, Republic Productions, Inc., North Hollywood, Calif.

Open afternoon.

Sound Session; R. M. Townsend, *Chairman.*

8:00 p.m. "A Direct Positive System of Sound Recording;" G. L. Dimmick, RCA Manufacturing Co., Camden, N. J., and A. C. Blaney, RCA Manufacturing Co., Hollywood, Calif.

"A Newly Designed Sound Motion Picture Reproducing Equipment;" J. S. Pesce, RCA Manufacturing Co., Camden, N. J.

"Class A-B Push-Pull Recording System;" C. H. Cartwright and W. S. Thompson, RCA Manufacturing Co., Hollywood, Calif.

"Report on Recent Activities of the Research Council Committee on Standardization of Theater Sound Projection Equipment Characteristics;" J. K. Hilliard, *Chairman.*

"Modern Instantaneous Recording and Its Reproduction Technic;" N. B. Neeley and W. V. Stancil, Norman B. Neeley Enterprises, Hollywood, Calif.

THURSDAY, APRIL 20TH

Photographic and Laboratory Session; D. E. Hyndman, *Chairman.*

10:00 a.m. "A Direct-Reading Photoelectric Densitometer;" D. R. White, DuPont Film Manufacturing Corp., Parlin, N. J.

"An Instrument for the Absolute Measurement of the Graininess of Photographic Emulsions;" A. Goetz, W. O. Gould, and A. Dember, California Institute of Technology, Pasadena, Calif.

"RCA Aluminate Developers;" J. R. Alburger, RCA Manufacturing Co., Camden, N. J.

"Some Factors Governing the Design, Construction, and Operation of a Motion Picture Laboratory;" Report of the Committee on Laboratory Practice; D. E. Hyndman, *Chairman.*

"Simplifying and Controlling Film Travel through a Developing Machine;" J. F. Van Leuven, Fonda Machinery Co., Los Angeles, Calif.

"A Reel and Tray Developing Machine;" R. S. Leonard, Municipal Light and Power System, Seattle, Wash.

2:30 p.m. **Visit to Warner Bros.-First National Studio;** under the direction of Major Nathan Levinson, Director of Recording. Visits were made to the Wardrobe and Property Departments, and also to the new unit of the Crafts Building. An opportunity was also afforded to visit the new ultra-modern laboratory, in addition to a general sight-seeing tour of the lot. Luncheon at the studio at 1:00 p.m.

8:30 p.m. *Blossom Room;* **Semi-Annual Banquet.**

Introduction of stars and prominent guests.

Dancing and entertainment.

FRIDAY, APRIL 21ST

Open morning.

Studio practice session; H. Griffin, *Chairman.*

2:00 p.m. "A New Magnetic Recorder and Its Adaptations;" S. J. Begun, The Brush Development Co., Cleveland, Ohio.

"Western Electric Microphones for Sound Recording;" F. L. Hopper, Electrical Research Products, Inc., Hollywood, Calif.

"A Cardioid Directional Microphone;" R. N. Marshall and W. R. Harry, Bell Telephone Laboratories, New York, N. Y.

"A Light-Weight Sound Recording System;" F. L. Hopper, E. C. Manderfeld, and R. R. Scoville, Electrical Research Products, Inc., Hollywood, Calif.

"Paramount Triple-Head Transparency Process Projector;" A. F. Edouart, Paramount Studios, Hollywood, Calif.

"A Classroom 16-Mm. Projector;" A. Shapiro, Ampro Corp., Chicago, Ill.

"Background and Aims of Erpi Classroom Films;" P. Cox, Hollywood, Calif.

"A High-Intensity Arc for 16-Mm. Projection;" H. H. Strong, Strong Electric Co., Toledo, Ohio.

"New 16-Mm. Recording Equipment;" D. Canady, Canady Sound Appliance Co., Cleveland, Ohio.

"Notes on French 16-Mm. Equipment;" D. Canady, Canady Sound Appliance Co., Cleveland, Ohio.

Open afternoon.

Television Session; S. MacKeown, *Chairman.*

8:00 p.m. "An Introduction to Television Production;" H. R. Lubcke, Don Lee Broadcasting Co., Los Angeles, Calif.

Report of the Television Committee; A. N. Goldsmith, *Chairman*.

"Application of Motion Picture Film to Television;" E. W. Engstrom and G. L. Beers, RCA Manufacturing Co., Camden, N. J.

"Continuous Type Film Scanner for Television;" P. T. Goldmark, Columbia Broadcasting Co., New York, N. Y.

"Television Studio Technic;" A. W. Protzman, National Broadcasting Co., New York, N. Y.

"Television Lighting;" William C. Eddy, National Broadcasting Co., New York, N. Y.

"Design Problems in Television Systems and Receivers;" A. B. Dumont, Allen B. Dumont Laboratories, Passaic, N. J.

SOCIETY ANNOUNCEMENTS

1939 FALL CONVENTION

OCTOBER 16TH–19TH

HOTEL PENNSYLVANIA, NEW YORK, N. Y.

At the meeting of the Board of Governors held on April 16, 1939, at Hollywood, the dates of the 1939 Fall Convention, to be held at New York, were established as October 16th to 19th, inclusive. The Convention will be held at the Hotel Pennsylvania.

Members are urged to make their preparations in advance for attending the meeting, and those who intend to submit papers for presentation are requested to communicate with the office of the Society at the earliest possible opportunity. The schedule of dates pertaining to manuscripts appears on the inside front cover of this issue.

Minimum hotel rates and excellent accommodations will be guaranteed by the Hotel to members, but in view of the great influx of visitors to New York because of the World's Fair, reservations should be made as early as possible.

Room reservation cards will be mailed to members of the Society early in September and they should be returned as promptly as possible to the Hotel.

A reception suite will be provided for the ladies and an excellent program of entertainment is being arranged by the Ladies' Committee.

Special *per diem* Hotel rates guaranteed to SMPE delegates, European plan, will be as follows:

Room for one person	\$3.50 to \$8
Room for two persons, double bed	\$5 to \$8
Room for two persons, twin beds	\$6 to \$10
Parlor suites, living room, bedroom, and bath, for one or two persons	\$12, \$14, and \$15

Parking accommodations will be available to those who motor to the Convention at the Hotel Fireproof Garage, at the rate of \$1.25 for 24 hours, and \$1.00 for 12 hours, including pick-up and delivery at the door of the Hotel.

Golfing privileges at country clubs in the New York area may be arranged at the Convention headquarters.

Registration headquarters will be located on the eighteenth floor of the Hotel at the entrance of the *Salle Moderne*, where the technical sessions will be held. Express elevators from the lobby will be reserved for the Convention. All members and guests attending the Convention are expected to register and receive their badges and identification cards required for admission to all the sessions of the Convention, as well as to several *de luxe* motion picture theaters in the vicinity of the Hotel.

The dates of the informal luncheon and the semi-annual banquet will be announced in a later issue of the JOURNAL. At the banquet the annual presentation of the SMPE Progress Medal and the Journal Award will be made, and the officers-elect for 1940 will be introduced.

An attractive program of papers, entertainment, and special functions will be arranged, the details of which will be announced later.

MID-WEST SECTION

At a meeting of the Mid-West Section, held at the manufacturing plant of the GoldE Manufacturing Co. at Chicago, Mr. Maurice Goldberg presented a paper describing "The GoldE Fluid Drive Take-Up" and related subjects. A buffet supper was served before the meeting.

STANDARDS COMMITTEE

At a meeting held at the Hotel Pennsylvania, New York, on May 19th, much time was devoted by the Committee to a consideration of the problem of sound-track dimensions, and in addition the Committee reviewed a number of projects submitted by the Deutscher Normenausschus, Secretariat for Committee 36 (Cinematography) of the International Standards Association. These projects included proposals of dimensions for feed-spools for projection; double 16-mm. film; 16-mm. camera and projector apertures; 8-mm. film and camera apertures; specifications for safety film; and raw film cores.

A recent proposal by the International Commission on Illumination regarding specifications of screen brightness was reviewed.

JOURNAL AWARD AND PROGRESS MEDAL

The following regulations pertaining to the Journal Award and the Progress Medal of the Society of Motion Picture Engineers are published in accordance with the provisions for such publication contained therein. Members of the Society who wish to nominate recipients for either or both the Awards should communicate their nominations to the General Office of the Society as promptly as possible.

JOURNAL AWARD

The Journal Award Committee shall consist of five Fellows or Active members of the Society who shall be appointed by the President and confirmed by the Board of Governors. The Chairman of the Committee shall be designated by the President.

A cash award ($50, or other sum as may be appropriated by the Board of Governors) shall be made at the Fall Convention of the Society to the author or authors of the most outstanding paper which is originally published in the JOURNAL of the Society during the preceding calendar year. This Award shall be known as the Journal Award. An appropriate certificate shall be presented to the author or to each of the authors, as the case may be.

A list of five other papers shall also be recommended for honorable mention by the Committee.

A majority vote of the entire Committee shall be required for the election to the Award. Absent members may vote in writing.

The Committee shall be required to make its report to the Board of Governors for ratification at least one month prior to the Fall Meeting of the Society.

These regulations, a list of the names of those who have received the Journal Award, the year of each award, and the titles of the papers shall be published annually in the JOURNAL of the Society.

The Journal Award Committee for the current year is as follows:

G. F. RACKETT, *Chairman*

L. A. JONES
M. C. BATSEL
J. G. FRAYNE
D. B. JOY

The Awards in previous years have been as follows:

1934—Peter Andrew Snell, for his paper entitled "An Introduction to the Experimental Study of Visual Fatigue." (*Published May, 1933*)

1935—Loyd Ancile Jones and Julian Hale Webb, for their paper entitled "Reciprocity Law Failure in Photographic Exposure." (*Published September, 1934*)

1936—E. W. Kellogg, for his paper entitled "A Comparison of Variable-Density and Variable-Width Systems." (*Published September, 1935*)

1937—D. B. Judd, for his paper entitled "Color Blindness and Anomalies of Vision." (*Published June, 1936*)

1938—K. S. Gibson, for his paper entitled "The Analysis and Specification of Color." (*Published April, 1937*)

PROGRESS MEDAL

The Progress Award Committee shall consist of five Fellows or Active members of the Society, who shall be appointed by the President and confirmed by the Board of Governors. The Chairman of the Committee shall be designated by the President.

The Progress Medal shall be awarded each year to an individual in recognition of any invention, research, or development which in the opinion of the Committee, shall have resulted in a significant advance in the development of motion picture technology.

Any member of the Society of Motion Picture Engineers may recommend persons deemed worthy of the award. The recommendation in each case shall be in writing and in detail as to the accomplishments which are thought to justify consideration. The recommendation shall be seconded in writing by any two Fellows or Active members of the Society, who shall set forth their knowledge of the accomplishments of the candidate which, in their opinion, justify consideration.

The Committee shall meet during the month of July. Notice of the meeting of the Committee held for the purpose of considering the award of the Progress Medal shall appear in the June issue of the JOURNAL. All proposals shall reach the Chairman not later than June 20th.

A majority vote of the entire Committee shall be required to constitute an award of the Progress Medal. Absent members may vote in writing.

The report of the Committee shall be presented to the Board of Governors for ratification at least one month before the Fall Meeting of the Society.

The recipient of the Progress Medal shall be asked to present a photograph of himself to the Society, and, at the discretion of the Committee, may be asked to prepare a paper for publication in the JOURNAL of the Society.

The regulations, a list of the names of those who have received the medal, the year of each award, and a statement of the reason for the awards shall be published annually in the JOURNAL of the Society.

The Progress Medal Award Committee for the current year is as follows:

A. N. GOLDSMITH, *Chairman*

J. I. CRABTREE
A. C. HARDY
O. M. GLUNT
E. W. KELLOGG

The 1935 Award was made to Edward Christopher Wente, for his work in the field of sound recording and reproduction (*cf. issue of December, 1935*).

The 1936 Award was made to Charles Edward Kenneth Mees for his work in photography (*cf. issue of December, 1936*).

The 1937 Award was made to Edward Washburn Kellogg for his work in the field of sound reproduction (*cf. issue of December, 1937*).

The 1938 Award was made to Herbert Thomas Kalmus for his work in color motion pictures (*cf. issue of December, 1938*).

ADMISSIONS COMMITTEE

At a recent meeting of the Admissions Committee at the General Office of the Society, the following applicants for membership were admitted to the Associate grade:

ANDERSON, H. F.
41 Marietta St., N. W.,
Atlanta, Ga.

BARRY, R. D.
3155 W. 75th St.,
Los Angeles, Calif.

BROWN, S. K.
Carter Hotel,
Welch, W. Va.

BYERS, R. E.
2212 Live Oak St.,
Dallas, Texas.

FALUDI, E.
31 Elvaston Pl.,
London, S. W. 7,
England.

GRANN, I.
19690 S. Lake Blvd.,
Cleveland, O.

GRAVES, F. O.
11202 Morrison St.,
North Hollywood, Calif.

GUDGEON, S. J.
92 Connaught Ave.,
Grays, Essex, England.

HALL, W. S., JR.,
607 N. Citrus Ave.,
Los Angeles, Calif.

HURD, E.
2719 Hyperion,
Hollywood, Calif.

JULIO, C. T.
Naval School,
Valparaiso, Chile.

KORRELL, W. F.
Western Equipment & Supply Co.,
Manila, Philippine Islands.

KRUPA, V. C.
130 West 46th St.,
New York, N. Y.

LI, N. F. C.
111 Station Ave.,
Haddon Heights, N. J.

LUTH, A. H.
300 Pitt St.,
Sydney, Australia.

MACKEOWN, S. S.
California Institute of Technology,
Pasadena, Calif.

MULKEY, D. L.
1217 Taft Building,
Hollywood, Calif.

NIKLASCH, J.
7635 Grand River Ave.,
Detroit, Mich.

PIKE, H.
25 Courland St.,
Five Dock,
Sydney, Australia.

QUIGLEY, G. P.
8024 Selma Ave.,
Hollywood, Calif.

ROSS, K.
63 Kingsley Ave.,
Rugby, England.

SCHEICK, J. A.
11427—200th St.,
St. Albans, Long Island, N. Y.

SEN, B.
45, Bowbazar St.,
Calcutta, India.

SHERLOCK, G. K.
643 S. Hill St.,
Los Angeles, Calif.

STRANDBERG, R.
225 E. 168th St.,
Bronx, N. Y.

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