B. E. STECHBART

JOURNAL

OF THE SOCIETY OF

MOTION PICTURE ENGINEERS

SYLVAN HARRIS, EDITOR

Volume XIX　　JULY, 1932　　Number 1

CONTENTS

JOURNAL
OF THE SOCIETY OF
MOTION PICTURE ENGINEERS

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Published monthly at Easton, Pa., by the Society of Motion Picture Engineers.

Publication Office, 20th & Northampton Sts., Easton, Pa.
General and Editorial Office, 33 West 42nd St., New York, N. Y.

Subscription to non-members, $12.00 per annum; to members, $9.00 per annum, included in their annual membership dues; single copies, $1.50. A discount on subscriptions 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 33 W. 42nd St., New York, N. Y.

Entered as second class matter January 15, 1930, at the Post Office at Easton, Pa., under the Act of March 3, 1879.

STANDARDIZATION OF PROJECTION LAMPS*

E. W. BEGGS**

Summary.—*One hundred and thirty types of picture projection lamps are today required to fill the demands placed on the lamp manufacturers. This large number of types, each being available in several different voltages and in most cases with either one of two kinds of bases, brings the total to over 500. The total annual demand for the entire country is only 240,000 units for lamps of this type. The result is that the lamps are expensive and that the amount of engineering that can be devoted to each type is entirely inadequate.*

This situation is partly because small improvements in lamps have been made almost annually in the past, and partly because of wide diversity of opinion among projector designers. By assembling and coördinating the ideas of equipment designers, an ideal set of light source requirements can be laid down. Based on these requirements the lamp manufacturers can then establish the characteristics of light sources to be introduced during the next few years.

Early in 1925, Mr. Hoover, then United States Secretary of Commerce, urged standardization and simplification of articles manufactured in this country. The advantages of such a program as was then begun were that the articles could be made in larger quantities and consequently at lower cost, that reduction in the number of types to be supervised would make possible higher quality, and that with greater interchangeability between specific articles of various brands, availability of any product would be increased. These advantages naturally applied to Mazda lamps, which are highly specialized manufactured articles of broad distribution. All of the factors involved in the program are of great importance to the far-flung but powerless ultimate consumers, and lie within the control of organized equipment manufacturers. Standardization of projection lamps, however, has not been widely discussed before this Society and now the need for it is great.

In 1931 the Mazda lamp manufacturers listed in their price schedules 134 types of lamps specifically for projection service. Even during the first few months of 1932, quite a large number of new projection lamp types have been added to the list.

* Presented at the Spring, 1932, Meeting at Washington, D. C.

** Commercial Engineering Dept., Westinghouse Lamp Co., Bloomfield, N. J.

Many of these types are available with several different bases and for more than one voltage so that actually the lamp manufacturers were forced to be ready to supply more than 570 different projection lamps to fill the national demand. The production schedule of the past year showed that almost all these were ordered. The total number of units manufactured was only 238,000, a relatively small demand to require as many different designs as are now listed. Besides this, it is occasionally found expedient to use lamps designed specifically for other types of service in order to meet requirements of peculiar projection problems. The types of lighting service for which these other lamps were actually designed are as follows:

Automotive Headlight	Floodlight
Airway Beacon	Airport Floodlight
Theatrical Spotlight	Radio Transmission
Photocell Exciter	Television
Airplane Headlight	Locomotive Headlight
Searchlight	Traffic Signal

This complicates the situation considerably beyond even that indicated by the data available on projection lamps alone.

An analysis of the present requirements reveals the sources of diversification. By separating the effect of voltage, lamp base, filament structure, bulbs, wattages, *etc.*, the importance of each factor can be discerned. From this, certain standardization procedure may appear practicable and the suitable steps toward the desired objective can then be taken.

TABLE I

Voltages Now Listed for Projection Lamps

A. Power Line Voltages,
   105, *110, *115, *120, 125, 130

B. "High Voltage,"
   220, 230, 240, 250, 260

C. Country Home Voltage,
   *28–32

D. Resistor Control Voltages,
   *28–32, *50, *52, *75, 90, 95, *100

E. Transformer Voltages,
   3, 5, 6, *6.5, 7.5, 8, 9.5, 12, 12.5, 14, 14.5, *20, 30. 32, 33

F. Battery Voltages,
   5–6, 6–8, 11–12, 28–32

* In common use.

VOLTAGE

Lamps are now available for picture projection service designed to operate on any one of 35 different voltages. These are shown in Table I.

Available data show that most of the lamps of the voltages listed are applied as indicated. Obviously there is some overlap in this application.

VOLTAGE APPLICATION

Somewhat more than half the projection lamps used in motion picture equipment today are operated directly from the power line. These are indicated by group A of Table I. An almost equal number of projection lamps are operated through a voltage reducing resistance unit, the latter being fixed by the manufacturer or controlled by the operator. These are indicated by group D of Table I. The remainder of the lamps used fall in one or more of the other four less important classifications.

VOLTAGE CONTROL

In a projector that the user is apt to carry from place to place so that he encounters varying voltages, some sort of voltage control should be provided. Also, for projectors which may on occasion (such as to combat daylight) require that the lamp brightness be stepped up to the maximum regardless of the consequent shortening of lamp life, this same control is needed. Such equipment is now commonly provided with variable resistance units arranged with a voltmeter or an ammeter so that the operator will know when the lamp is operating at the proper voltage or amperage. The lack of agreement as to the relative merits of the voltmeter *vs.* the ammeter has made it very difficult for the lamp designer to produce a product that will give the same performance in all apparatus.

The most common types of control are:

(1) Resistor and voltmeter.
(2) Resistor and ammeter.
(3) Variable resistor.
(4) Resistor and selector switch.
(5) Transformer with taps, and with voltmeter or ammeter.

In Fig. 1 is shown the effect of the voltage on the lamp performance. In Fig. 2 is shown the effect of the amperage on the lamp performance. From these two curves it is evident that the same accuracy in voltage setting produces almost double the uniformity in lamp performance as an equal accuracy in ampere setting. In addition to this, the use of a voltmeter makes it possible to use more than one wattage of lamp in a projector so equipped. Also, since lamp makers life test their product normally and most effectively at constant voltage, and since the published life of lamps is usually "life at volts," the voltage method is generally the proper control. For these reasons the voltmeter may be more desirable than the ammeter.

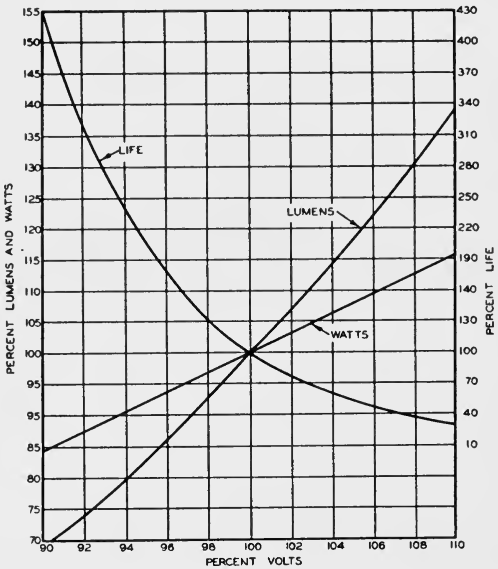


FIG. 1. Relation between voltage impressed on the lamp and its performance.

Of course, where very high amperages and low voltages are involved the ammeter may be preferable because it eliminates the effect of contact resistance. It should be borne in mind that operation of a lamp at constant amperage results in a burn-out life about half that of a lamp burned at constant voltage. The lamp run at constant amperage will maintain its light output somewhat better throughout life, whereas one run at constant voltage will fall off approximately 10 to 20 per cent. Nevertheless, the basic fact that lamp design is founded on voltage operation makes the voltmeter the preferred means of gauging lamp operating conditions.

To clarify the relative effect of voltage and amperage operation a specific instance will aid. The 250 watt, 50 volt lamp is operated at 50 volts in some machines and at 5 amperes in others. Any new lamp taken at random will produce practically the same illumination in either case. As the filament wears away during life, however, it becomes necessary gradually to increase the voltage so as to force 5 amperes through the filament wire. Actually the temperature of the filament will rise slightly under this forcing unless the tungsten wire sags, which does not commonly happen. This results in increasingly

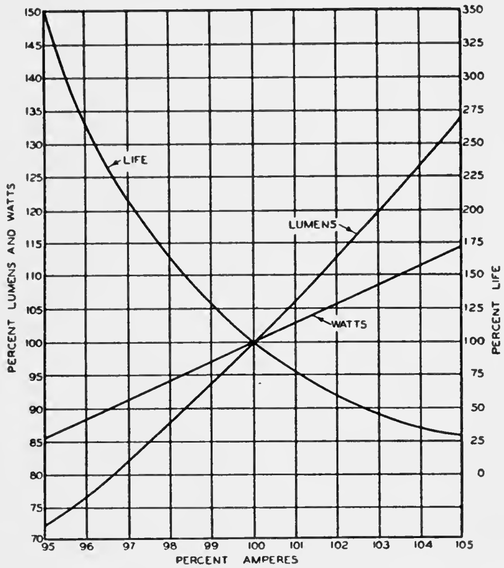


FIG. 2. Relation between the current forced through the lamp and its performance.

rapid evaporation of tungsten, which hastens the ultimate end of the lamp's life.

Some projection equipment provides voltage reduction by means of a resistance unit permitting changes in this resistance by the operator at will, and at the same time provides no meter to give the operator knowledge of the actual lamp operating conditions. Such equipment is apt to subject the lamp to extreme overload without the operator's being aware of the situation, a practice that evidently should be discouraged.

Certain motion picture projection equipment, particularly that in which the 900 watt Mazda motion picture lamp is used, utilizes a tapped transformer to reduce the voltage, and a voltmeter is provided for lamp control.

Another combination involves the use of a small fixed resistor which is sufficient to cut the voltage down from the minimum normally encountered to the rated voltage of the lamp. Other small resistors controlled by a selector switch are arranged to be introduced when higher voltages are encountered. In this manner a control device without a meter is provided, which makes it possible for the operator to run the lamp at approximately normal voltage at all times if he knows what the line voltage is. He can also operate the lamp below or above the normal voltage if he wishes. This compromise system is quite effective, and is similar to one used in certain radio equipment. It functions properly only when the lamp consumes the amperes for which the system was designed.

All these methods of voltage control affect lamp performance and standardization. One method should be adopted, if possible, so that the lamp performance will be approximately the same in all apparatus. The use of a resistor and voltmeter is proposed.

VOLTAGES ENCOUNTERED THROUGHOUT UNITED STATES

Table II shows the distribution of voltage within the 100–130 volt range for the years 1929 to 1931, inclusive, as indicated by sales of large Mazda lamps.

TABLE II

Voltages from Power Lines in U. S. within 100–130 Range

	Per Cent		
Volts	1929	1930	1931
100–105	0.1	0.1	0.1
110	6.5	5.2	3.7
115	49.5	48.9	48.0
120	39.4	41.3	43.9
125	3.4	3.5	3.3
130	1.1	1.0	1.1

Note that the 120 volt group has been growing, chiefly at the expense of the 110 volt group. Reports for 1932 show a further trend toward 120 volts. It is important also to appreciate a new factor, which is the tendency of the power companies to raise the voltage approximately two volts at the power panel of the building they are supplying with current. This has been found necessary to compensate for service voltage drop in the wiring of buildings throughout the country, resulting from the gradual increase in the use of electric apparatus during the past ten years. This increase in voltage at the power panel in part compensates for the voltage drop throughout the wiring of the building, and consequently should be borne in mind particularly where the new 25 hour higher intensity lamps are applied. Where no voltage control is provided in the projector, the voltage of the lamp should probably be the same as the voltage published by the power company supplying the current (thus agreeing with the socket voltage) unless, of course, the customer, for his own reasons, wishes the lamps to be otherwise.

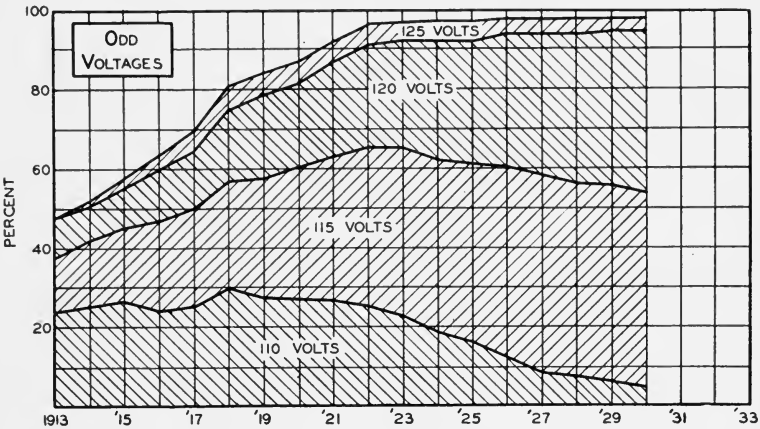


FIG. 3. Distribution of lamps by voltage within the 100–130 volt range.

Fig. 3 shows, in somewhat more detail, the growth of the 110, 115, and 120 volt groups since 1915. As far as distribution is concerned these three voltages represent practically 100 per cent of the voltage in the 100–130 group. Very few cases exist today where other voltages will be encountered.

A-C. VS. D-C. AND ALTERNATING CURRENT FREQUENCIES

No discussion of voltage is complete without mention of alternating *vs.* direct current, and of the varying frequencies of the former that may be encountered throughout the country. There is still an appreciable amount of direct current encountered, particularly in the centers of such cities as New York, Detroit, Chicago, and Boston. This is being gradually reduced but still can not be ignored.

Sixty-cycle alternating current represents 90 per cent of the electric power produced today in this country. Of the remaining 10 per cent there is some direct current in restricted areas of large cities, there is a great deal of 50 cycle alternating current on the Pacific Coast, and there are odd frequencies such as 25, 30, 33, and 40 cycles now to be met in the Eastern Great Lakes district and Canada. More than 93 per cent of the residential customers of electric power receive 60 cycle alternating current and the trend everywhere is definitely toward that form of current.

THE LAMP BASE

There are now seven bases used in the majority of picture projection lamps. They are as follows:

(1) S. C. Bayonet Candelabra.
(2) D. C. Bayonet Candelabra.
(3) Medium Prefocus.
(4) Medium Screw.
(5) Mogul Prefocus.
(6) Mogul Screw.
(7) Focusing Ring.

The most important of these in percentage of the total demand is the medium prefocus base. The next in order is the single contact bayonet candelabra (automotive)base, which is also effectively a prefocus device. Next in order comes the medium screw base with the special focusing ring attached and, following this, the remainder of the demand is shared by the mogul prefocus, mogul screw, medium screw, and the double contact bayonet candelabra base.

The use of prefocus lamps is definitely growing. Such devices greatly increase the satisfaction of the user and any piece of apparatus requiring the operator to focus the lamp should undoubtedly be discouraged. This is not only because the user prefers prefocused equipment from the standpoint of convenience, but also because by the elimination of the screw bases standardization will be prompted.

FILAMENT CONSTRUCTION

For projection service many, far too many, types of filament construction have come into use. In fact, there are probably more than twenty different filament designs used for this type of service. Eight important constructions are shown in Fig. 4. The first four, the C-13, C-13D, C-13A, and CC-13, are most appropriate for the lamps to be operated directly from the house lighting circuit or for voltages above 30. The lower group of four constructions, the C-2, 2-C-2, C-6, and

C-8, are mostly suitable for lamps of 20 volts or less. The C-13D filament is of the biplane construction reported by Mr. Mili in the succeeding paper in this issue of the JOURNAL.

THE LAMP BULB

During 1931, the T-10 bulb represented about 75 per cent of the demand for lamps used in 16 millimeter picture projectors. The T-20 bulb represented almost 100 per cent of the demand for 35 millimeter machines. The T-8, T-8$^1/_2$, and T-10 bulb lamps were used extensively in film slide equipment.

Until last year, practically all lamp filaments were mounted at or near the axial center of the bulb. Lens designers increased the light

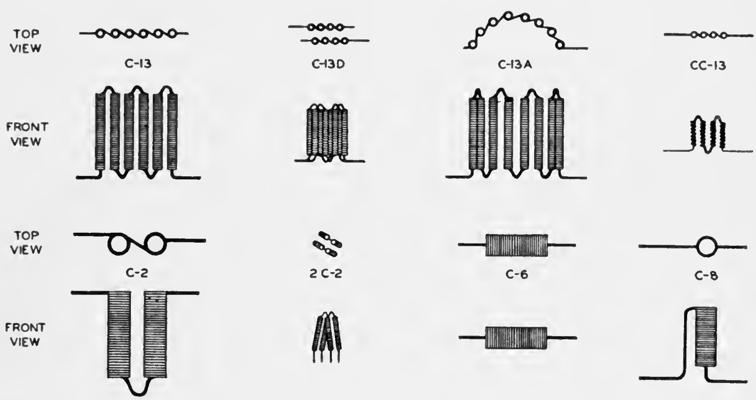


FIG. 4. Representative filament construction in use for projection service.

acceptance of their lenses, requiring larger filaments arranged in the lamp in such a way that they could be mounted closer to the condenser lens.

In 1931, this movement reached the point where centered filaments were no longer capable of fulfilling all the lens requirements, and lamps with offset filaments were created. Working in another direction, there were developed lamps having biplane filament light sources mounted in the center of the T-10 bulb. Mr. Mili's research indicates that the new lenses have been designed to accommodate relatively large filaments of high wattage close to the condenser lens, resulting in more severe conditions and greater danger of softening of the glass of the bulb.

These changing requirements of the projectors have made it necessary to study more critically the bulb glass, the bulb capacities and shapes, as well as the cooling mechanism provided by the projector. The new requirements seem to throw last year's standardization efforts into chaos. For this reason the lamp manufacturers make a plea for caution, and urge careful consideration of each new lamp and housing design before its adoption.

LAMP WATTAGE

The biplane filament construction will ordinarily require double the wattage of the monoplane construction for any given lens system. The wattage consumed by the lamp and resistor will ordinarily be unchanged. Nevertheless, the biplane structure will greatly increase the lamp wattages in common use. Also, changes in the concentration in the monoplane type of lamp has, in general, caused a step-up of wattage. This has further added to the seeming confusion with the result that, in 1932, projector lamp standardization is farther away than in 1931. Lamp manufacturers are, therefore, faced with a serious situation and are compelled to make efforts to improve matters.

A PLEA FOR COÖPERATION

The details given above indicate many of the various factors involved. Basically, the conditions being met today result from the fact that picture projection places complex requirements on the light source; that the apparatus, particularly in the 16 millimeter field, is relatively new and the requirements are changing; and that there is a general lack of appreciation of the advantage of standardization.

The complexity of the requirements demand a high degree of engineering skill in designing projectors. The changes which are occurring should not be stifled, but should be more uniformly coördinated and guided. An appreciation of the advantage of standardization, however, can be gained by analysis. If the results of standardization already achieved in general lighting lamps might be possible in projection lamps, the advantages become obvious. In Mazda lamps for general illumination of the home, for example, which have many of the characteristics of projection lamps, the list prices range as low as 20 cents. This is partly because the six types of lamps listed for this service in 1931 covered a total demand of over 200 million units for the entire United States for that year. Contrast this with the 238,000 projection lamps divided among 134 types. The chart in Fig. 5 shows the reduction in lamp prices since 1914. This was largely made possible by standardization.

Consider the possibilities of similar cost reduction of projection lamps as it would affect the practicability of *overvoltage operation.* By referring to the curves in Fig. 2, the enormous rise in lumen output is readily apparent. Suppose that the lamp price could be reduced to one-third the present figure; lamps could then be operated at 110 per cent of rated voltage without increasing the lamp operating cost. This would increase the screen illumination by about 40 per cent. At 125 per cent rated voltage, the screen brightness would be more than doubled.

Several specific recommendations can be made in order to improve standardization: Adopt 100 volt lamps operated with resistors and voltmeters, as the standard for the industry. When the cost of the

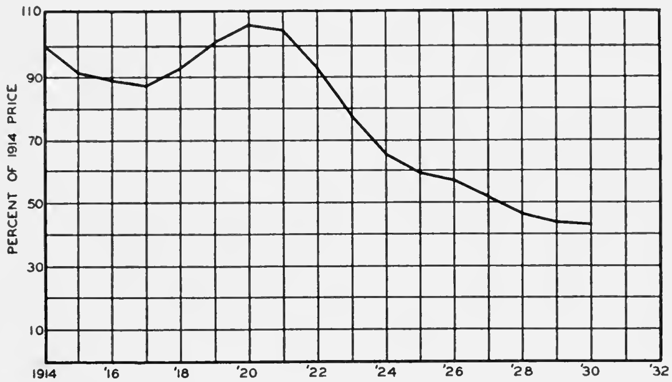


FIG. 5. Per cent price reduction of large Mazda lamps since before the World War.

apparatus prohibits this refinement, the selector switch, or its equivalent, should be used and in other cases the lamps should be operated direct from the power line. Use prefocus bases in all equipment.

Standardization may entirely change the trend of lamp design and application, but when the changes follow standardization they come gradually and systematically. The result is to the benefit of the public and all those interested in the motion picture industry. The Mazda lamp manufacturers are committed to do their part of the work. They solicit suggestions and coöperation from the designers and builders of projection equipment. They urge that a careful survey of the lamp situation be made, and trust that in the future they will be called upon to provide lamps and lamp data to the designer early in his work rather than after the projector has been laid out or built, as has been the case in the majority of instances in the past.

DISCUSSION

Mr. Farnham: Mr. Beggs has brought out in considerable detail the large number of types of projector lamps that have been produced through the ramifications of bulb sizes, voltages, filament constructions, lives, and bases. It so happens that whenever a projector has been developed and a new lamp is designed for it, the lamp seems to be forever with us, whether or not the projector continues to be made or has been discarded; the reason being that a few people continue to use the projector and so long as there is a demand for the lamp, no matter how small, it is continued on the list. So, without meaning to detract from Mr. Beggs' plea for standardization of projection lamps, I might mention that about ninety per cent of the projection lamp business is confined to about twenty distinct types.

Furthermore, the projection field, particularly the 16 millimeter part, is going through a very active stage of development. New types of projectors are being produced at frequent intervals, and such a situation makes standardization difficult. I know of developments now in progress in the lamp laboratories which in a short time may make many of our present types obsolete.

Nevertheless, standardization is necessary, and its importance should be kept in mind by every one who uses projection lamps, and by close coöperation between the lamp manufacturers and the producers of projection equipment, a far better degree of standardization can be achieved.

Mr. Beggs did not mention one important cause of confusion. Many types of projection lamps are created unnecessarily, merely because projector manufacturer "A" asks for a lamp that will give his projector more light than "B's" projector. Then manufacturer "B" immediately returns and asks for a lamp to produce a brighter screen than "A's" equipment, and so on. In such cases, the the lamp is sometimes only a partial answer to the problem. Some manufacturers seem to place on the lamp manufacturer the entire burden of providing the additional light, to avoid the expense of making changes in their projectors. During the past year the optical people have made marked improvements in both condensing lenses and objectives, which make possible the obtaining of nearly twice the illumination now available from any projector on the market. Of course, these improvements will require modification of the projector, but sooner or later some manufacturer will adopt these new lenses and the rest will have to follow. Why not make use now of these new developments and obtain the optimum screen results, even though this would require that the projector be redesigned? Lamp and projector manufacturers would be spared the troubles attending a succession of small changes which, after all, would lead to this result.

Mr. Beggs: Variations in voltage, base, and design life are almost as serious as variations in filament form, bulb, and rating. Let us standardize on one voltage for all high intensity lamps—perhaps 100 volts. For cheap lamps we may adopt the line voltage. Let us standardize exclusively on prefocused lamps. Let us use either voltmeters or ammeters, but not both. Such steps will reduce the actual number of types required through future years to only a fraction of the present number.

BIPLANE FILAMENT CONSTRUCTION—A HIGH INTENSITY INCANDESCENT LAMP LIGHT SOURCE FOR MOTION PICTURE PROJECTION*

J. T. MILI**

Summary.—*Manufacturers of motion picture projectors have been continuously demanding increasingly brighter and more uniform light sources. The biplane staggered filament construction, consisting of two parallel rows of coils, so placed that the coils in one plane fill the spaces between coils in the other, is now being presented as the lamp manufacturer's answer to this demand of the industry. A report is presented on comparative tests made with monoplane and biplane filament lamps ranging in wattage from 200 to 1000, with several types of optical systems. A description of the methods pursued in taking screen lumen readings and making bulb temperature measurements is also included.*

The desirability of a Mazda high intensity incandescent lamp for motion picture projection which could be operated on either alternating or direct current at or near the prevailing line voltage in the United States, and having a greater average source brightness and uniformity than the types now in common use, has led to a re-investigation of the biplane filament construction. The relative merits of this filament construction, which consists of two parallel rows of coils so placed that the coils of one row fill the spaces between the coils of the other, as shown in Fig. 1, were outlined as early as 1918 in a paper[1] presented before this Society by Mr. A. R. Dennington, of the Westinghouse Lamp Company.

Since then some attempts, both here and abroad, to develop a practical design of the biplane filament have met with little success, chiefly, perhaps, because at that time only low voltage lamps were being considered, whereas the advantages of the biplane filament seem greatest with the 100 volt lamp. About a year ago this laboratory, in conjunction with optical and projector designers, undertook to carry on a series of researches with the idea of determining the most

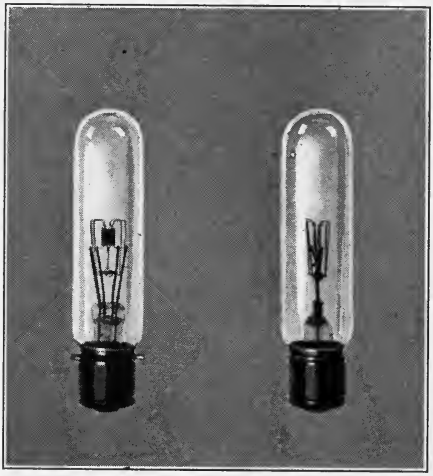
* Presented at the Spring, 1932, Meeting at Washington, D. C.

** Commercial Engineering Laboratory, Westinghouse Lamp Co., Bloomfield, N. J.

suitable filament construction for motion picture projection lamps. The biplane filament construction which is now being discussed is the outcome of these investigations.

LIGHT SOURCE CHARACTERISTICS

By using the double row of filament coils the average brightness of the light source is, as might be expected, almost doubled. This is shown graphically in Fig. 2, which indicates the extent of this increase at various wattages for 115 volt biplane and monoplane light sources suitable for direct operation from the lighting circuit, and the 50 volt



Front View Side View

FIG. 1. 400 watt 100 volt T-10 bulb biplane filament projection lamp.

monoplane, which has been extensively used in recent years where increased picture brightness has been demanded. The measurements were in each case made without a reflector, and in a direction normal to the filament planes.

The photographs in Fig. 3 exhibit the actual reduction in source size and increase in brightness and uniformity produced by the biplane (C-13D) construction as compared with the monoplane (C-13), with filaments of identical electrical rating. The light sources photographed were 1000 watt, 115 volt sizes, and are shown with and without the use of a spherical silvered glass reflector.

For a comparison of the two filament constructions as applied to projection purposes, vertical and horizontal candlepower distribution curves, shown in Figs. 4 and 5, were taken, with sources of approximately equal dimensions and with a spherical mirrored reflector. Under such conditions, the amount of light in the usual acceptance angle of a condenser system, *i. e.*, 70 to 110 degrees, is about 60 per cent greater with the biplane than with the monoplane. This is because a biplane lamp of equal source dimensions permits the use of twice the wattage of the monoplane.

SCREEN ILLUMINATION TESTS

The comparison was further extended by making tests to determine the screen performance of the two types of filament construction in some of the existing commercial optical systems. Table I gives relative values of initial screen illumination for lamps with C-13

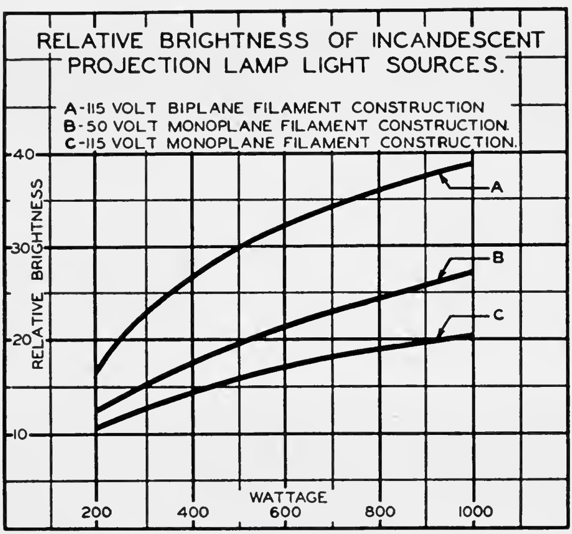


FIG. 2. Relative brightness of 115 volt biplane, and 50 and 115 volt monoplane, light sources.

and C-13D filament constructions of approximately the same source area, when used in four widely divergent optical systems designed for 16 millimeter projection. It may be seen from these figures that with any system an average increase of approximately 60 to 70 per cent in screen illumination may be expected from the use of the 100 volt biplane filament over the 100 volt monoplane of the same source size, and about 45 per cent over the 50 volt monoplane. This is achieved by doubling the lamp wattage in the biplane types.

TABLE I

Relative Initial Screen Illumination Values with Biplane and Monoplane Projection Lamps in 16 Mm. Optical Systems

Lamp Data			Screen Illumination Data*			
			Condenser			
			Spheric 1 in.	Aspheric $1^3/_4$ in.	Aspheric 1 in.	Aspheric $1^3/_4$ in.
			Objective			
			$f/2.0$	$f/2.0$	$f/1.65$	$f/1.65$
			Distance from Filament to Condenser			
Watts	Volts	Fil. Constr.**	18 mm.	23 mm.	12.5 mm.	16 mm.
			Illumination			
200	100	CC-13	100.0	100.0		100.0
200	50	C-13	123.5	122.0		135.0
400	100	C-13D	187.0	184.0		178.4
300	100	C-13	100.0	100.0	100.0	100.0
300	50	C-13	116.3	116.0	116.0	115.0
600	100	C-13D	172.0	162.0	173.0	158.7

* Includes the use of a spherical mirror.

** C-13 indicates the monoplane, C-13D the biplane, and CC-13 the coiled coil monoplane type of filament construction.

Similar increases in screen illumination may be obtained, as shown in Table II, by means of the biplane in two widely used 35 millimeter film projection systems. The data given are based on equal life to burnout when operated with a mirror reflector.

TABLE II

Relative Initial Screen Illumination Values with Biplane and Monoplane Projection Lamps in 35 Mm. Optical Systems

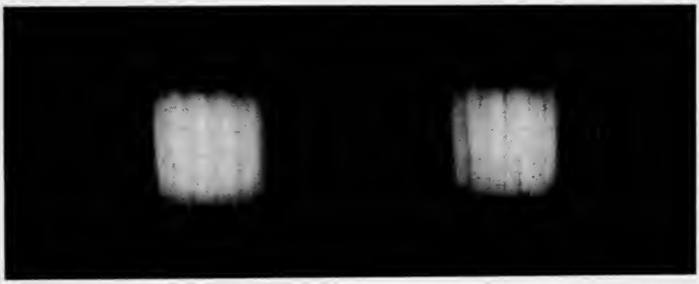
Lamp Data			Screen Illumination Data*	
			Condenser	
			Prismatic	Aspheric
			Objective	
			No. 2; 5.5 in. focus	No. 2; 5.5 in. focus
			Distance from Filament to Condenser	
Watts	Volts	Fil. Constr.**	2 in.	$1^7/_8$ in.
			Illumination	
500	100	C-13	100.0	100.0
500	50	C-13	117.2	112.5
1000	100	C-13D	159.0	164.6

* Includes the use of a mirror.

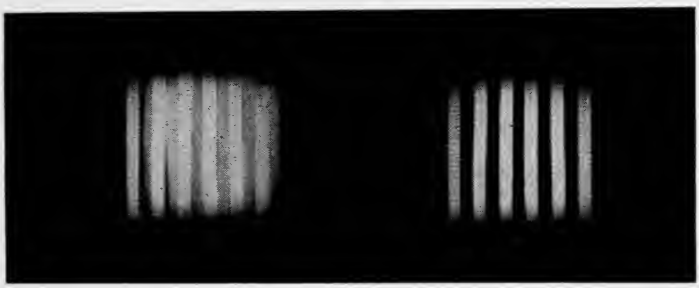
** C-13 designates the monoplane type of filament construction, C-13D the biplane.

All the measurements were made with the filament at the designed distance from the condenser and do not take into account screen appearance, which in some cases was equally satisfactory with both filament constructions, but in others was less satisfactory with the monoplane.

1000 watt 115 volt biplane filament.
(*A*) with reflector (*B*) without reflector.



1000 watt 115 volt monoplane filament.
(*C*) with reflector. (*D*) without reflector.



Ratio of light brightness.

	Source area	Ratio
A/C	.512	1.63
B/D	.547	1.84

FIG. 3. Relative light source area and uniformity of monoplane and biplane filament lamps of the same electrical rating.

Figs. 6 and 7 illustrate the method of mounting lenses on the optical bench, and the integrator used for obtaining total screen lumen readings. For measurements of uniformity, use was made of a Weston Photronic cell illumination meter as shown in Fig. 8.

The increase in total screen illumination, due to the use of a spherical mirror with the biplane filament, has been found to be on the average approximately 30 to 35 per cent. This increase is due partly to the reflected light which filters through the coils between filament turns, partly to the light which passes back between the filament coils, especially at horizontal angles from 35 to 55 degrees on either side of the optical axis, and finally to the rise in filament temperature caused by the mirror image, which in this case is superimposed on the filament itself.

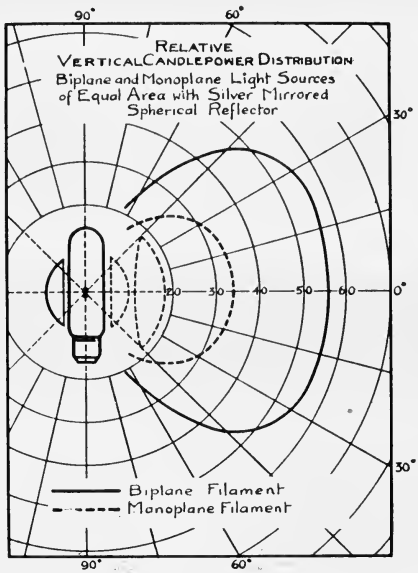


FIG. 4. Candlepower distribution in the vertical plane passing through the optical axis.

INFLUENCE ON OPTICAL DESIGN

It has often been stated that maximum efficiency in a motion picture projector would be obtained by focusing the image of a solid light source at the film gate. However, since the available light sources are not absolutely uniform, projectors must be designed with the filament focused in a plane beyond, rather than at the film aperture, in order to obtain an evenly illuminated screen. With the biplane construction the light source is quite uniform in brightness, so it becomes possible to focus the filament in a plane nearer the aperture than is now practical with the monoplane, thereby gaining in efficiency without entailing a loss in screen quality. This brightness uniformity is shown photographically in Fig. 3. Full utilization of this factor will come only with lens systems designed specifically for the new filament construction.

Furthermore, even with a well-designed projection system, owing to the existence of aberrations in the condenser, it is quite possible to get color fringes or banded appearances on the screen. These are "out-of-focus" images of the filament, and, if produced, are much less troublesome with the biplane since the periodic variation in intensity across the source is less with it than with the monoplane.

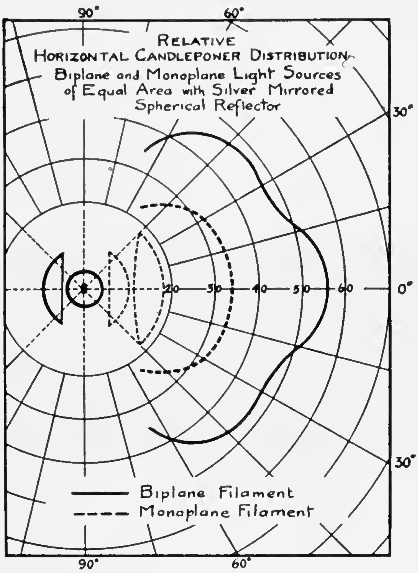


FIG. 5. Candlepower distribution in the horizontal plane.

UNIFORMITY OF PERFORMANCE

In order to render as simple as possible the operation of placing new lamps in the projectors, most manufacturers use prefocus base lamps. This, of course, assumes that the tolerances allowed in the making and setting of prefocus sockets and bases will not appreciably change the performance of the projector with each lamp renewal. The biplane filament reduces the need for extremely accurate adjustment of lamp and mirror, as demonstrated by a test run to determine the actual extent of this effect.

In the test, a group of nine 250 watt, 50 volt projection lamps with the monoplane filament, and nine 400 watt, 100 volt projection lamps with the biplane filament, both types with medium prefocus bases, were picked at random from the factory product. A lamp of each type was set in a representative commercial 16 millimeter projector designed for prefocus base lamps, and properly adjusted for the best screen illumination. Then the rest of the lamps in each group were placed successively in the projector without changing the socket or mirror setting, and relative readings of the screen illumination were obtained. These results are embodied in Table III.

TABLE III

Effect of Adjustment on Lamp Performance

Relative Variation in Screen Illumination as Lamps with Medium Prefocus Bases Are Interchanged in Commercial 16 Mm. Projector. Test Run with Representative Lot of Commercial Lamps

	Per Cent Screen Lumens	
Lamp No.	400 Watt, 100 Volt Biplane	250 Watt, 50 Volt Monoplane
1*	100.0	100.0
2	95.2	91.0
3	95.2	85.6
4	94.8	91.0
5	92.7	82.0
6	92.2	84.4
7	92.4	93.3
8	99.3	96.7
9	93.7	93.7
Maximum Deviation	7.8	18.0
Average Deviation	5.0	9.2

* Lamp No. 1 adjusted for best possible focus.

The monoplane lamps show a maximum drop in screen lumens of 18 per cent, for Lamp No. 5, and an average drop of 9.2 per cent. With the biplane lamps, the maximum screen lumen drop is only 7.8 per cent (Lamp No. 6), while the average drop for the whole group is 5.0 per cent.

With the biplane the mirror increase is only slightly more than half that obtained with the monoplane. Hence less loss in illumination on account of faulty mirror setting or other similar causes would be expected. A series of readings taken with the mirror at the proper focal position and then at several other settings behind and in front of this point confirms this. The drop in illumination was but half as great with the biplane as it was with the monoplane, and, of course, there was less change in uniformity.

THE COOLING PROBLEM

The use of biplane staggered filament lamps for 16 millimeter projectors, on account of the relatively large wattages involved and the

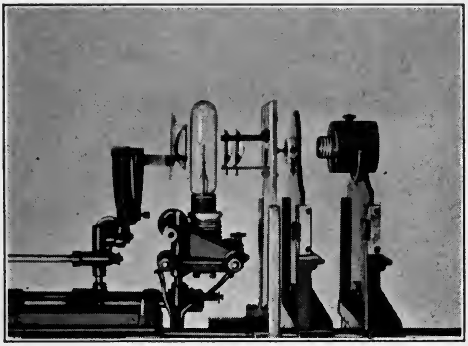


FIG. 6. Optical bench set-up.

small distances between the filament and the first condenser surface, for which optical systems are now being designed, introduces an acute lamp cooling problem. For instance, some systems have recently

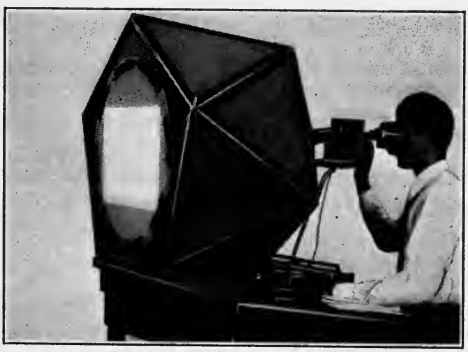


FIG. 7. Integrating photometer for total screen lumen measurements.

been designed for a separation of only 12.5 millimeters between the condenser and the filament. This would require placing the filament in the center of a bulb with a diameter of less than 1 inch or else in an offset position in a larger bulb. Under such conditions an extremely active draught of air will be required in order to prevent the bulb from bulging. The lamp manufacturers are willing to cooperate with designers in this matter, although the determination of the amount of ventilation needed for cooling lamps in the various types of projectors and the method of applying it are naturally problems for the equipment manufacturer. Temperature tests indicate that no bulging or devitrification of the hard glass now used for projection lamp bulbs will occur if the temperature at the hottest point

FIG. 8. Measurements of screen brightness uniformity with a Weston Photronic cell illumination meter.

FIG. 9. Equipment for measuring bulb glass temperature.

on the bulb is less than 500°C. The hottest spot usually lies exactly opposite the filament on the condenser side.

Fig. 9 illustrates the method of determining bulb glass temperature. As shown in the inset, a thermocouple is cemented to the bulb wall directly in front of the filament. Readings are taken with a calibrated millivoltmeter or a potentiometer after temperature equilibrium has been reached. The photograph shows readings being taken on a lamp outside the projector. Naturally each projector design must be tested with each type of lamp in question, and with the lamp and machine in actual operation.

Hitherto, low voltage lamps requiring large rheostats and transformers for their operation have been the only means of obtaining reduced source size and increased source brightness with a corresponding increase in screen illumination. Biplane projection lamps of the types here reported are being made for voltages ranging between 100 and 130. This makes possible direct connection of the lamp to the lighting circuit, whether a-c. or d-c. or, as is preferable, the use of a small rheostat in series with the 100 volt lamp for close regulation and more uniform performance.

REFERENCE

[1] DENNINGTON, A. R.: "Incandescent Lamps for Motion Picture Service," *Trans. Soc. Mot. Pict. Eng.* (April, 1918), No. 5, p. 36.

DISCUSSION

MR. GAGE: In the construction of the biplane filament as described in this article, two monoplane filaments are mounted side by side in such a way that if one observes perpendicularly to the plane of the filaments, the filaments of the rear plane fill in the gaps between the filaments of the front plane; and if observed from this direction, the entire area of the filament appears to be covered with tungsten coils, giving the greatest brightness that can be obtained by this construction—that is, the projected area is nearly filled with hot tungsten. If, however, the lamp is slightly rotated, the individual filaments in the rear plane will be shaded by those in the front plane, and the appearance will be exactly the same as though only the front filaments were observed, and blank spaces will appear between the individual coils of the monoplane filament. It is true that these spaces can be filled with images of the filament by using a suitable concave mirror, but the efficiency of such reflection does not exceed 75 per cent when the lamp is new, and a very slight blackening of the bulb results in a drop in brightness to a low value. The result is that the maximum average brightness of the filament image is greatest along the axis of the condenser and the optical system of the projector; whereas the beams, proceeding from the filament in a diagonal direction and striking the edge of the condenser, have a low average brightness, owing to the spaces left vacant between the coils of the filament. As it is these diagonal rays that serve to illuminate the edges of the picture, a general tendency of the projected screen image to be less intense toward the edge of the picture than in the center, is aggravated. While there are many arguments to the effect that it might be advantageous to illuminate the edge of the picture slightly less than its center, partly on the ground that the main interest of the picture generally occurs near the middle of the screen, careful observation of both professional and amateur motion pictures shows that the center of interest is often to be found at one extreme edge or corner of the picture, and apologies for ununiform screen illumination can hardly be tolerated when optical systems allowing a high uniformity of screen illumination may be devised. To set the tolerances for what might be classed as satisfactory uniformity of screen illumination is, however, not my purpose in this discussion. In the case of biplane filaments, I suggest that in order to compensate for the natural tendency of optical systems to be more efficient in the axial than in the marginal direction, owing to the increased reflection of the diagonal rays and to the vignetting effect of the diaphragms in projection objectives, the rear row of filaments be mounted directly behind the front row, thus showing such an aspect to the edges of the condenser as to provide greater brightness in this directions, in order to compensate for the lessened efficiency of the optical system. The spaces between the filaments, as seen in the axial direction will, of course, be filled as well as possible with the reflected light from the concentric spherical mirror.

MR. RAYTON: It is well understood that standardization is one of the later stages in the life's history of any development. In fact, it has been stated that the next step is obsolescence. Nevertheless, there is nothing to be gained by postponing standardization longer than is necessary, and I, therefore, wish to second the plea that it be delayed no longer than is necessary. None of us would wish to see standardization accomplished at the expense of further improvement, and it is now a question whether the lamp manufacturer has reached a limit beyond which he is not soon likely to go. Conditions have been chaotic, but out of the chaos improvements have come. The lamp designer and the lens designer have at times been distressed by an apparently needless multiplicity of demands, but nearly all developments viewed in retrospect disclose an immense amount of apparently wasted effort. In view of the increase in brightness of the projected image now possible, this effort in connection with 16 millimeter projectors has not been in vain.

The biplane filament lamps have been a very interesting, and will doubtless prove to be a profitable, development. From the standpoint of the design of optical systems, the filament area has a tendency to be too small. If we ask the lamp designer for a larger area, he can meet the requirement only by increasing current consumption. This means more heat and possibly a larger bulb. If the diameter of the bulb is increased, the filament-to-condenser distance increases, and possibly no gain in illumination is realized unless we increase the size of the condensers and, in turn, the size of the whole projector. Relief has been offered in the form of offset filaments, but this is a complication for the lamp maker that multiplies the number of kinds of lamps he has to produce and increases costs.

At the present time, we would say that the lamp competent to produce the brightest possible picture with the best available optical system, employs a biplane filament lamp with a filament area of 8.5 by 8.5 millimeters, with distance from filament to bulb wall not more than 16 millimeters. Such a lamp would consume about 600 watts, according to the best information we have, and would require to be set ahead of the center of the bulb. These dimensions would not allow for decentration of the lamp, but would assume perfect adjustment.

MR. FARNHAM: Mr. Mili has brought out very well the advantages of the biplane filament construction over the monoplane form, but he has unfortunately not presented the complete picture with regard to 16 millimeter projectors. There is no question that the biplane filament construction places more hot tungsten within a given source area, and were that the sole criterion, all motion picture projector lamps would have been changed to the biplane form just as quickly as our recent improvements in filament wire made it practicable. However, the biplane filament is fundamentally more costly than the monoplane, and there are yet other considerations.

For wattages ranging from 50 to 300, monoplane construction appears to be more desirable, considering all factors. Optical systems generally employed for 16 millimeter motion picture projectors are so designed as to utilize a source area represented by a circle from eight to ten millimeters in diameter. Tubular bulb projection lamps of the 115 volt class, in wattages ranging from 50 to 300 watts, can have monoplane sources that either do not fill this usable source area or just fill it. Conversion of any of these lamps to the biplane construction will result in practically no gain in screen illumination because, although the mass of the source is placed slightly closer to the optical axis, the loss of light due to shadowing of the rear coils by the front coils and the reduced mirror advantage are so great as to make any net gain negligible in proportion to the increased lamp cost.

Where the maximum amount of light is required—with wattages above 300—the biplane construction possesses the advantage. Monoplane sources greater than 300 watts are larger than the 8 to 10 millimeters usable source area, and hence part of the source is not utilized (although there is some increase in screen illumination because of the somewhat higher average temperature of the usable area).

Considering the problem of ventilation, most projectors using lamps of the 50 to 300 watt range depend on either a natural or a moderate volume of forced ventilation through the lamp house; hence substitution of the biplane construction with its inherent doubling of the wattage would in many cases result in excessive temperatures and poor lamp performance. Where the selling price of the projector will permit, a high volume of forced ventilation, of the order of 40 to 50 cubic feet of air per minute, requiring a high-speed fan and introducing the problem of noise elimination, lamps of 500 to 600 watt ratings in small tubular bulbs, offsetting the filament if necessary, can be employed. The biplane filaments of such lamps make full use of the available source area, and maximum screen illumination is obtained.

Projectors of the low and medium priced class can hardly be expected to carry the added burden of a greater lamp cost, particularly when the screen results are only slightly better or not better.

MR. MILI: Mr. Gage's suggested modification of the biplane filament construction has already been considered, and lamps having such a filament construction have been compared, using a $1^3/_4$ inch aspheric 16 millimeter lens system, with the present staggered construction. This comparison indicates that a somewhat smaller total screen lumen output, with no appreciable increase in brightness at the corners, will be obtained by using this modified construction.

Mr. Rayton's data on the best light source dimensions for 16 millimeter projectors are n good agreement with our own findings. Such an experimental lamp was used in the tests herein reported.

Replacing a monoplane filament by a biplane filament of the same electrical rating and life will result in a gain in screen illumination, if the monoplane light source is too large to be accommodated fully by the lens system. This gain is even greater when the biplane is substituted for the C-13A filament now standard for the 1000 watt line voltage projection lamp. For example, in the most commonly used 35 millimeter optical systems, the C-13D filament produces about 40 per cent greater screen brightness than the C-13A.

ILLUMINATION IN PROJECTION PRINTING OF MOTION PICTURES*

CLIFTON TUTTLE AND D. A. YOUNG**

Summary.—*In projection printing of motion pictures, it is essential that the illumination in the printing plane be uniform and of high intensity. It is also desirable that the light in the negative plane be more or less diffused in order to minimize the effect of scratches and reduce contrast. Since the introduction of diffusion into an optical system is accompanied by a loss of intensity and possibly also of printing plane uniformity, experiments have been made to determine what conditions are most favorable from the points of view of uniformity and diffuseness.*

In the design of projection printing optical systems there are three points of special interest to consider: First, it is essential that there be a certain degree of uniformity of illumination in the printing plane. Second, it is desirable that the intensity be as great as possible in order that the time of exposure may be reduced to a minimum. Third, it is important that the illumination in the negative plane be not entirely specular. Diffuse light tends to eliminate the printing of accidental scratches and dirt on the negative and to reduce the contrast of the optical image.

The fulfillment of the first and third of these desiderata almost invariably is prejudicial to the best interests of the second, and the conditions favoring the first are not always desirable from the point of view of the third. Thus, a study of all of the factors involved may lead to the discovery of a set of optimum conditions.

We have, therefore, attempted a systematic determination of essential data applying to various optical systems in the hope that the possession of such data may aid the designer of a projection printer in the choice of his optical system and its component parts.

While these data are primarily intended for use in conjunction with motion picture printing, they can in most cases either directly, or by extrapolation, be applied to other similar projection printing problems.

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* Presented at the Spring, 1932, Meeting at Washington, D. C. Communication No. 496 from the Kodak Research Laboratories.

** Research Laboratories, Eastman Kodak Co., Rochester, N. Y.

THE LAMP

Since the principal purpose of this work is to find the conditions which will give a maximum amount of light with acceptable illumination conditions of uniformity and diffuseness, we have selected a high intensity source—the 500 watt monoplane filament projection type lamp—for special study.

Regardless of the type of optical system to be used, it is of interest to determine the intensity distribution in planes parallel to the filament and at various distances from it. This can be computed,[1] but for multiple filament lamps the computation becomes very laborious, and, moreover, this calculation would disregard the effect of the glass bulb itself, one side of which acts as a cylindrical mirror, while the other side acts as a weak negative cylindrical lens.

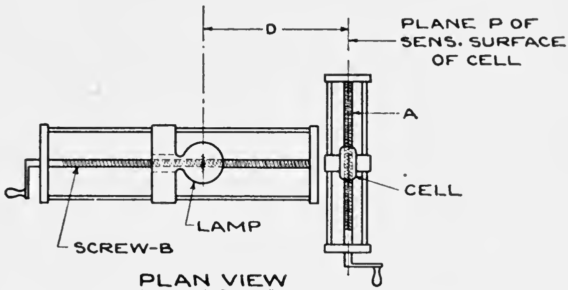

FIG. 1. Apparatus used to determine the distribution of intensity in optical printing systems.

Consequently, it was decided to do this part of the work by measurement rather than by calculation. We have used the set-up shown in Fig. 1, using a Weston Photronic cell and a Leeds & Northrup high sensitivity galvanometer. The sensitive surface of the cell was covered with an opaque diaphragm containing a slit 1 millimeter wide by 3 millimeters long. This diaphragm was made of aluminum leaf and was in direct contact with the sensitive surface. By turning screw A, the light-sensitive cell would be moved in a plane parallel to the filament any desired distance and in measured increments. By adjusting screw B, the distance, D, from the lamp filament to the cell could be varied. Thus, it is possible to measure the intensity in any plane, P, along a horizontal line through the axis, since the galvanometer deflection is proportional to the illumination. The intensity variation along this line was adopted as a criterion of evenness of illumination. The data are shown graphically in Fig. 2: the ordinate scale representing $\log_{10}$ photographic meter-candles* with the lamp operated at its rated voltage, the scale of abscissas representing the distance from the optical center line in millimeters. This plot shows that to illuminate a motion picture frame 23 millimeters wide with no measurable falling off of intensity from center to edge, the frame must be located at least 280 millimeters from the lamp filament.

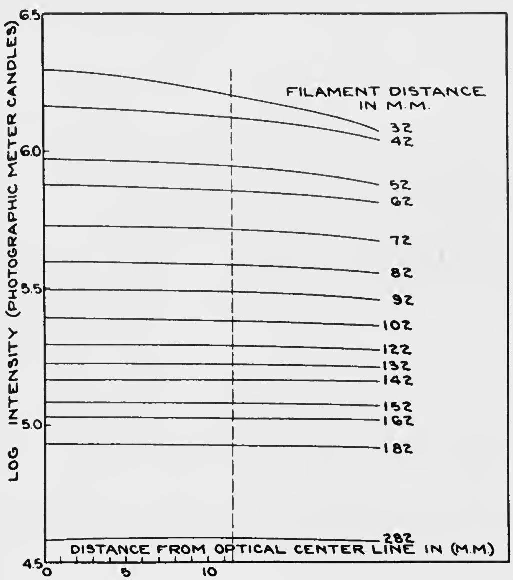

FIG. 2. Horizontal distribution of intensity from a 500 watt projection type lamp at various distances from the filament.

It is of interest to present these data in the form of a table. To facilitate the application of the information to the various systems to be considered later, the circle diameter, which, for a given brightness variation tolerance, can be used at various distances from the lamp, is shown in Table I. The column headings are self-explanatory

* The effect on positive film of a source operated at a color temperature of 5000°K. is used throughout this paper as a standard of comparison. Thus, a value given as 10,000 meter-candles indicates that the same effect would be produced on positive film by an illumination of 10,000 meter-candles (visually determined) from a source of approximately daylight quality.

TABLE I

(*All Dimensions in Millimeters*)

Distance from Lamp Filament to Plane	Center-to-Edge Brightness Ratio 1.02	1.04	1.06	1.08	1.10
32	6.0	9	10.0	11.6	15.0
42	10.0	12	16.6	20.0	22.0
52	13.3	18	22.0	25.0	28.4
62	13.3	22	25.0	26.6	32.0
72	15.2	25	32.0	35.0	38.6
82	22.0	32	36.0	38.4	..
92	20.0	35	36.8	..	..
102	22.0	33	42.0	..	..
112	23.2	40	..	..	..
122	30.0	..	..	..	..
132	28.0	..	..	..	..
142	30.0	..	..	..	..
152	33.3	..	..	..	..
162	40.0	..	..	..	..

An examination of Table I shows that there is an approximately constant ratio between the filament distance and diameter of field which can be used at any given uniformity tolerance. The value of this ratio is significant since it is indicative of the amount of light which can be gathered either by a condenser to be imaged on the film or by the film aperture itself, if no condenser is used. This ratio of filament distance to field diameter may be called the "*f* value" and it seems worth while to show in Table II how this value varies with the uniformity tolerance. The last three values are extrapolated.

TABLE II

Center-to-Edge Brightness Ratio	*f* Value
1.02	4.4
1.04	2.9
1.06	2.5
1.08	2.2
1.10	1.9
1.12	1.5
1.14	1.2
1.16	0.9

In addition to the type of non-uniformity shown by the preceding data, there is another phenomenon which occurs to a greater or lesser extent with any glass-enclosed source. In planes close to the lamp bulb there are present ghost images of the filament, due probably to the mirror action of the back side of the lamp bulb. While these images are faint, they may be of sufficient intensity to cause trouble in some optical systems if the aperture is placed within 100 millimeters of the filament.

PRINTING OPTICAL SYSTEMS

Optical System A.—The simplest optical system that can be used for projection printing consists of a lamp, a negative aperture, a diffusing material in the plane of the negative aperture, a lens to image this negative in a plane known as the printing plane, and a printing plane aperture. Such a system is shown in Fig. 3. The lamp, *A*, is a 500 watt monoplane filament projection lamp of the type previously discussed; *C* is the negative aperture so arranged that a diffusing material, *B*, can be added at will; *D* is the printing lens, and *E* the printing plane. In this particular set-up, *D* is a 75 millimeter, *f*/4.5 Kodak anastigmatic lens. The distance, *a*, was made 100 millimeters; *b* and *c* are each 150 millimeters, and the printing lens works, of course, at 1:1. Once having chosen the printing lens and magnification, the dimensions *b* and *c* are definitely fixed. A reasonable value for dimension *a* must, however, be chosen. This distance should be so assigned that the lamp is as close to the negative aperture as is compatible with the largest permissible brightness change from center to edge of the negative frame. Since the maximum allowable brightness change is the limiting factor in the placing of the lamp, a quantitative value for this ratio by an analysis of the optical system of photographic reproduction as a whole may be determined. First, let it be assumed that uniform illumination in the positive plane is desired.

It can be shown that the image of a uniformly bright object formed by any lens will decrease in brightness from center to edge as the fourth power of the cosine of the angle which the extreme ray makes with the optic axis. If this calculation be carried out for a 50 millimeter camera lens covering a frame 23 millimeters wide, it is found that the edge-to-center brightness ratio is about 0.9.* If a negative of a uniformly bright object be developed to a gamma of about

* Besides the falling off of intensity as the fourth power of the cosine, with nearly all commercial lenses there is some additional falling off caused by lens barrel vignetting. Measurements of this effect made on a number of commercially available motion picture camera objectives show that the effect of vignetting results in an edge image brightness in extreme cases only one-sixth that of the center brightness, while it is seldom greater than one-half.

0.5, it will have a center transmission which is about 95 per cent of the edge transmission. If this negative is evenly illuminated and printed at 1:1 with a 75 millimeter lens, because of the unavoidable $\cos^4$ falling off from the center to the edge, the image in the printing plane will be about 2 per cent brighter at the edge than at the center. To compensate for this, the lamp to negative distance, *a*, should

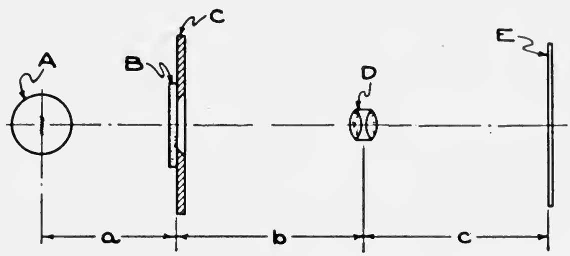

FIG. 3. Projection printing system *A*.

be so chosen that there is about 2 per cent falling off in illumination from center to edge. This distance (see Fig. 2) proves to be about 100 millimeters. System *A*, shown in Fig. 3, can be used only with some diffusion in the negative aperture, as otherwise the printing lens would project to the printing plane remnants of the filament image. The printing plane distribution of illumination is shown in Fig. 10 for various kinds of diffusion.

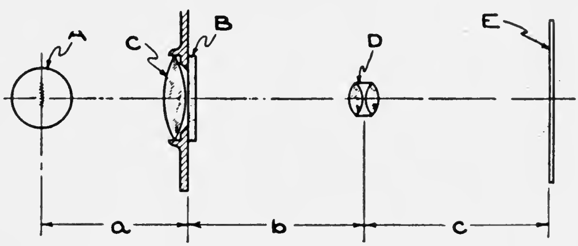

FIG. 4. Projection printing system *B*.

Optical System B.—The second common type of printing optical system is shown in Fig. 4. In this system, a filament image is formed in lens *D*, by lens *C*. Lens *C* is a 13 diopter spectacle lens and forms a filament image which just fills the *f*/4.5 aperture of lens *D*, thus making the system as efficient as such a system can be. The illumination in the negative aperture falls off less than 1 per cent from center to edge, and if it were not for the falling off due to the $\cos^4$ of the half angle of the printing lens, the same degree of evenness should obtain in the printing plane. Thus, the addition of diffusing material to a system of this sort is intended solely for the purpose of lowering the print contrast and decreasing the visibility of scratches and other accidental marks on the negative. The

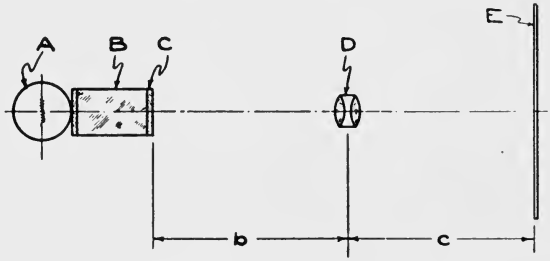

FIG. 5. Projection printing system *C*.

brightness fall-off in the printing plane is shown in Fig. 11 for several varieties of diffusion. It is noticeable that this ratio remains nearly constant, regardless of the type of diffusion.

Optical System C.—The third type of printing system consists of a rectangular bar of glass or quartz, *B*, one end of which is covered with flashed opal No. 3 (see Table III), the other end, *C*, being

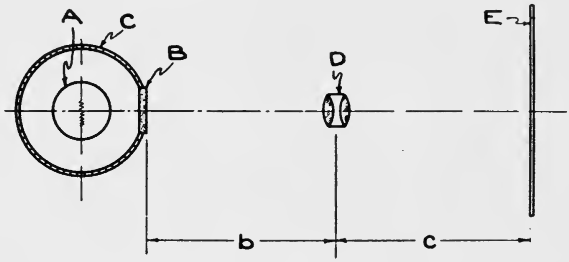

FIG. 6. Projection printing system *D*.

covered with some diffusing material. This system is shown in Fig. 5. The integrating bar depends for its effect upon the total internal reflection of all light passed through diffusion *B*. The multiple reflections tend to even out whatever initial non-uniformity exists. The glass or quartz of the bar must be very clear, white, and free from bubbles and striations. The edges of this rather expensive and fragile device must be very perfect. The brightness fall-off in the printing plane for this system is shown in Fig. 12.

Optical System D.—The fourth system of interest has as its basic component the Ulbricht integrating sphere. This device is commonly used as a diffuse light source, but apparently has not been used to any great extent on printers. The system as used by us is shown in Fig. 6. The sphere is about $5^1/_2$ inches in diameter and painted with lithophone-sodium silicate paint. Various degrees of diffusion were placed over the aperture, with results as shown in Fig. 13.

When a lamp is used within an enclosure such as the whitened sphere, the filament is heated by re-radiation from the walls. The wattage supplied to the lamp no longer is a criterion of its color temperature and its life characteristics.

Precautions must be taken to insure that the results obtained with the lamp in the sphere are comparable with those obtained in the other cases.

Lacking an optical pyrometer to determine directly the color temperature of the filament, it has been assumed that at the same value of resistance for the filament (measured by E/I) it must be at the same temperature.

It was found that for the same resistance, the lamp in one measured case was consuming 14 per cent more wattage outside of the sphere than it did inside.

The Condenser Relay System.—A conventional type of relay system consisting of a condenser near the lamp which is imaged by a field lens on diffusing material* in the negative plane may be suggested as a possible means of illuminating the negative aperture. Use of such a set-up enables one to increase the distance between lamp and aperture to almost any desired value, but has little else to recommend it. Since the condenser is imaged on the negative aperture, it is obvious that the illumination on the condenser must be at least as uniform as that desired in the negative aperture. Aperture values which may be used with various degrees of uniformity in the condenser plane are shown in Table II.

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* It does not seem worth while to consider the case where a lens is used in the negative plane to image the relay lens in the projection lens. In this case, the aperture of the system is fixed by the projection lens. Better results can be secured with optical system *B*, since the loss due to the added glass-air surfaces of condenser and relay lenses would be avoided.

If it were practically possible to place the negative aperture almost in contact with the 500 watt bulb, the frame would collect from the filament center a cone of light equivalent to about $f/1.5$. The falling off of intensity from center to edge of the frame would, in this case, be about 12 per cent. From the standpoint of intensity alone, there is then no advantage to be gained by using a condenser relay system, unless the aperture is greater than $f/1.5$ and unless a falling off of intensity from center to edge greater than 12 per cent is permissible.

Practically, it would probably be undesirable to place the negative frame closer than about 50 millimeters from the filament, thus gathering a cone of light not greater than about $f/2$. The center-to-edge falling off would be about 10 per cent.

The previous statement, regarding the advantage of a condenser relay system may be amended to read: A condenser system of effective aperture slightly greater than $f/2$* would result in a gain of intensity over that practical with no lenses between lamp and negative frame. Such a system, however, would have a center-to-edge brightness difference of more than 10 per cent. If a more uniform illumination of the negative is required, there is no advantage whatever in the use of a condenser system.

DIFFUSING MATERIALS

Diffusing materials naturally fall into one of two general classes: First, those which depend on surface roughness for their diffusing action (ground or sand-blasted glass are examples of this class of materials), and second, those which scatter light because of small imbedded particles of foreign material or small air bubbles. To this second group belong the opal glasses—pot and flashed.

Ground glasses are prepared by pressing flat glass surfaces on a rotating plate sprinkled with some abrasive material, usually emery. Grades of powdered emery commonly used vary in average particle size from about 0.025 to 0.0004 inch in diameter. Results obtained in grinding glass appear capable of being repeated, so the fineness of the abrasive used seems to be a sufficiently good specification for the resultant surface. Sand-blasted glass can not be so specified as the resultant surface varies in roughness with the air pressure of the blast as well as with the particle size.

Opal glasses[2] are produced by the addition of cryolite or other

* Allowing for the four glass-air surfaces of a condenser relay system with the unavoidable light loss of 16 per cent, this value should be about $f/1.85$.

alumina-bearing materials to the melt, and perhaps in some cases by the introduction of small air bubbles in the melt. It is believed that in the best opals the diffusing particles are themselves transparent but of a different refractive index from the glass matrix.

Now, the scatter becomes greater and the absorption becomes smaller as the particle size is increased until some optimum value is reached. For small particles, the scatter is approximately pro-

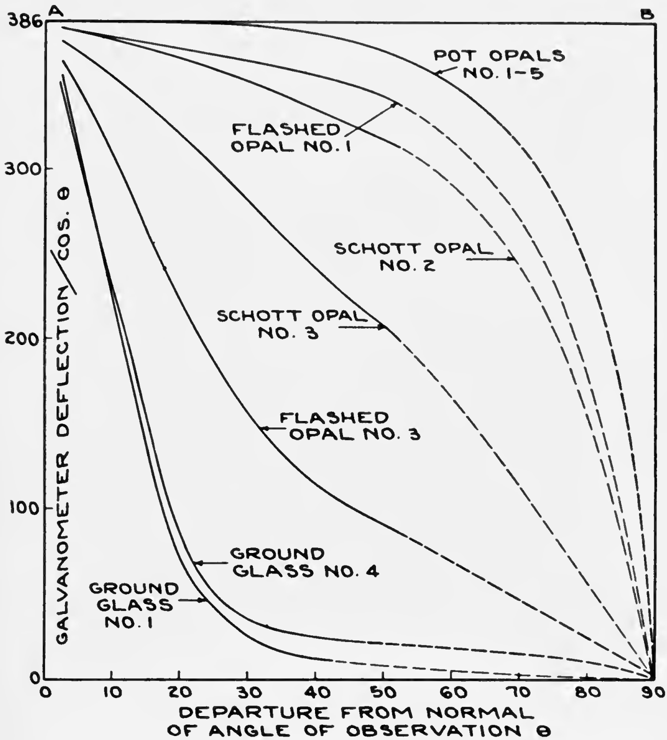

FIG. 7. Brightness distribution curves for various diffusing materials.

portional to the inverse square of the wavelength. Thus, a diffusing material may be loaded with particles of just the right size to act as the best possible diffuser for a given wavelength. Such a material may be as completely diffusing at a thickness of about 0.2 millimeter as it is at any greater thickness. Other pot opal diffusers are much less dense and do not reach their maximum diffusing efficiency under a thickness of 2 millimeters.

Flashed opal glasses vary greatly in their diffusing characteristics, some transmitting specularly in the far red and infra-red while diffusing well the shorter wavelengths; others are much less selective. The thickness of flashing is not a criterion of diffusion efficiency.

In subsequent remarks use will be made of goniometer distribution curves in evaluating the diffusion characteristics of the various

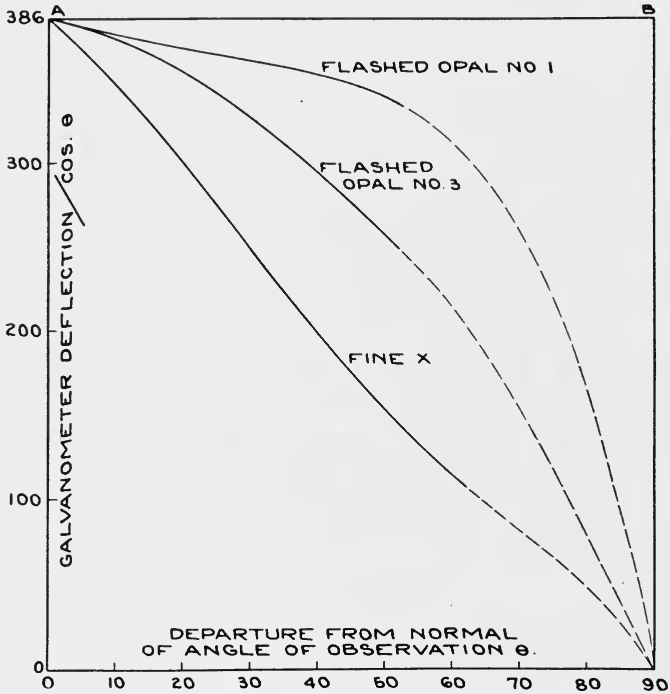

FIG. 8. Brightness distribution curves for various diffusing materials used in conjunction with optical system *C* (integrating bar).

materials. These curves,* such as are shown in Fig. 7, were plotted from data obtained in the following way: A Weston Photronic cell diaphragmed to a 1 millimeter slit opening, as before described, was mounted on the arm of a spectrometer table. The arm was rotated about a vertical axis passing through the center of the diffusing medium. The diffusing medium was illuminated by a collimated

* Distribution curves for ground glasses Nos. 2, 3, and 5 are not shown in Fig. 7 because they lie very close to the curves for ground glasses Nos. 1 and 4.

beam of light normally incident. Now, the quotient of the galvanometer deflection divided by the cosine of the angle of departure of the goniometer arm from the line normal to the sample, is a measure of brightness. A perfect diffuser, by definition, would appear equally bright to the cell mounted on the goniometer arm at any angle of departure from the optical axis up to $(90-1/\infty)$. The distribution curve from 0 to 90 degrees for a perfect diffuser would, then, be the

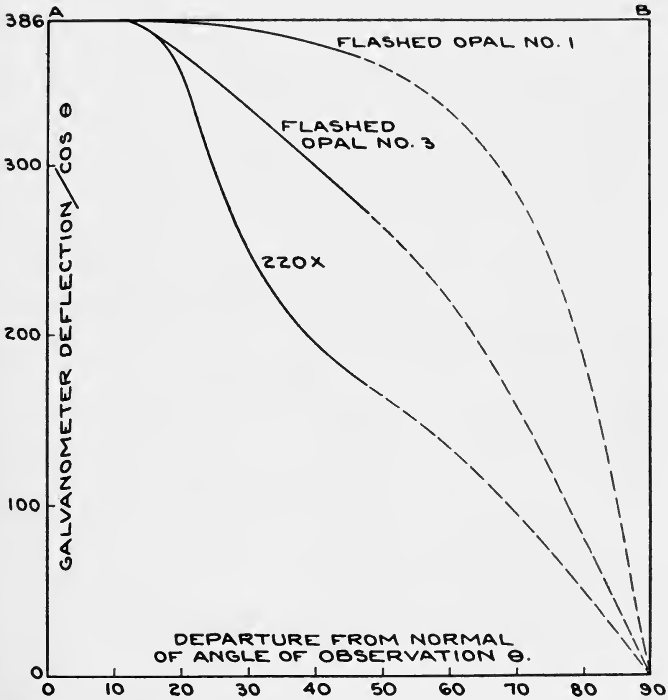

FIG. 9. Brightness distribution curves for various diffusing materials used in conjunction with optical system D (integrating sphere).

straight line, AB (Fig. 7). If we now plot distribution curves from 0 to 90 degrees of the various diffusing media, we can say that the *diffusion efficiency* of the medium is the ratio of the area under the curve for the medium to the area under AB, which represents the distribution curve of a perfect diffuser. The value of diffusion efficiency thus determined is given in column 4, Table III. Column 5 gives the transmission of the medium as measured by a densitometer with a diffuse light source.

In the case of optical system *A* or *B* where the incident light is more or less specular, the data of Fig. 7 can be used to specify the diffusion in the negative aperture. In the case of optical systems *C* and *D*, where the incident light is already diffuse to a great extent, distribution data applying to these particular set-ups must be obtained. Fig. 8 shows the angular distribution in the negative plane when the integrating bar is used. In all cases, the end of the bar next to the lamp was covered with flashed opal No. 3 (see Table III). The other end was covered with flashed opal No. 1, flashed opal No. 3, and ground glass No. 1 in turn.

TABLE III

Characteristics of Diffusing Media

Material		Description	Comments	Diffusion Efficiency	Total Transmission %
Ground Glass	No. 1	Abrasive "fine *x*"	Last stage before polish	14.0	85.0
Ground Glass	No. 2	Abrasive "smooth *x*"	Very fine texture	15.1	85.0
Ground Glass	No. 3	Abrasive 220 *x*	....	16.0	80.0
Ground Glass	No. 4	Abrasive 150 *x*	....	17.8	76.0
Ground Glass	No. 5	Abrasive 70 *x*	Texture too coarse to be used in focus	18.0	69.0
Flashed Opal	No. 1	Flashing 0.3 mm. thick	....	80.7	42.7
Flashed Opal	No. 3	Flashing 0.1 mm. thick	....	36.0	55.0
Pot Opal	No. 1	3.0 mm. thick	Slightly yellow	89.3	10.0
Pot Opal	No. 2	2.0 mm. thick	Slightly yellow	89.3	13.8
Pot Opal	No. 3	1.0 mm. thick	Slightly yellow	89.3	27.0
Pot Opal	No. 4	0.5 mm. thick	....	89.3	40.8
Pot Opal	No. 5	0.25 mm. thick	....	89.3	52.5
Schott Pot Opal	No. 1	3.0 mm. thick	Neutral in color	89.0	21.0
Schott Pot Opal	No. 2	1.0 mm. thick	Not uniform enough for printing	..	42.0
Schott Pot Opal	No. 3	0.5 mm. thick	Not uniform enough for printing	56.0	60.0*

Fig. 9 shows distribution as measured for the integrating sphere, the exit aperture being covered with flashed opal No. 1, flashed opal No. 3, and ground glass No. 3. Diffusion efficiencies for systems *C* and *D* are shown in Table IV.

TABLE IV

Diffusion Efficiencies for Optical Systems C and D

Optical System *C*	Ground Glass No. 1	47.6
	Flashed Opal No. 1	77.5
	Flashed Opal No. 3	64.0
Optical System *D*	Ground Glass No. 3	51.0
	Flashed Opal No. 1	83.0
	Flashed Opal No. 3	64.0

MEASUREMENTS OF UNIFORMITY AND RELATIVE INTENSITY IN THE PRINTING PLANE

Apparatus similar to that shown in Fig. 1 was used to measure the intensity distribution in the printing plane for the optical systems previously described.

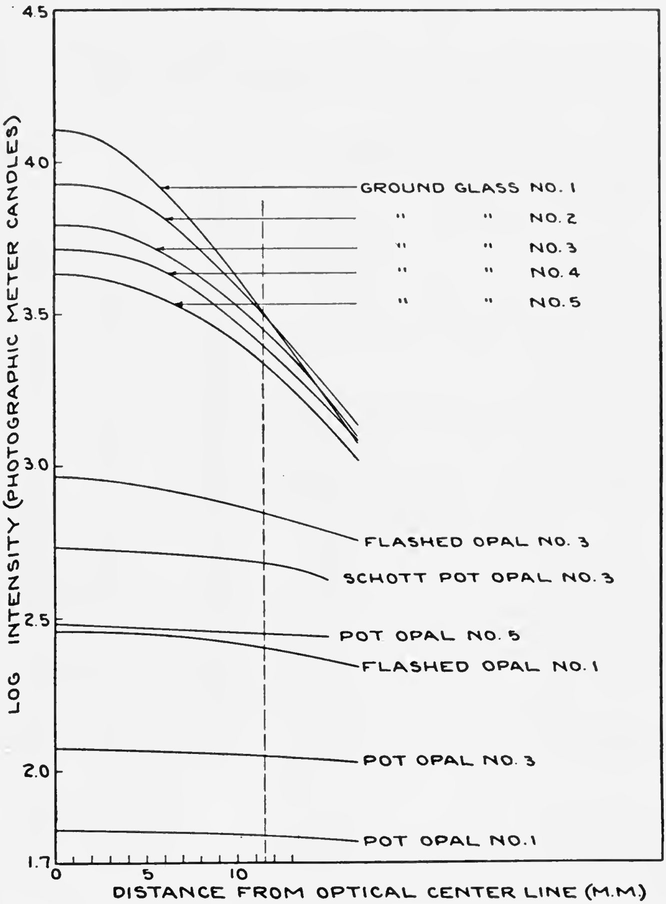

FIG. 10. Horizontal distribution of illumination in printing plane of optical system *A* with various diffusers in negative plane.

The results are shown graphically in Figs. 10, 11, 12, and 13. The intensities plotted logarithmically are in photographic meter-candles. The abscissa values show horizontal displacement off the optical axis in millimeters.

Optical system *A*, *B*, or *C* can be modified by the addition of a concave mirror placed behind the lamp in such a way that a filament image is interlaced with the filament itself, resulting in an intensity increase of about 60 per cent throughout the system and having a negligible effect on uniformity.

For the convenience of the reader, the essential data for the different systems are summarized in Table V.

TABLE V

Essential Data Showing Characteristics of Optical Systems

	Diffusing Material	Axial Intensity Without Concave Mirror	Axial Intensity With Concave Mirror	Center Intensity Edge Intensity	Diffusion Efficiency
Optical System *A*	Ground Glass No. 1	12,600	20,200	4.0	14.0
	Ground Glass No. 2	8,500	13,600	2.7	15.1
	Ground Glass No. 3	6,300	10,080	2.2	16.0
	Ground Glass No. 4	5,250	8,400	2.2	17.8
	Ground Glass No. 5	4,360	6,980	2.0	18.0
	Flashed Opal No. 3	922	1,470	1.3	36.0
	Schott Opal No. 3	536	860	1.12	56.0
	Pot Opal No. 5	302	480	1.07	89.3
	Flashed Opal No. 1	288	460	1.12	80.7
	Pot Opal No. 3	170	272	1.05	89.3
	Pot Opal No. 1	64	100	1.05	89.3
Optical System *B*	No Diffusion	85,000	130,000	1.05	0.0
	Ground Glass No. 1	6,450	10,300	1.05	14.0
	Ground Glass No. 5	2,040	3,250	1.07	18.0
	Flashed Opal No. 3	675	1,080	1.17	36.0
	Schott Opal No. 3	316	510	1.12	56.0
	Flashed Opal No. 1	170	270	1.10	80.7
Optical System *C*	Ground Glass No. 1	2,615	4,180	1.10	47.6
	Flashed Opal No. 1	950	1,520	1.07	77.5
	Flashed Opal No. 3	1,690	2,710	1.10	64.0
Optical System *D*	Ground Glass No. 3	13,500		2.3	51.0
	Flashed Opal No. 1	2,040		1.11	83.0
	Flashed Opal No. 3	4,060		1.11	64.0

Discussion of Table V.—System *A*, with any diffusion less than that offered by flashed opal No. 3, is probably quite out of the question for projection printing because of non-uniformity in the printing plane. With diffusion efficiencies greater than 50 per cent, the uniformity would probably be satisfactory.

It is, of course, possible to modify system *A* by placing the negative plane closer to the lamp filament. An approximate determination both as to the resultant intensity and uniformity for various distances of lamp to negative can be made by reference to the data of Fig. 2.

Optical system *B*, compared with *A*, shows a loss of axial intensity if any diffusion is placed in the negative plane, but a great improvement in uniformity over that of system *A* for diffusion efficiencies less than 18 per cent. It is evident that nothing is to be gained by

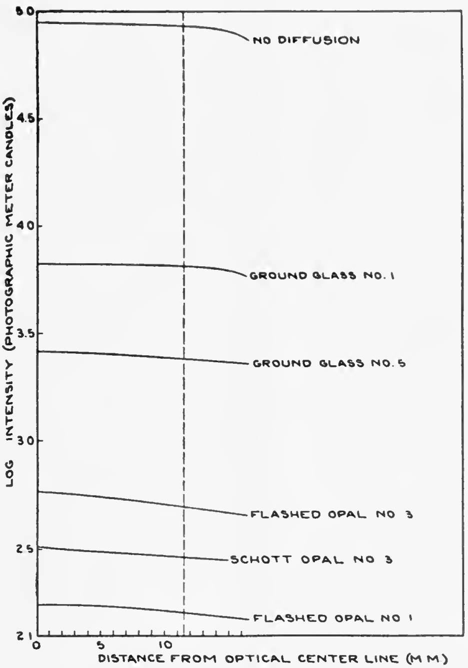

FIG. 11. Horizontal distribution of illumination in printing plane of optical system *B* with various diffusers in negative plane.

the use of system *B*, when diffusion efficiencies as great as 36 per cent are used.

Comparing the results of optical systems *C* and *D*, it seems that the uniformity of illumination is slightly better with the integrating bar, but that the available intensity is slightly greater with the sphere. Both are excellent as diffuse sources. The sphere covered with ground glass unfortunately can not be used because it does not illuminate the printing plane with satisfactory uniformity.

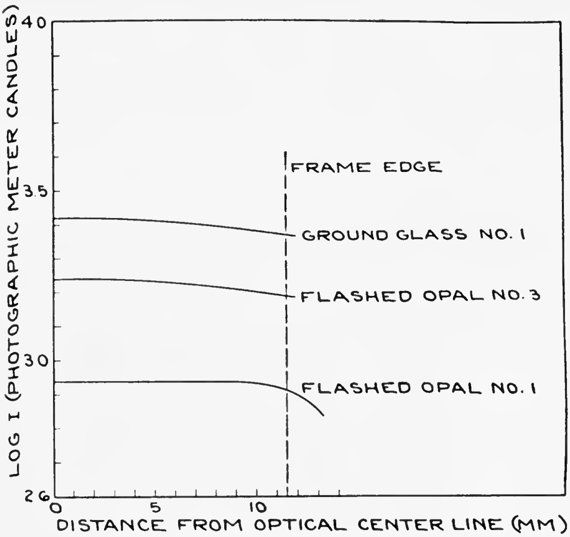

FIG. 12. Horizontal distribution of illumination in printing plane of optical system *C* with various diffusers in negative plane.

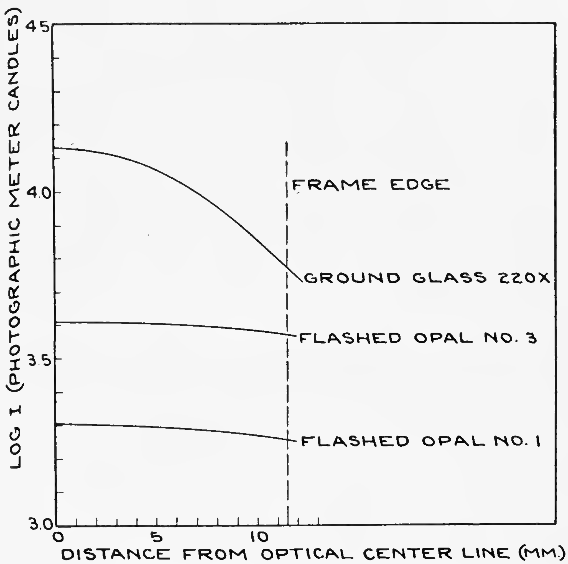

FIG. 13. Horizontal distribution of illumination in printing plane of optical system *D* with various diffusers in negative plane.

THE FUNCTION OF DIFFUSION IN AN OPTICAL SYSTEM

The most important function of diffusion in a projection printing system is to decrease the imaging of scratches which may be present on the negative. Since an increase in diffusion efficiency usually results in loss of printing intensity, it seems important to find out just how much diffusion is needed to accomplish the desired end.

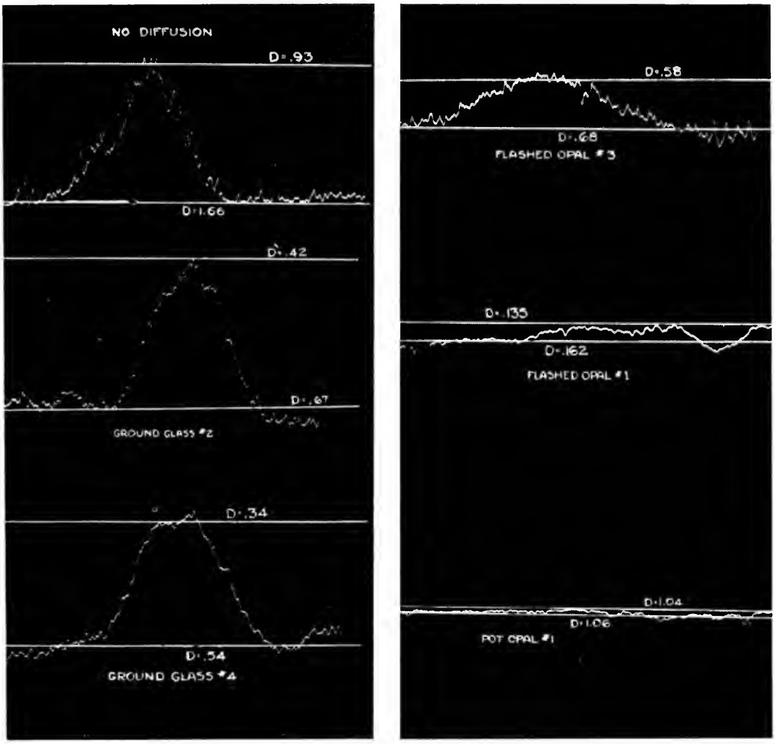

FIG. 14. Microdensitometer traces of scratch images.

It is difficult to get quantitative data on the subject, but the results of three different experiments are discussed briefly below.

The first experiment consisted in printing with optical system *B* the image of a scratch made with a diamond pyramidal point on a flashed photographic density. By placing various degrees of diffusion immediately behind the negative it was possible to vary the visibility of this scratch on the prints. From a visual inspection of these prints, it appears that there is a very little improvement in scratch elimination beyond a diffusion efficiency of 60 per cent.

In the second experiment, a long scratch which varied in depth from end to end was produced on a piece of flashed photographic density. This wedge-shaped scratch was made by causing a pyramidal cut hardened steel point to travel along the strip a distance of 150 millimeters at an increasing load. The density was then mounted under a traveling microscope in such a way that the scratch could be observed throughout its length at a magnification of 50x.

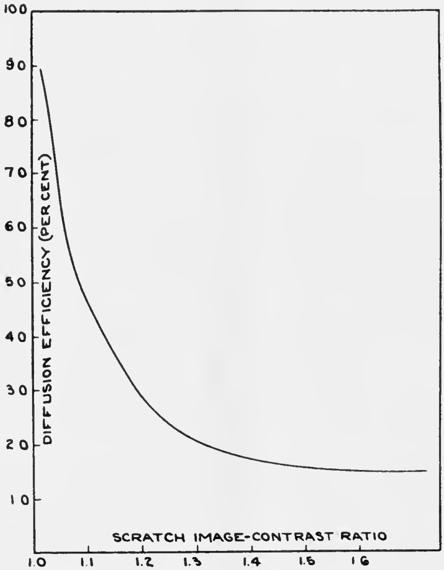

FIG. 15. Curve showing relation between contrast of a scratch image and the diffusion efficiency existing in the negative plane.

Various degrees of diffusion were then placed under the scratch and readings were taken of the disappearance point. Three observers seemed to be in remarkably good agreement as to the whereabouts of these points. Results of the experiment are shown in Table VI.

The third method of attack on the scratch elimination problem was as follows: scratches about 0.01 millimeter wide on negative material were projection printed at a magnification of 250x on positive film. Density variation of these scratch images was examined by means of a recording microdensitometer. Typical traces ob-

TABLE VI

Minimum Load to Cause a Scratch Visible with Various Degrees of Diffusion

Load (Gms.)	Diffusion Efficiency for Disappearance of Scratch
1.2	0.0
3.0	36.0
3.0	40.0
6.7	42.0
6.7	80.7
6.7	89.3

tained on this instrument are shown in Fig. 14, the density values of the scratch image and its background being marked on the traces. By applying the usual methods of photographic photometry, it was possible to determine the contrast existing between the scratch image and its background for various degrees of diffusion in the negative plane. Fig. 15 shows a curve which correlates the contrast of the optical image of a scratch and the diffusion efficiency in the

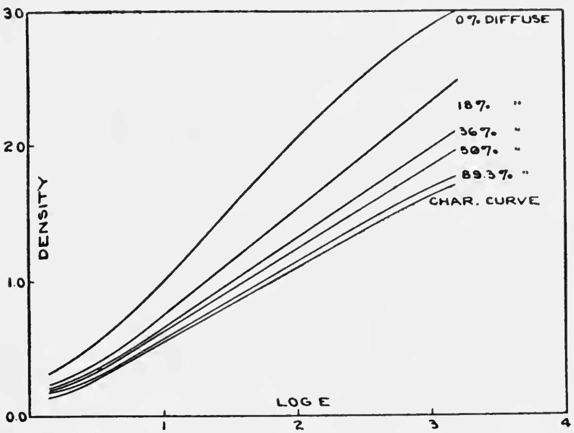

FIG. 16. Family of characteristic curves showing the effect of the use of various degrees of diffusion in printing the same negative.

negative aperture. A glance at this curve shows that the contrast between a scratch image and its background will continue to decrease as long as the diffusion efficiency increases. The curve shows very plainly that a diffusion efficiency in the neighborhood of 55 per cent is about as high as is necessary since the scratch-background contrast ratio is changed very little by any increase in diffusion efficiency beyond 55 per cent. For values below 55 per cent, the scratch-background contrast increases very rapidly as the diffusion efficiency is decreased. Ground glass seems to be of very little use as a diffuser. These data seem to bear out the conclusion which might be drawn from the other two experiments.

The second important point in regard to the amount of diffusion used in a projection printing system is its effect on the contrast of the projected image. It is well known that the contrast of an image in a specular system is much greater than that in a diffuse system. To study this effect in the various optical systems, a series of flash densities on motion picture panchromatic negative were measured under various diffusion conditions. The results are shown in Table VII.

TABLE VII

Density as Determined in Various Optical Systems

D‡	Dm (ϵ = 89.3%)	Dm/D‡	Dm (ϵ = 80.7%)	Dm/D‡	Dm (ϵ = 56%)	Dm/D‡	Dm (ϵ = 36%)
0.17	0.16	0.95	0.17	1.00	0.19	1.12	0.21
0.48	0.46	0.96	0.47	0.98	0.51	1.06	0.53
0.63	0.63	1.00	0.66	1.05	0.70	1.11	0.75
0.72	0.75	1.04	0.78	1.08	0.83	1.15	0.90
1.0	0.98	0.98	1.06	1.06	1.11	1.11	1.21
1.4	1.38	0.99	1.44	1.03	1.52	1.09	1.68
1.7	1.68	0.99	1.80	1.06	1.89	1.12	2.10
Average Density Factor		0.99		1.04		1.11	

D‡	Dm/D‡	Dm (ϵ = 17.8%)	Dm/D‡	Dm (ϵ = 15%)	Dm/D‡	Dm (ϵ = 0%)	Dm/D‡
0.17	1.23	0.24	1.41	0.24	1.41	0.29	1.70
0.48	1.10	0.64	1.33	0.70	1.46	0.85	1.77
0.63	1.19	0.89	1.41	0.96	1.52	1.15	1.83
0.72	1.25	1.08	1.50	1.15	1.60	1.34	1.86
1.0	1.21	1.47	1.47	1.47	1.47	1.82	1.82
1.4	1.20	2.00	1.43	1.89	1.35	2.59	1.85
1.7	1.23	2.52	1.47	2.68	1.57	3.00	1.76
Average Density Factor	1.20		1.43		1.48		1.80

D‡ = diffuse density
Dm = measured density
ϵ = diffusion efficiency

It is of interest to show the effect of the projection system on the effective gamma of the negative. The family of curves shown in

Fig. 16 is illustrative of the effect on negative gamma when various degrees of diffusion are used.

CONCLUSIONS

The following is a list of the systems which give a diffusion efficiency of over 55 per cent and which, at the same time, are capable of a high illumination and uniformity in the negative plane:

1. Optical System *A* with mirror with Schott Opal No. 3, 860 meter-candles.
2. Optical System *A* with mirror with Pot Opal No. 5, 480 meter-candles.
3. Optical System *C* with mirror with Flashed Opal No. 1, 1520 meter-candles.
4. Optical System *C* with mirror with Flashed Opal No. 3, 2710 meter-candles.
5. Optical System *D* with Flashed Opal No. 1, 2040 meter-candles.
6. Optical System *D* with Flashed Opal No. 3, 4060 meter-candles.

Optical system *B* is not mentioned in this table, since there is nothing to recommend its use with diffusion efficiencies greater than 36 per cent.

Optical system *A* can be used to produce higher printing intensity if the distance between the lamp filament and negative plane is decreased. When this is done, the uniformity of illumination is, of course, decreased.

For the usual run of studio negatives of which the densest have a total diffuse transmission of about 2 per cent,[3] a maximum printing exposure of about 80 meter-candle-seconds would be required. Assuming that the projection printer pull-down is designed to expose for one-half of the cycle, one can compute the requisite illumination approximately

$$160\,R = I$$

where R is the rate in pictures per second and I is the intensity in meter-candles which must be available in the printing plane.

The procedure which was followed to determine the value of diffiusion efficiency is not easy to follow without special equipment. It is also true that even with a reliable goniophotometer, the adjustments must be carefully made in order to get true distribution curves. Considerable reliance may be placed upon the distribution data which have been presented, not because of any certainty as to the absolute accuracy, but because all measurements have been made with the *same* set-up and therefore the relative values of areas beneath the curves should be significant.

As a simple method of determining the relative diffuseness of various systems, it seems possible that the measurement of density in a system may be a reliable criterion of diffusion efficiency.

With this end in view, the relation between diffusion efficiency and the ratio of effective density to diffuse density for panchromatic negative film is shown in Fig. 17. By using the same photographic material, one should be able to determine the diffuseness of a system on the basis of the observed density ratio. If the ratio of density

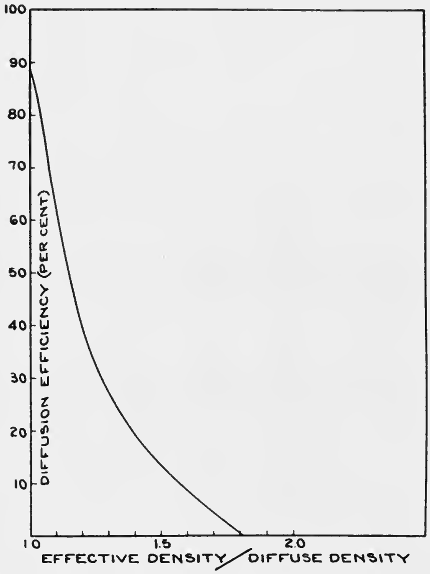

Fig. 17. Curve showing the relation between diffuseness of a printing system and the effective "q factor" or density ratio (for Eastman Type II panchromatic negative).

measured in the system to diffuse density is less than 1.13, it should be safe to assume that the diffuseness of the system exceeds the arbitrary value, 55 per cent, which appears to be sufficient diffusion for the avoidance of scratches.

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A NEW LIGHT CONTROL FOR PRINTING MACHINES*

KURT SCHNEIDER**

Summary.—*This paper describes a new device for automatically controlling the intensity of the printing light so that the successive scenes of each print receive the respective exposures that have been previously assigned to them. By means of a keyboard having numbered keys corresponding to twenty-four light intensity steps, the control can be rapidly set for a negative having as many as one hundred and sixty scenes. A recording indicator enables a quick check-up with the timing card, and facilitates an accurate control of printing.*

In the printing of motion picture film, the necessity of employing a means of varying the exposure intensity to obtain a print of uniform density, regardless of negative density, has long been recognized. One of the earliest methods used to accomplish this consisted in employing a device which allowed the lamp used in the printer to be placed at various distances from the printing aperture, thus varying the intensity of the light at the point of contact between the negative and positive during the printing exposure. The device mentioned was manually operated, depended entirely on the skill of the operator for results, and could be used only with very slow printers. As the length of pictures and the number of scenes increased and large numbers of prints became necessary, automatic devices for accomplishing this purpose were developed.

These devices may be divided into three classes, namely:

(1) Devices in which the exposure is varied by changing the area of the aperture through which the exposure takes place. This type of device, which operates with constant speed printers in which the time of exposure is fixed, has been used in various forms either as a manually operated, semi-automatic, or fully automatic light control.

(2) Devices used with the usual type of printer operating at constant speed and with fixed lamp position, in which the intensity of the printing light is changed by varying the amount of resistance in the lamp circuit. This method is fully automatic when the control

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* Presented at the Spring, 1932, Meeting at Washington, D. C.

** Oehler Machine Co., Inc., Long Island City, N. Y.

is properly connected with a circuit interrupter, a device which is actuated by notches on the edge of the negative film.

(3) Devices in which the intensity of exposure is varied by interposing a specially printed film or a filter having the proper opacity between the light source and the printing aperture. This type of light control is fully automatic, although it has not been widely used.

The device about to be described comes under the second classification. The same method of control, however, can be used to control

FIG. 1. Front view of the keyboard automatic light control, showing the keyboard, the scene numbering drum, and the recording indicator.

the opening of an optical diaphragm instead of the amount of resistance in series with the printing lamp.

The keyboard automatic light control is a new device to be used with motion picture film printing machines for automatically controlling the intensity of the printing light, so that the successive scenes of each print receive the respective intensities of exposure previously assigned to them. Before a negative is printed, the correct printing intensity for each scene must be charted. During the printing operation, the intensity of the printing light is regulated to give the charted light intensities by automatically varying the amount of resistance in the lamp circuit. In this way, differences in the negative density are compensated for, and a print of uniform density is obtained.

The assignment of printing exposure to each scene of a negative is commonly known as "timing," and in practice is accomplished visually by an expert judge of negatives or with the aid of a sensitometer. From these assigned printing intensities, the keyboard automatic light control can be rapidly set by means of numbered keys corresponding to a series of light intensity steps. Although twenty-two is the largest number of steps of light intensity ordinarily used, the keyboard automatic light control has twenty-four keys for registering light intensity values, the two additional keys serving special purposes. The device can be set for a negative having as many as one hundred and sixty scenes.

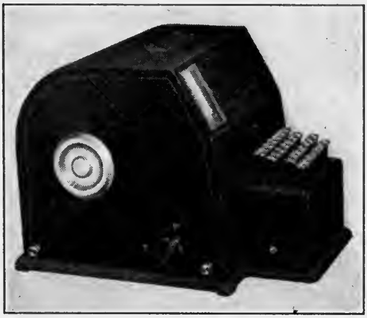

FIG. 2. Side view of the keyboard automatic light control.

As the light control is set, the number of each successive scene and the number representing the degree of exposure intensity are shown by a recording indicator. This feature of the device consists of a bank of pilot lamps, one of which illuminates the number representing the exposure intensity being set or with which the film is being printed at the time; and a drum dial graduated from 1 to 160, representing the numbers of the scenes being set or printed. The graduated drum is rotated an equal step each time a key is pressed. It is viewed through a rectangular lens through which the scene numbers and the fixed scale indicating the "timing," "printing," and "clearing" positions may be clearly seen. The recording indicator allows accurate setting, enables a quick check-up with the timing card, and facilitates an accurate control of printing.

The operation of the keyboard automatic light control is very simple. In order to set the control for the light intensities given by a timing card, the switch at one side of the control must first be placed in the timing position, indicated by *T*. This releases the keys, which are all automatically locked when the switch is in the printing position. Pressing the key marked "Dial" then permits the graduated drum dial to be rotated by means of the dial knob at the left of the control. When scene number 1 is opposite "Timing," as viewed through the rectangular lens, the control can be set by pressing the numbered keys in the same order as the succession of light intensity values given by the timing card. A good plan is to have the timing card give the scene numbers in their consecutive order as well as their required light intensities. This will permit very accurate as well as rapid setting, because the number of each successive scene and its corresponding light intensity are simultaneously given by the recording indicator.

It hardly seems necessary, but a check-up of the timed scenes can be quickly made by returning scene number 1 of the graduated drum dial to its original position opposite "Timing" and then operating the "Shift" key, which causes the successive scene numbers and their corresponding light intensities to be repeated by the recording indicator.

If it is desirable to change the light intensity of any scene, for instance, scene number 158, the graduated drum dial is rotated until scene number 158 is opposite "Clearing," after which the operation of the key marked "One Clear" releases the light intensity setting of that particular scene. To assign a new light intensity to scene 158, number 158 of the graduated dial is brought opposite "Timing" and the key representing the new degree of light intensity is pressed.

The keyboard automatic light control is connected electrically to the printer lamp and circuit interrupter of the printing machine. After the control has been set, according to the light intensities given by the timing card, the graduated dial is brought opposite "Printing," and the switch placed in the printing position. The device is then ready to control the printing operation so that the successive scenes of each print receive the exposures that have been assigned to them. During printing, the intensity of the printing light is controlled by automatically varying the amount of resistance in the lamp circuit.

The change-over mechanism is quick and positive in action. The contacts of the light control are made of an alloy of platinum and iridium and are entirely enclosed, thus insuring against contact faults. When the required number of prints has been made, the control can be set for a new negative in the following manner. The switch is placed in the timing position and the drum is given one complete revolution while the key marked "All Clear" is pressed down. The light control can then be set for the light intensities given by the new timing card in the same way as described before.

The essential elements of the keyboard automatic light control consist of the following:

(1) A drum adapted to carry steel balls in selected circumferential positions on its outer face.

(2) A system of key-operated levers by means of which the balls are placed in their selected circumferential positions or removed from the face of the drum.

(3) A contact mechanism consisting of a number of plunger contacts which are closed one at a time by the cam-like action of the balls as the drum is intermittently rotated.

THE DRUM

The drum is concentrically mounted within a stationary cylinder on a common shaft with a ratchet gear, a ball elevating wheel, and a graduated dial. It is intermittently rotated by a specially designed solenoid movement or by levers operated by numbered keys. On the outer face of the drum are a number of lateral carrier grooves which are transversely cut by longitudinal clearing grooves. The inner face of the cylinder also contains longitudinal grooves which are called guide grooves. As the drum is intermittently rotated, the balls that have been placed on its face are maintained in their relative circumferential positions by means of the drum carrier grooves and the cylinder guide grooves.

THE KEYBOARD

The keyboard has twenty-four keys numbered from 1 to 24, and four keys marked respectively, "Shift," "Dial," "One Clear," and "All Clear." A safety device prevents the operation of more than one key at a time. Operating a numbered key causes a ball from one of the channels in the cylinder to be pushed into one of the carrier grooves of the drum. The channels, of which there are twenty-four, each corresponding to a numbered key, receive balls from a magazine and are constantly kept full. When a numbered key is pressed, a ball is placed in a selected position on a lateral line of the drum surface. Each time a numbered key is released, the drum is rotated an equal step.

By means of the "Shift" key, the drum is rotated in equal steps without placing balls on the drum surface. The "Dial" key releases the ratchet mechanism, allowing the drum to be rotated freely by means of the knob at the left of the machine. Operating the "One Clear" key gives a lateral movement to a sliding member in the cylinder. This sliding member has longitudinal grooves which are in line with the grooves of the cylinder, and are somewhat greater in length than the diameter of one ball. Its lateral movement across the face of the drum causes one of the balls to be transferred from its position in a carrier groove to a clearing groove, from which it passes to an elevating wheel and is returned to a magazine located above the cylinder.

Operating the "All Clear" key gives a lateral movement to another sliding member in the cylinder. This sliding member also has longitudinal grooves in line with the cylinder grooves. In addition, it has angular grooves, one of which is placed next to each longitudinal groove. When the "All Clear" key is pressed down, the "All Clear" slider is moved laterally across the face of the drum and the ratchet mechanism is released. As the "All Clear" key is held down and the drum is manually rotated, the balls are shunted by means of the angular grooves and transferred from the guide grooves to the clearing grooves. In this way the balls are all removed from their selected circumferential positions with one complete revolution of the drum.

THE CONTACT MECHANISM

The contacts are made of a special alloy and are entirely enclosed. They are of the plunger type and are closed under pressure by the circuit-closing balls which act very much like cams as the drum is rotated. Two independent circuits are closed by each contact plunger, one being the lamp resistance, while the other is the pilot bulb indicating the degree of printing light intensity. Each time a numbered key is operated, a pilot lamp illuminates the number corresponding to the key number and the required degree of light intensity. The bank of pilot lamps may be said to act as a recording indicator because, after the machine has been set, the series of light intensities that have been assigned to the scenes of a negative may be repeated by operating the "Shift" key which causes the numbers representing the required degrees of exposure to be illuminated successively in the same order as originally given by the timing card. During printing, the bank of pilot lamps, in combination with the graduated dial, simultaneously give the number of each scene and the light intensity with which it is being printed.

Before printing, number 1 on the graduated dial is brought opposite "Printing," and the selector switch at the left of the machine is placed in the printing position. In this switch position, all the keys are locked. The first circuit-closing ball is already in position as the printing machine is started, and remains there until the first notch of the negative film passes the circuit interrupter of the printing machine. When the interrupter circuit is closed at the beginning of the notch, a solenoid magnet in the light control compresses a mechanical force which is released when the interrupter circuit is broken. In this way, an extremely fast change-over to the succeeding light intensity is obtained and arcing is reduced to a minimum.

For each additional positive print all that is necessary to be done is to return number 1 on the graduated dial opposite "Printing" and to place the selector switch in the printing position before running the film through the printer.

CONCLUSION

The following advantages may be found in the keyboard automatic light control:

(1) The large number of scenes that can be controlled by a small and compact device.

(2) The ease and rapidity with which the settings may be made.

(3) The recording indicator which enables an accurate control of timing and printing, and allows a quick check-up to be made.

(4) The fast and positive change-over mechanism which eliminates light lag caused by magnet sluggishness and the slow-acting escapement movement of the usual type of light-board control.

(5) The prevention of contact faults by the use of an alloy of platinum and iridium for contacts.

SOUND MOTION PICTURE EQUIPMENT FOR THE U. S. NAVY*

S. W. COCHRAN**

Summary.—*A brief account of the origin of sound motion pictures in the U. S. Navy; treats of the problems involved in designing equipments satisfactorily for naval service, and describes in detail an RCA Photophone Type PG34B1 equipment, the largest of three types of equipment being supplied to the U. S. Navy. The equipment described herein is designed for service on the largest type of fighting ship. It is devoid of batteries, performs in accordance with naval specifications, is easily serviced, and is provided with a remote volume control.*

HISTORICAL

Within the past year the U. S. Navy has contracted for sufficient sound motion picture reproducing equipment to equip practically every ship and shore station within that vast protective organization of the nation. The unsuspecting motion picture engineer is probably unaware of the fact that motion pictures form the basis of approximately 50 per cent of the entertainment of the U. S. Navy.

It is the purpose of this paper to present a brief history of sound motion pictures in the Navy, to relate briefly the origin of the Naval specifications covering this type of equipment, and to discuss the problems involved in the design of equipment satisfactory for Naval Service. The solutions to the problems confronted will be treated in conjunction with the description of an RCA Photophone PG34B1 equipment, the largest of three types being supplied to the U. S. Navy, and designated by the Navy as the Type 1, Class A, equipment.

The magnitude of the present motion picture organization within the Navy and the extent of its facilities are amazing. There are 287 exhibiting units, with a potential audience of approximately 80,000 men, distributed over the major portion of the globe. In the past, the Navy has leased two prints of each of approximately 300 feature pictures each year.

Naval film is serviced and distributed by three principal exchanges located in New York, N. Y., San Diego, Cal., and Cavite, P. I.

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* Presented at the Fall, 1931, Meeting at Swampscott, Mass.

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

These exchanges are supplemented by fleet exchanges, one of which is assigned to each major operating unit of the fleet, and by smaller exchanges at Naval bases.

There are two very important reasons for the advent of sound motion pictures in the Navy—first, the ever-prominent policy of the Navy to be modern and, second, the shortage of high quality silent feature pictures. The Navy has already purchased approximately 255 sound features and will continue to purchase them at the rate of approximately 300 sound features per year. A film library consisting of 1200 features will be maintained and replenished at the rate indicated. This briefly introduces the subject of this paper.

On what basis does the average exhibitor select the sound equipment for his theater? It is probably safe to assume that listening tests, price, and manufacturer's performance data on competitive equipment are the determining factors. It is Naval routine to purchase materials and equipment from an approved list of suppliers by virtue of open bidding on a specification. The first logical step in this system is the completion of the specification. The Navy called in the products of the suppliers of sound reproducing equipment. Competitive equipment was tested scientifically on the same test floor, with the same test equipment, and under the same test conditions.

These laboratory tests furnished a positive indication of what was available in the industry, and provided a means of determining what characteristics of sound reproducing equipment best fitted the theater. They did not indicate the specific requirements of the Naval service. It was for the purpose of ascertaining the major specifications of a sea going motion picture sound reproducing equipment, that apparatus of an approved supplier was assigned to sea duty aboard a battleship. Many interesting and complicated problems, which will be treated in the following paragraphs, were studied, and an abundance of valuable data and information was collected. This is the origin of the present Naval specification for sound motion picture equipment.

A modern high quality sound reproducing equipment, of the type used in the better theaters, is permanently installed in a location free from serious atmospheric effects and devoid of severe radio frequency fields. The major units of such an installation are grouped relatively close together. The audience which the equipment serves may vary in magnitude, but at all times occupies an area well distributed about the source of sound.

Each large ship of the Navy carries a battery of radio transmitters operating at wavelengths covering nearly the entire radio frequency band. The high frequency radiation is extremely serious. It penetrates practically every part of the ship. The problem of grounding becomes complicated. Potentials as high as 1000 volts have been measured between the muzzle of a gun and the armored deck below.

Salt air and salt water are ever-present on shipboard. Sea water is the general purpose cleansing agent on "men of war," and it can not always be confined to the object of the cleaning process. Equipment and instruments aboard ship are constantly exposed to sea air and are often exposed to sea water. The effects of immersion or exposure are twofold—the metal corrodes, and the insulating materials acquire a highly conducting coating that greatly lessens the value of the material as an insulator. It is therefore very apparent that metal contacts, terminals, and machine parts must be inherently self-protecting against the elements if they are to do Naval service. Insulating materials must be non-hygroscopic.

The topside or main deck of a battleship serves a multitude of purposes. Among other things, it is the ship's theater. A deck area which may be a gymnasium and a general work area in the morning, and the scene of gun drills in the afternoon, serves as the theater of the ship in the evening. This arrangement implies that certain parts of the sound motion picture equipment must be on the topside to operate during the performance. From experiments at sea, it was found advisable to locate as much of the total equipment as possible below the weather deck, so as to receive as much protection from the elements as a location of that nature can afford. A layout of this sort necessitates that the projectors and associated sound mechanisms and apparatus be linked with the heavier amplifiers, power supply units, and controls below decks by means of cables. The audio cable and transmission system must be so designed and constructed as to prevent serious effects from the radio frequency fields, previously mentioned, and yet maintain the frequency response standards required by Naval specifications. It is essential that complete control of the equipment be centered at the projector station, the logical place for control operations. Under these circumstances, overload and automatic protective devices on the equipment below decks are imperative. A complete system of remote control is also involved.

A visit to a Naval vessel is very impressive, and is particularly so to the mechanical engineer. Each part of the ship and each part of the equipment is the symbol of ruggedness and durability. That is Navy standard. If one wonders why it should be so necessary, the havoc wrought by concussion from gunfire and vibration would be ample evidence to be convincing to any one. Our floating fortresses are designed primarily for one purpose which they serve nobly. There is little room allotted for entertainment facilities. The service demands, therefore, that the sound equipment for shipboard use be sturdy, durable, and rugged, yet condensed in form and light in weight.

The spread of a sea going audience is hardly comparable even with the opera house, with its innumerable balconies. On the battleship the picture performance is staged usually on one of the quarter decks, an area approximately 25 feet wide and possibly 180 feet in length. The size and shape of the audience varies with ships, but it is safe to suggest that the average audience on the deck is approximately the shape of the quarter deck described. The turrets, masts, rigging, and superstructure form the balconies and boxes. The sky seems to be the vertical limit. Picture the audience then as a long narrow body with great vertical depth made up of attentive movie fans, all of whom are anxious to hear the sound accompanying the picture but who possess no desire to be blasted by volume approaching the threshold of feeling.

This sea going audience is a regular one and, barring very inclement weather or ship's activities which prevent, the motion picture performance is a nightly feature. In the era of square riggers, the problem of securing a practical screen might have been an easy one, but sails on "men of war" have long since passed. In the past, the Navy has witnessed silent features projected on a heavy screen of canvas usually laced over a rugged pipe frame, which, when properly braced by guys, is the vertical support. The advent of sound complicates the screen situation. The old canvas screen is not sufficiently porous to permit its use as it is, and can not be satisfactorily punched because the punching process does not leave the holes clean. The problem was that of obtaining a screen that had a transmission efficiency of 90 per cent at 1000 cycles, that would stand a grab test of 335 pounds in the warp and 250 pounds in the filling (equivalent to that of very heavy canvas), and that would submit to washing in salt water. It must also stand up under the siege of fuel oil soot of high sulfur content, salt spray, and rain.

In addition to the problems which originated due to the sea going nature of the application, there was that part of the Naval specification that required that no batteries be utilized in any part of the equipment. It was generally known that copper oxide rectifiers were not desired by the customer. Naval specifications specified 115 volts d-c. as the available power supply for all equipment. As a result of these three limitations it must be apparent that the final design must incorporate some form of power conversion unit, and also utilize the available power source to the maximum extent, if complications were to be limited to a minimum.

In the foregoing paragraphs an attempt has been made to describe

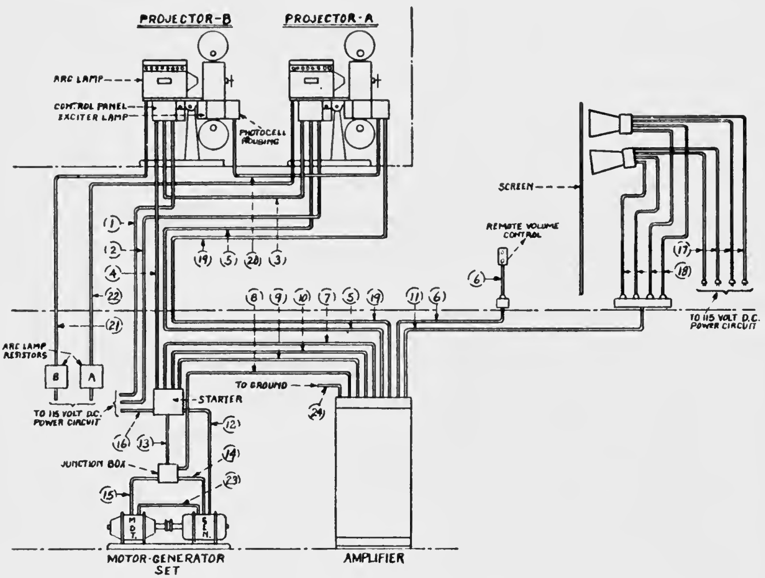

FIG. 1. Schematic diagram illustrating the major parts of a Type 1, Class A, equipment.

the conditions and limitations under which Naval sound motion picture reproducing equipment must operate. The remainder of the paper is devoted to the description of equipment designed and constructed to comply with Naval specifications. Every effort has been made to associate the problems at hand with the solution as exemplified in the final product.

It seems logical for the sake of clarity, first to present an approximate diagram of the equipment to be described. Fig. 1 shows the major parts of a Type 1, Class A, equipment. The location of the units varies with the ship. In general, two projectors with sound heads and associated control equipment, a remote volume control station, a screen, and four reproducers comprise that portion of the total installation located on or above the weather deck. The amplifier, motor-generator, and magnetic starter are assumed to be mounted below decks.

The projectors may be permanently mounted in a compartment in the main-mast, on the superstructure, or in a portable booth on the quarter deck. The sound screen is erected on the quarter deck possibly 100 feet from the projector station. The four reproducers are suspended behind it or above it by means of a ship's boat crane or suitable frame work. The remote volume control station is situated in the first few rows of the audience which occupies the quarter deck-area in front of the screen. The amplifier, motor generator, and associated equipment are located adjacent to each other in a protected area below decks. At best, this is an approximation of the possibilities involved in making shipboard installations on the various types of battleships. With this picture of the general arrangement of units in mind, each part can be described and its relation to adjacent units more easily understood.

PROJECTOR

The projector utilized in this application is a standard Simplex Type "S" machine modified to meet the specific requirements of Naval service. All metal contained in the machine is inherently resistive to corrosion. Sheet metal is required to be brass or an approved aluminum alloy. Bolts and rivets in sheet metal are of the same material as the metal, and bolt heads in exposed locations are copper plated. The projector is finished with a weather-resisting enamel. It is safe to assume that metals which are inherently resistive to corrosion and which are further protected by a suitable finish must withstand the siege of a humid salt atmosphere and salt water, in so far as corrosion is concerned. There can be no extensive electrolytic action due to contact of dissimilar metals when due precaution is exercised in joining similar metals with bolts and rivets of the same metal. These are the conditions under which the projector is constructed.

The Navy leases two prints of each feature picture it sees fit to exhibit, which must serve the entire Navy. It is only natural that the organization should be vitally interested in the manner in which this film is handled. The projector contains sprockets which are hardened, ground, and polished to prevent excessive wear and deformation of sprocket teeth. The shape of the sprocket teeth, the size of the sprockets, and the general alignment of the projector parts are such that the projector will pass a continuous film loop a minimum of 400 cycles without any indication of wear on the film. This film loop should indicate no need of repair at the completion of 800 cycles through the machine.

SOUND HEAD

The sound head, although a major unit, may well be classed as an accessory to the projector in that no adapters or machining operations are required to fit it to the projector.

It is composed of a main casting which contains the film handling mechanism and sound take-off devices, and a sheet metal phototube housing. The sound head is shown in Fig. 2. The main casting and film handling parts embody the same general features of construction as does the projector head, in that all parts resist corrosion and are designed to produce maximum film life.

The sound head derives its power from the picture head through a train of gears. The constant speed sprocket and the take-up sprocket are the driven members. Film enters the sound gate through a set of guide rollers by means of which the sound track is aligned with the image of the optical slit. The film is held snugly, though gently, against the gate shoe by means of adjustable tension springs on the gate. This particular feature is very important in handling film in the torrid temperatures of the tropics, where the wax protective coating on the film is very sensitive to abrasion and pressure and is very apt to pile up on the gate shoe. After leaving the sound gate the film wraps about the impedance roller and then passes to the constant speed sprocket and take-up sprocket in that order. The impedance roller is attached to a small flywheel, the inertia of which tends to keep it running at a constant speed, thus imparting a constant speed to the film. The take-up sprocket maintains a loop between itself and the constant speed sprocket to prevent changes in film speed introduced by the take-up mechanism from carrying through to the constant speed sprocket.

The exciter lamp is mounted in a socket which is removable from the projector and which permits prefocusing. It is possible to change exciter lamps with less than 30 seconds' interruption in a performance. The optical system is contained in a single barrel which is bolted to the center plate. It is focused by rotating a thumb nut on the objective. A spring lock prevents variation of the adjustment.

The shell of the phototube housing is of brass, heavily copper plated to increase its conductivity. The layer of copper on its surface materially increases its effectiveness as a shield against high frequency radiation. The phototube circuit is wholly contained within a metal compartment which is removable from the phototube housing as a unit by removing four bolts on the face of the housing. The UX-868 phototube (caesium cell), which is utilized in this equipment, is coupled to the amplifier system, all of which is below decks, by means of a low impedance transmission line and two line coupling trans-

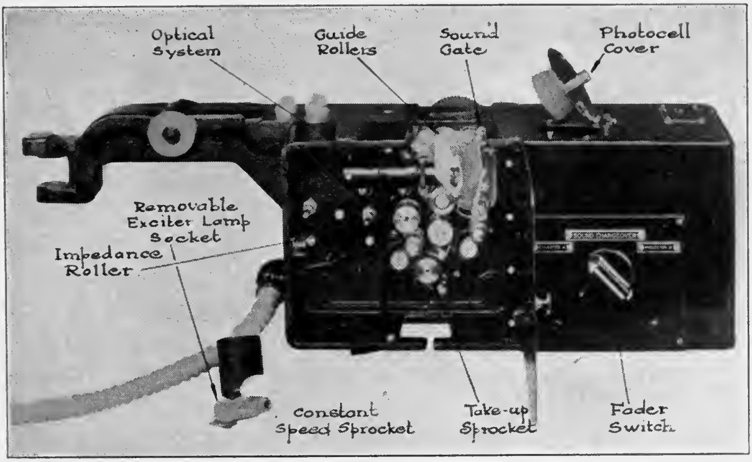

FIG. 2. The sound head.

formers. One of the transformers with its loading resistor, a protective resistor, and suitable filter capacitors is cushioned in sponge rubber (to prevent microphonics) and mounted in a metal container. This container is placed in a second container and is sealed in wax to prevent the entrance of salt air and water. This sealed unit is mounted within a third metal compartment, previously referred to as being removable from the phototube housing, and is wired to the phototube socket, the fader switch, and the terminal board, all of which are a part of the removable compartment.

The fader switch is installed in the front face of this compartment, on the operating side of the projector, as indicated in Fig. 2. The phototube socket is bolted to the upper face of the unit in a manner such that the UX-868 operates in the vertical position.

The circular opening in the upper face of the housing, through which the phototube is inserted and removed, is normally covered by a metal plate to which has been added a suitable pad of sponge rubber. A design of this nature reduces extraneous noise due to vibration of the phototube.

At the beginning of this paper, the necessity of successfully combating the effects of radio frequency fields, vibration, salt water, and salt air was highly stressed. The descriptions of the projector and sound head have been presented with the sole object in mind of relating the problems to the solutions.

CONTROL PANEL

In direct contrast to the usual theater installation, the reproducing equipment on a battleship is of necessity widely scattered. It must be installed where there is room for it, and where it can be utilized. It is only logical to believe that the controls in an installation of that type should be centered at the vantage point, the projector.

For this purpose a control panel was designed to be mounted on the projector. Fig. 3 shows the control panel so mounted. It includes an ammeter for measuring exciter lamp current, a rheostat, and three fixed resistors for reducing the 115 volt, d-c. supply to 10 volts for the exciter lamp, a power switch for the exciter lamp circuit, and a push button station and indicator lamp for remote control of the motor generator.

It might be well to explain at this point that the 10 volt, 5 ampere exciter lamp utilized in the sound head is operated from the ship's power supply, thereby eliminating the need of batteries or low voltage generators. It is desirable to use the 5 ampere lamp for this application in preference to a higher voltage lamp because of the strength of its filament, its ability to withstand vibration, and its large light output.

The control panel is of heavy brass properly finished.

PROJECTOR DRIVE MOTOR AND CONTROL

Anticipating fluctuations in ship's supply voltages, the Navy has specified that the projector speed shall not vary more than plus or minus 1 per cent with fluctuations in line voltage of plus or minus 15 per cent, without any manual adjustment to take care of the line fluctuation.

The motor on the projector is a d-c. machine containing a centrifugal governor and control in a special end bell. The governor is very sensitive to slight changes in speed. It opens and closes a shunt on one end of several tapped resistors in the field circuit of the motor. The control contacts which the governor operates are spaced by rotating an adjustment on the end bell. By this means it is possible to select the constant motor speed desired. The flywheel on the motor shaft

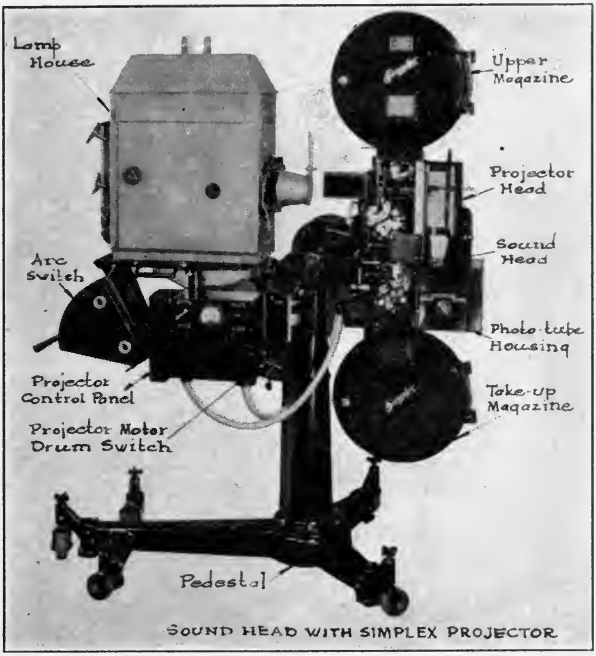

FIG. 3. The sound head and control panel mounted on Simplex projector.

stores enough kinetic energy to carry the system over the time interval required for the motor to respond to the action of the governor.

A small drum controller operates the motor. The switch mechanism of the controller is so arranged that the motor is braked dynamically by placing full excitation on the field and simultaneously short-circuiting the armature. The operating lever returns to the neutral position from the braking position as quickly as the hand pressure is relieved.

The assembly of the complete projector is shown in Fig. 3.

AMPLIFIER

The amplifier units, consisting of one voltage amplifier and two power amplifiers, are concentrated in one vertical rack together with a motor generator control panel. The complete unit is shown in Fig. 4.

The construction is particularly rugged and durable. The general structural features are to be noted in Fig. 5. The rack is made of channel iron supported by heavy angle iron feet. The lighter transformer and capacitor units are supported in the horizontal position

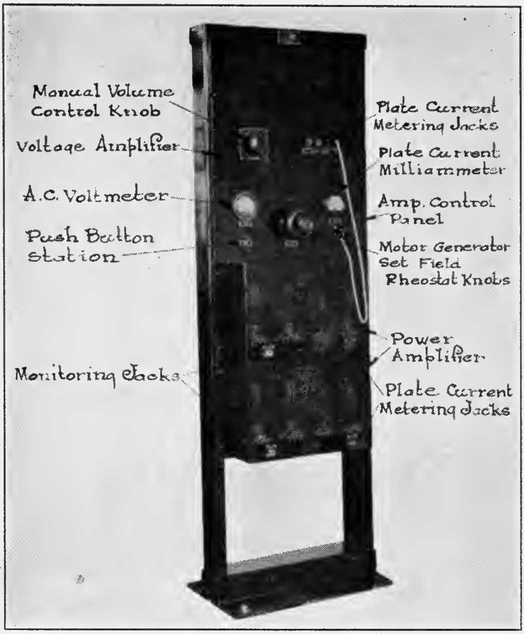

FIG. 4. Front view of amplifier.

from vertical panels which are bolted to the rack. This construction is particularly apparent in the voltage amplifier. The transformer and capacitor packs on the power amplifiers are heavy and are therefore mounted feet down on a heavy horizontal base. Each amplifier unit is a complete operating unit and is removable as such from the front of the rack. The dimensions of this rack are 72 by 24 inches, the maximum permitted by the Naval specifications. The lowest panel is 18 inches from the deck. The rack, panels, transformer and capacitor cases, and all other parts that are liable to corrode are heavily cadmium-plated.

A front view of the interior of the rack is shown in Fig. 6.

The voltage amplifier is a three-stage unit consisting of one UY-224 Radiotron resistance coupled to the second stage, a UY-227 Radiotron which is, in turn, transformer coupled to the third stage, and two UX-245 Radiotrons connected for push-pull operation. This amplifier is entirely a-c. operated, and contains its own power supply

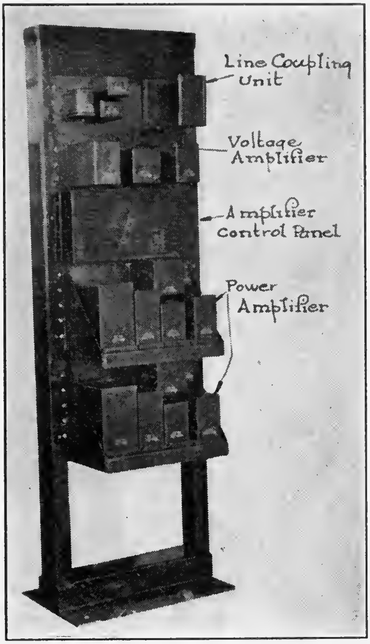

FIG. 5. Rear view of amplifier.

including a power transformer, one UX-280 Radiotron rectifier, and a complete filter. The phototube also derives its polarizing voltage from this power supply. The volume control is a potentiometer between the first and second stages of the amplifier. It consists of a tapped switch, between the contacts of which are connected individual metallized resistors of a type approved by the Navy.

The volume control is operated by a handle protruding through the face panel or by a push button station located at a remote point.

The push button control operates a capacitor motor installed in the voltage amplifier and geared to the volume control shaft. The capacitor motor is a two-phase, low-voltage induction motor which operates in conjunction with a capacitor which may be placed in series with either phase, depending upon the desired direction of rotation.

As a means of checking the operation of the amplifier under static conditions, a plate current metering jack is provided for each stage. The jacks are so shunted that all plate currents may be read accurately

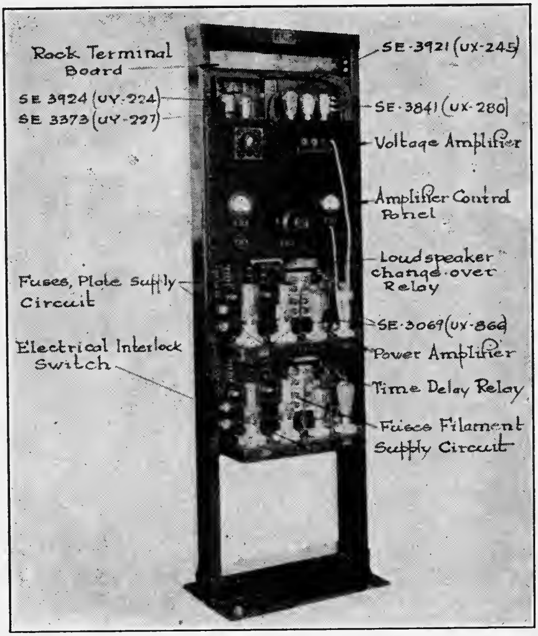

FIG. 6. Front view of amplifier showing the interior of the rack.

on one milliammeter provided on the amplifier control panel, to be described later.

Each important transformer in the voltage amplifier contains three varieties of shielding. The shielding prevents the transfer of undesirable frequencies from one winding to another, and materially reduces the effect of powerful magnetic fields from within and of electrostatic fields from without. Supplementing the shielding of transformer units, the first two stages of the voltage amplifier, along with their immediate accessories, are contained within a heavy metallic shield. Although the volume control is within this shield the capacitor drive motor is without. Shielding alone is not adequate when economically used in combating the effects of magnetic fields set up by power transformers and reactors within the amplifier. It is applied after the offending units have been so positioned and placed with respect to the audio units that the inductive effect is reduced to a minimum. Careful consideration of these points permits compactness of design, as exemplified in this amplifier, with an exceedingly low ratio of hum to audio power output.

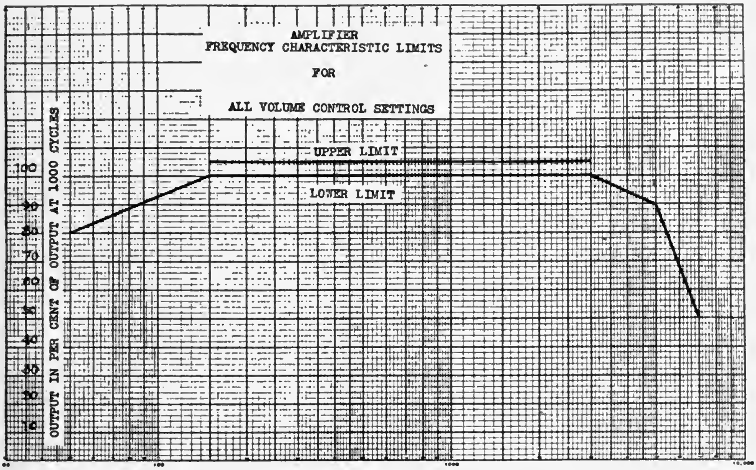

FIG. 7. Limit curves showing specifications for amplifier frequency characteristics.

The metal tube cradles of the voltage amplifier rest on rubber cushions, and make no contact with metal at any point. The volume control is the only manual adjustment on the amplifier system. All other adjustments are automatic.

There are two power amplifiers on the rack, identical in design and removable as units. Each amplifier consists of one stage of two UV-845 Radiotrons connected for push-pull operation. The power for these tubes is derived from the power supply system consisting of a filament transformer, a plate transformer, a filter, and two UX-866 Radiotrons (half-wave rectifiers). A tapped input transformer couples the power amplifiers to the low-impedance line which interconnects the voltage and power amplifiers. Normally the two power amplifiers operate with the full primary windings of their input transformers in parallel. However, if it becomes necessary to remove one power amplifier from the rack for any reason, proper operation of the remaining unit may continue by changing over to the tap on the input transformer. This maintains the correct line loading. It also permits the use of the same type of power amplifier in another Naval equipment of one-half the power rating. Each power amplifier normally feeds two reproducers. The output transformers are tapped to accommodate more or less than that number, however, making the amplifier versatile in its application.

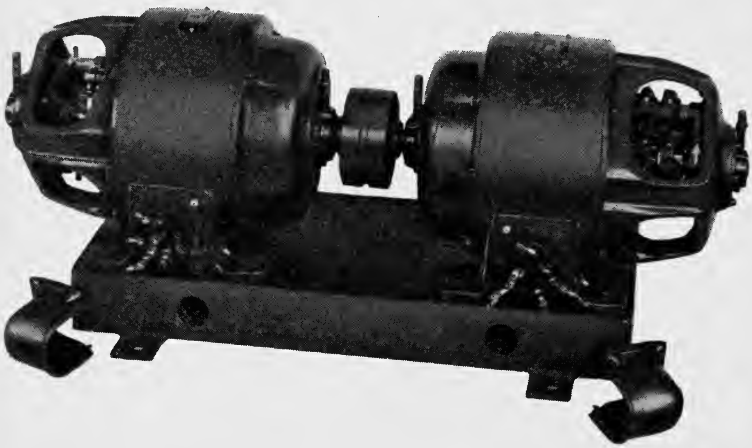

FIG. 8. Motor-generator set.

The general features of construction described in the voltage amplifier apply to the power amplifier.

The UX-866 Radiotrons (mercury vapor rectifiers) require the application of cathode voltage thirty seconds in advance of the anode voltage. For this purpose an oil dash-pot time-delay relay has been incorporated in the design.

Inasmuch as each power amplifier supplies two of a total of four reproducers under normal operating conditions, it is important that some provision be made for the continued operation of the four reproducers in the event of the failure of either unit. This function is performed by one relay in each amplifier. These relays are energized with power from the rectifier circuits. When both relays are closed (indicating normal operation) each power amplifier carries two reproducers. When only one relay is energized (indicating one power amplifier not operating) the four reproducers operate from the remaining power amplifier. When the rectified current in either power amplifier is sufficiently low (indicating the failure of a unit in the rectifier circuit) one relay opens. When the load on the rectifier circuit is too great (indicating a flashover or tube failure) fuses in the a-c. supply circuits to the filament or plate transformer burn, causing one relay to open.

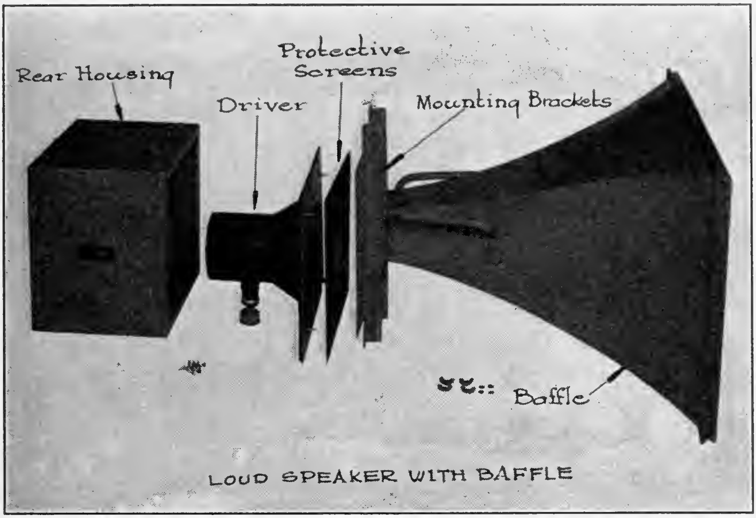

FIG. 9. Loud speaker with baffle.

Jacks are provided for monitoring the audio input and output to each power amplifier.

The tubes are set forward of the rack in order that the heat radiated may be dissipated in the surrounding air and be prevented from ascending between the rack channels.

The units are protected by heavy perforated metal cages. The removal of either of the cages releases an interlock which opens the a-c. supply circuit of the high potential power transformer, thereby eliminating the shock hazard. The total output of the rack is 80 watts of undistorted audio power.

The remaining panel on the amplifier rack is the control panel. Its contents include an a-c. voltmeter for measuring the a-c. voltage applied to the rack, a d-c. milliammeter and plug cord for measuring plate current in each amplifier stage, a push button station for motor generator starting, and motor and generator field rheostats. The field rheostats are mounted in tandem. They are controlled by concentric knobs appearing on the face of the panel. This construction is very economical of space.

The push button station supplements similar controls on the projector control panels. This is the only switch on the amplifier rack. It controls the power supply to the entire audio system. Depressing the start button causes the solenoid in the magnetic

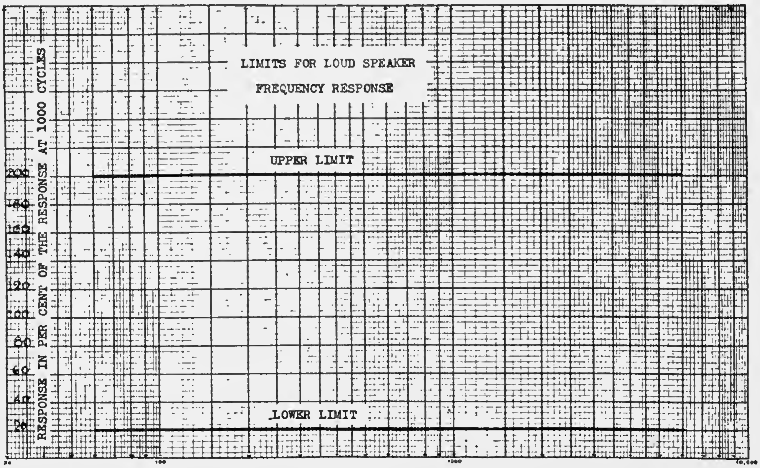

FIG. 10. Frequency response curve of the unit.

starter to be energized, which, in turn, closes the d-c. circuit of the time-delay relays in the power amplifiers and places the motor-generator in operation. By this means power is applied to all the units concerned in the proper sequence. This eliminates the possibility of operating the power amplifiers without having the time-delay relays functioning as intended. Fuses in the rear face of the panel protect the remote control lines.

In concluding this description of the amplifier, it is fitting that its performance be adequately treated. The limit curves shown in Fig. 7, established by the Naval specifications, best attest to the quality of amplifier performance.

Returning to the original problems for a moment, bear in mind the thought that the amplifier rack and its components were designed to bear up and perform in accordance with Naval specifications under the severest onslaughts of salt water, humidity, vibration, concussion, and radio frequency radiation. The need of an efficient system of remote control and of equipment adequately protected against possible injury from overload was duly emphasized at the beginning of this paper. These points are to be associated with the actual amplifier design, involving special shielding features, shock mountings, the application of protective finishes, automatic switching, remote control, and protective features as described above.

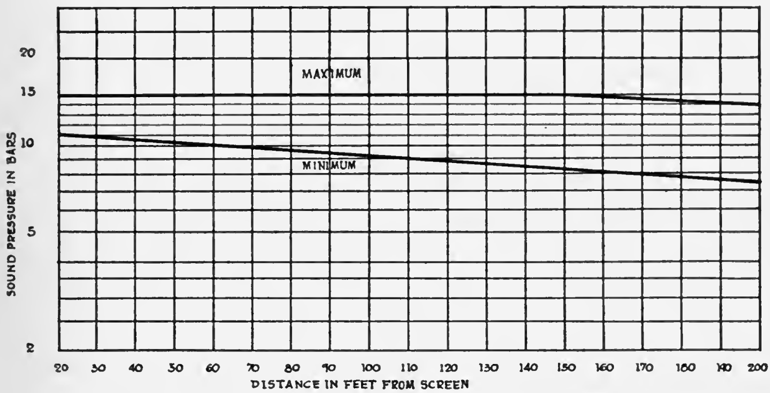

FIG. 11. Sound pressure distribution limits at 1000 cycles.

MOTOR-GENERATOR

It is the purpose of the motor-generator to supply all the a-c. power required by the equipment. The motor is a 3 hp., 115 volt, d-c. compound wound unit, and the generator is a 110 volt, 60 cycle, $1^1/_2$ kva. unit with a special series field which carries the motor line current. Motor speed and generator voltage are controlled by the field rheostats previously described as part of the amplifier control panel. This motor-generator is shown in Fig. 8.

A magnetic starter controlled by push button stations on the amplifier and projector control panels performs the starting function.

REPRODUCERS

Four directive baffles of the type indicated in Fig. 9 are supplied with this equipment. The entire baffle is of metal, heavily cadmium-plated. The driver is a cone dynamic unit sealed, where possible, with wax. The cone is protected by two wire mesh screens and two cloth screens placed across the throat of the baffle. The driver is bolted to a heavy metal plate which is the cover to the rear housing of the baffle. This rear housing (with driver) is detachable as a unit from the baffle by removing four wing nuts.

The maximum dimensions of the unit do not exceed the 26 by 48 inch limits set by the Naval specifications. It is easily carried by two men as required. The frequency response curve of this unit falls within the limits indicated on Fig. 10, as specified by the Navy.

To obtain a sound pressure distribution curve that will fall within the limits indicated on Fig 11, it was necessary to mount the four baffles in two tiers of two baffles each, with the highest point of the upper tier at a maximum height of twenty feet above the level of the test area.

Upon these units falls the burden of reproducing and distributing high quality sound under many atmospheric conditions and over a wide area.

SCREEN

The problem involved in the design of a screen was that of securing a material that was 90 per cent efficient in the transmission of sound at a frequency of 1000 cycles, yet capable of standing a grab test of 250 pounds in the filling, stand washing in salt water, and resist the effects of fuel oil soot of high sulfur content. Heavy duck would meet these requirements with the exception that it will not transmit sound at the required efficiency. Neither does it perforate with a clean cut.

The final product is a combination of a durable cloth that is easily perforated and a checker network backing composed of ribs of several ply duck.

The ribs of duck have the required strength to withstand the grab test. There is sufficient perforated material exposed in the open spaces of the network to permit the required transmission of sound.

THE DUPLICATION OF MOTION PICTURE NEGATIVES*

J. I. CRABTREE AND C. H. SCHWINGEL**

Summary.—*In 1926, Capstaff and Seymour*[1] *published a paper giving directions for making duplicate negatives using a new film manufactured specifically for that purpose. Good quality and tone reproduction were possible by this method although the graininess of exhibition prints was not entirely satisfactory.*

Since then, improved films have been available, and the present paper contains a description of the tests performed during a search for the most satisfactory sensitive materials and processing technic. The experiments showed that in order to minimize graininess, the master positive must be developed to a relatively high gamma (1.85) in a positive developer, and the duplicate negative to a correspondingly low gamma (0.55 or less). There are also given data which explain why the high gamma master positive in conjunction with a low gamma duplicate negative gives the most satisfactory graininess.

I. INTRODUCTION

The unsatisfactory quality of many of the duplicate motion picture negatives produced to date has been due partly to the use of unsuitable film emulsions for their preparation, and partly to a lack of understanding of the conditions under which good duplicates can be made.

A good duplicate negative is one capable of giving a print which is a facsimile of a print made from the original negative. It should reproduce accurately the tones of the original negative unless the contrast range has been modified to correct some fault. Also, the definition and the graininess of the duplicate should be of the same order as those of the original.

Heretofore, no extensive survey has been available for the purpose of choosing the best photographic material and processing technic for the production of good duplicates. In an article entitled "The Duplication of Motion Picture Negatives"[1] by J. G. Capstaff and M. W. Seymour, the use of Eastman duplicating film (emulsion series No. 1503) was advised for both master positive and duplicate

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* Presented at the Spring, 1932, Meeting at Washington, D. C. Communication No. 488 from the Kodak Research Laboratories.

** Research Laboratories, Eastman Kodak Co., Rochester, N. Y.

negative, both of these being developed to a gamma of unity. Following this, C. E. Ives and E. Huse[2] published additional notes and gave precautions necessary for the production of good quality duplicate motion picture negatives utilizing the above procedure.

The results obtained were very satisfactory with regard to quality and tone reproduction, but the graininess of the exhibition prints left much to be desired.

It was stated by some laboratories that better results with respect to graininess were obtained by making the master positive on motion picture positive film with lavender support developed to a high gamma, and the duplicate negative on par-speed negative film developed to a correspondingly low gamma.

Early in 1929 two new films were put on the market for use in duplicating. They were Eastman duplicating positive film with lavender support (emulsion series 1355) and Eastman duplicating negative film (emulsion series 1505). These films were recommended as being more suitable for duplicating purposes than the 1503-1503 combination. Emulsion 1505 was faster than 1503, and with emulsion 1355 it was possible to print under the same printer conditions as with motion picture positive film.

In an article entitled "The Graininess of Motion Picture Film,"[3] one of the authors showed that the graininess of a positive print increased with increasing density of the negative from which it was printed. He also pointed out that the graininess of a positive printed from a negative developed to a high gamma was greater than that printed from a negative of the same density contrast, but which was developed to a lower gamma.

With these facts under consideration and in order to determine the most suitable sensitive material and processing technic for duplicating purposes, the present investigation was undertaken.

II. METHOD EMPLOYED FOR DETERMINING A SATISFACTORY DUPLICATING PROCESS

More than 200 separate tests were required for the purpose of finding the most suitable procedure to follow in the making of good duplicate motion picture negatives. Each test consisted of the printing of a master positive from the original negative and then printing a duplicate negative from this. In all cases, the duplicate negatives were made with a printing contrast equal to that of the original negative. The contrast of the duplicate negative was judged by the degree of development required to produce a print of given contrast. Each test embodied some change in the process, either in the sensitive materials, the developers, or the processing technic employed.

Matched exhibition prints on Eastman motion picture positive film were prepared from all original and duplicate negatives and these were compared on projection, the measure of graininess being taken as the ratio of the distance of the observer from the screen to the vertical dimension of the screen. By distance from screen is meant the minimum distance at which graininess was not apparent to the eye, with the line of sight normal to the screen at its lower edge.

It is true that the distance at which graininess was zero varied with the observer, but comparisons have shown that the variation was not more than 10 per cent among individuals having normal eyesight. A greater accuracy can not be expected and this method of comparison seemed satisfactory from the standpoint that quality and graininess were compared under practical projection conditions. The screen size was 43 by 57 inches, with a screen brightness between 10 and 11 apparent foot-candles. The projector was operated at a speed well above that at which flicker was noticeable.

The standards used for comparison were prints made from the original negatives, and new standards were made for every series and at all other times when the processing needed to be checked.

Gammas reported in this work were determined from sensitometric strips made on the film under discussion and exposed in the printer. These sensitometric strips were processed along with the master positive or duplicate negatives. All densities were measured on a Capstaff densitometer.[4]

(*A*) *Sensitive Material.*—An emulsion suitable for duplicating must fulfill the following conditions: (*a*) The emulsion must have sufficient latitude to permit the correct reproduction of the greatest scale of tones likely to be met with in the original negative; (*b*) it must have the ability to reproduce fine detail, otherwise a serious loss in picture definition will occur; (*c*) the developed image must have a minimum graininess, otherwise the cumulative effect in making the master positive and duplicate negative will produce excessive graininess in the exhibition print; (*d*) it must have sufficient speed to permit printing the master positive or duplicate negative without extensive modifications of the printer optical system.

The emulsions listed below were those among the eighteen different emulsions tested which showed the most promise of being suitable for duplicating purposes. Only the data relative to these will be given and discussed in this article.

Emulsion Series Number	Film
1302	Eastman Motion Picture Positive Film, Lavender Support
1355	Eastman Duplicating Positive Film, Lavender Support
1503	Eastman Duplicating Negative Film, Yellow-dyed
1505	Eastman Duplicating Negative Film, Yellow-dyed
1201	Eastman Negative Film

(*B*) *Original Negatives.*—The original negatives chosen for this work were of average density contrast. Since graininess is most apparent in the lighter tones, such as in the face and in other uniform areas of low density, the scenes selected were principally close-ups.

(*C*) *Type of Printer Employed.*—The master positives, duplicate negatives, and exhibition prints were printed on a Bell & Howell continuous printer which had been tested and approved as giving good definition. It was found to be very important that the film be in uniform contact over the entire area of the printer aperture, otherwise a patchy, uneven image was produced. To test the printer for uniformity of contact, a print was made from a strip of evenly fogged and developed negative film. Perfect adjustment of the printer was indicated by an even density in the print, while imperfect adjustment gave the patchy unevenness referred to above. The printer was also tested for steady operation by exposing a length of positive film in the printer, without a negative, and then examining it for unevenness after development.

(*D*) *Processing Methods.*—Several methods of processing the films were used, including (*a*) rack and tank, and (*b*) continuous machine. There appeared to be no difference in the graininess of the images obtained by the different methods, although machine processing gave the most uniform results.

Too much emphasis can not be placed upon the necessity for good development technic. It must be remembered that the production of a final print in a duplicating process requires four distinctly separate development operations and, since all defects are cumulative, these defects will be greatly magnified in the exhibition print. It is the accumulation of the small defects and errors which gives the "duped" appearance to prints made from unsatisfactory duplicate motion picture negatives.

(*E*) *Developers.*—In addition to such standard developers as formulas *D*-16 and *D*-76,[5] a large number of developers of special composition also were tried.

Only the experimental results obtained from the use of two of these special developers will be given. The formulas will be known as Special Developers No. 1 and No. 2. Developer No. 1 contained potassium iodide, and Developer No. 2 was one capable of giving high contrast.

III. DISCUSSION OF RESULTS

Table I contains the data relating to the emulsions tabulated above. All the duplicate negatives listed were made so as to have

TABLE I

(*Print from Original Negative—Graininess Ratio = 5.4*)

No.	Emulsion Number	Developer	Gamma	Minimum Density	Emulsion Number	Developer	Gamma	Minimum Density	Quality	Graininess
1	1503	*D*-76	Approx. Unity	0.45	1503	*D*-76	Approx. Unity	0.40	Good	7.5
2	1503	*D*-76	Approx. Unity	0.40	1503	*D*-76	Approx. Unity	0.62	Good	7.8
3	1505	*D*-76	Approx. Unity	0.20	1505	*D*-76	Approx. Unity	0.42	Fair	8.1
4	1505	*D*-76	Approx. Unity	0.50	1505	*D*-76	Approx. Unity	0.45	Good	8.4
5	1355	*D*-16	1.52	0.30	1505	*D*-76	0.69	0.50	Good	6.5
6	1355	*D*-16	1.52	0.30	1503	*D*-76	0.69	0.50	Good	6.7
7	1355	*D*-16	1.85	0.30	1505	*D*-76	0.55	0.25	Very Good	6.3
8	1355	*D*-16	1.98	0.40	1505	*D*-76	0.52	0.25	Fair	6.3
9	1355	Special Dev. No. 1	1.61	0.28	1505	*D*-76	0.62	0.40	Very Good	6.7
10	1355	Special Dev. No. 1	1.62	0.51	1505	*D*-76	0.61	0.37	Good	7.0
11	1355	*D*-16	1.60	0.50	1505	*D*-76	0.60	0.45	Good	6.7
12	1355	*D*-76	1.05	0.51	1505	*D*-76	1.00	0.50	Good	8.3
13	1355	Special Dev. No. 2	2.02	0.21	1505	*D*-76	0.50	0.42	Good	7.5
14	1355	Special Dev. No. 2	2.04	0.50	1505	*D*-76	0.50	0.40	Very Good	7.2
15	1302	*D*-76	2.00	0.50	1201	*D*-76	0.50	0.45	Fair	7.9
16	1302	*D*-76	2.00	0.50	1505	*D*-76	0.50	0.42	Fair	8.1
17	1302	*D*-76	2.62	0.30	1201	*D*-76	0.38	0.30	Fair	6.5

the same printing contrast as that of the original. The contrast of the duplicate negative was judged by the degree of development required to produce a given contrast in the positive printed from it.

(*A*) *Results Obtained with Various Emulsions in Which Both*

*Master Positive and Duplicate Negative Were Developed to a Gamma of Unity**.—Tests Nos. 1 to 4, inclusive, and No. 12 (Table I) were made for the purpose of determining the effect of varying the type of duplicating emulsion on graininess and quality. All master positives and duplicate negatives in these tests were developed in *D*-76 developer to equal degrees of contrast (gamma 1.0).

From the data it will be seen that emulsion 1503 produced images with less graininess than the faster duplicating emulsions 1505 and 1355. The quality was good in all cases except that of test No. 3, where the loss occurred in the master positive. The reason for the poor quality in the master positive was that the low densities were printed too low on the density scale and, therefore, the highlight densities were printed in the region of underexposure. It was found necessary with emulsions 1503 and 1505 to print to a minimum density greater than 0.4 for a gamma of 1.0 in order to insure good tone reproduction. With emulsion 1355, lower minimum densities were permissible. Comparison of the results from tests Nos. 1 and 2 showed that an increase in density in the duplicate negative caused a very slight increase in graininess. Likewise, from the results of tests Nos. 3 and 4, it was seen that an increase in density of the master positive caused the same effect. Results from tests Nos. 9 and 10 also confirmed this observation. This fact is not new and is in agreement with the previous findings of one of the authors.[3]

(*B*) *Results Obtained Using the 1355-1505 Process*.—In tests Nos. 5 to 14, inclusive, Eastman duplicating positive film, emulsion series No. 1355, was used for the master positives and the yellow-dyed duplicating negative film for the duplicate negatives. With the exception of test No. 6, Eastman duplicating negative fast, emulsion series 1505, was used for the duplicate negatives. Tests Nos. 5 and 6 were for comparing the merits of emulsions 1503 and 1505, when used for the duplicate negative and developed to a low gamma. There appeared to be practically no difference in the graininess or quality when comparisons were made between the exhibition prints.

Test No. 8 shows the results obtained when the master positive was developed to a very high gamma in developer *D*-16. The duplicate negative, which had been printed to the lowest minimum

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* For explanation of emulsion characteristic curves with regard to exposure, latitude, tone rendering, gamma, *etc.*, see references 6 and 7.

density in the region of correct exposure, was developed to a correspondingly low gamma. The result was a very low graininess ratio (6.3), when compared with the results of the other tests. However, the quality was not as good as with the lower gamma master positive due to the necessity of printing the high master positive densities in the region of overexposure. By lowering the gamma slightly (1.85), the quality was improved. This was illustrated by the results obtained from test No. 7 in which there appeared to be no increase in graininess over that in test No. 8.

Tests Nos. 9 and 10 were for the purpose of determining whether or not a special contrast iodide developer would permit the use of lower minimum densities for the master positive. It apparently had no advantage in that respect and was objectionable because the graininess was slightly worse than in the case where *D*-16 was used (tests Nos. 10 and 11).

Tests Nos. 13 and 14 were made using a special high contrast developer. Results showed that the quality was good, but the graininess was worse than in those tests where *D*-16 was used for developing the master positive.

(*C*) *Comparison between 1355-1505 and 1302-1201 Processes.*—Tests Nos. 15 and 16 were made for the purpose of comparing the results obtained from the 1355-1505 and 1302-1201 processes; also for determining the effect of using emulsion 1505 for the duplicate negative in the 1302-1201 process. The results showed that for equal gammas the graininess was appreciably better when the 1355-1505 process was employed. No advantage was gained by using emulsion 1505 instead of emulsion 1201 in the 1302-1201 process.

Test No. 17 showed that graininess results comparable with those obtained in test No. 7 were obtained when 1302 was developed to a very high gamma (2.62). The quality was poor and development defects were noticeable, caused by the very low degree of development necessary for the negative.

IV. FACTORS AFFECTING GRAININESS DURING EXPOSURE AND DEVELOPMENT

In the foregoing tests, the graininess of the original negative exerted a pronounced effect on the graininess of the duplicate negatives and prints. In order to eliminate this effect and to determine the influence of exposure and development on graininess, the following tests were made.

Lengths of the various films tested in Table I were given uniform flash exposures and developed by the rack and tank method. The degrees of development were determined from step tablet readings from exposed strips developed on the racks with the flashed films. The negative types of material were developed in the borax developer *D*-76, and the positive material in the positive developer, formula *D*-16.

It has been found throughout this investigation that, whenever a negative emulsion was developed in a positive type of developer, graininess was greater than when the material was developed to an equal degree in the borax developer. The borax developer is not suitable for positive development, however, because of its inability to produce the necessary high gamma.

The graininess of the developed flashed strips was judged by the method described for all preceding tests. In these observations the assumption was made that the graininess of the photographic material was proportional to the distance from the eye of the observer to the screen. Since the visual acuity of the observer was subject to variations due to such factors as adaptation level, fatigue, and general physiological conditions, allowances were made for these whenever measurements were made.

Before making measurements, the person chosen for the viewing was allowed to remain for a length of time in a room which had an illumination level approximating that encountered when viewing the screen. This preliminary precaution was necessary in order to fix the adaptation level of the observer and minimize errors arising from variations of this. Numerous check determinations were made, and in no case were values found deviating more than 10 per cent.

Each screen test consisted of the projection of not more than 225 feet of film to be viewed, after which the observer was allowed to rest for a period of ten to twenty minutes before continuing. In this way, errors arising from eye fatigue were minimized.

The values for graininess reported were the result of a large number of observations made by three observers of normal vision, which were averaged when drawing the curves.

(*A*) *Variation of Graininess of a Constant Density with Degree of Development.*—Lengths of the flashed film were developed for varying degrees to give gammas covering the useful range for each of the emulsions used. The exposures were varied to give a density of 0.8 in every case. The graininess ratios determined by projection were plotted against the gammas to give the curves shown in Fig. 1. The results show that for negative emulsions the graininess increased very rapidly with increase in the degree of development, while for the positive types of film, the graininess rapidly reached a maximum and then remained practically constant, or even decreased slightly with increasing degrees of development, over the useful range of the material.

These results seem to show why the method using a high gamma master positive and a low gamma duplicate negative, which were printed on positive and negative emulsions, respectively, gave less

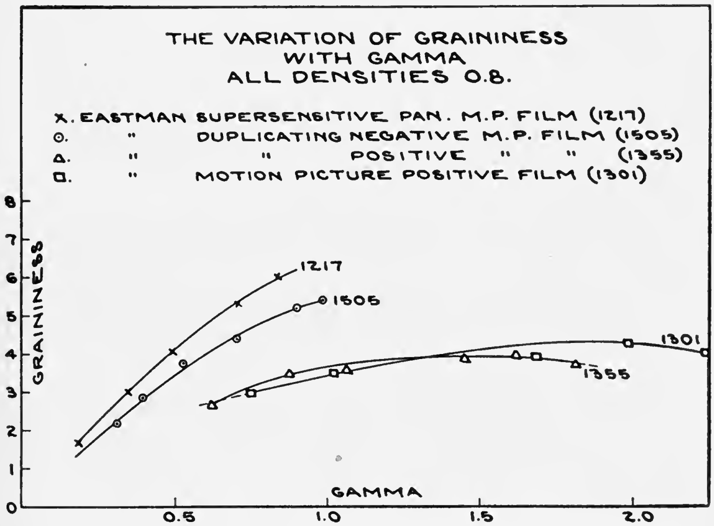

FIG. 1. The variation of graininess with gamma—all densities 0.8.

graininess than the earlier recommended method in which both master positive and duplicate negative were printed on a negative emulsion and developed to a gamma of unity.

These experiments also confirm those of Crabtree and Carlton[6] who predicted that "the graininess-gamma curve for a negative material over the useful range of gamma (0.5 to 1.0) is probably straight and rather steep, while the graininess-gamma curve for the positive (gammas 1.2 to 2.2) has a long shoulder which must be almost parallel to the gamma axis."

For this discussion it can be assumed that the graininess of a print is the additive result of the inherent graininess of the master positive and duplicate negative materials, although actually it appears to be somewhat less than this total. The graininess ratio of a flashed length of duplicating negative film (emulsion series 1505), developed to a gamma of unity, was approximately 5.5 units, and a print from this on the same material and developed to a gamma of unity on this assumption, would therefore have a graininess approximately double this, or 11 units. Considering a second example, where the master positive was printed on duplicating positive film (emulsion series 1355), and developed to a gamma of 1.85 when the graininess ratio

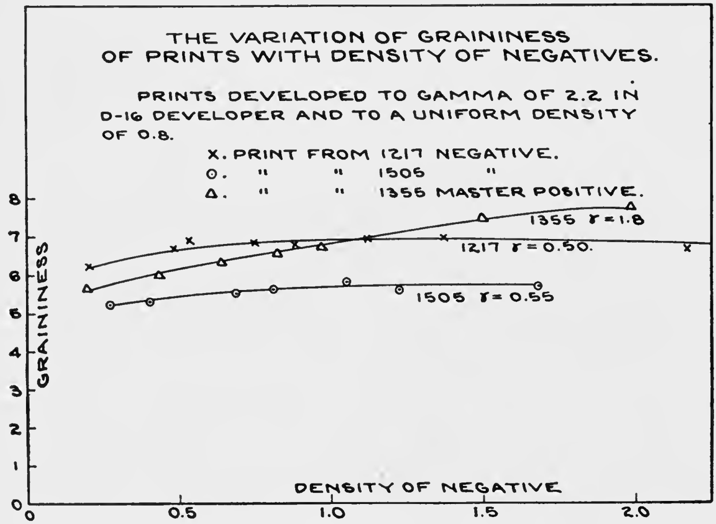

FIG. 2. The variation of graininess of prints with density of negatives. Prints developed to a gamma of 2.2 in *D*-16 developer and to a uniform density of 0.8.

was approximately 3.8 units; and then printing the duplicate negative on duplicating negative film (emulsion series 1505), developed to a gamma of 0.55, which furnished additional units of 3.8 (see curve in Fig. 1), it is seen that the duplicate negative would have a graininess ratio approximating 7.6 units. It is apparent, therefore, that the graininess should be much less in the case of a duplicate negative prepared by the latter method than one prepared by the former method.

In Fig. 1 the graininess curve for duplicating positive film is contrasted with that of motion picture positive film for the purpose of showing that the graininess ratio is lower for the duplicating material at high gammas.

(*B*) *Variation of Graininess with Density.*—Lengths of film were given varying flash exposures, and developed to the gammas recommended. It was considered that the graininess could not be judged correctly from these because of the varying screen brightnesses, so prints were made on motion picture positive film from the various densities, and exposed so as to give a density of 0.8 with equal degrees of development.

The graininess ratios of these films were determined and plotted against the negative densities to give the curves of Fig. 2, which show that for the master positive the densities should be as low as possible on the density scale, while in the case of the duplicate negative printed on negative materials, the graininess increases only slightly with increase of density of the negative. It is also seen that the graininess of Eastman supersensitive panchromatic film is greater than that of Eastman duplicating negative film, but the curves run parallel to one another.

V. FACTORS AFFECTING GRAININESS DURING PRINTING

(*A*) *The Effect of Loss in Definition on Graininess.*—Tests were made to determine the effect on graininess of imperfect negative-positive contact in printing. These were accomplished in two ways: (*a*) by adjusting the printer gate so as to permit the negative to be out of contact with the positive stock during exposure, and (*b*) by printing through a thickness of Kodaloid.

The results were similar in both cases, and showed that whenever a loss in picture definition occurred there was also a diminution in graininess. The slight loss in picture definition was not objectionable in certain types of prints, particularly with close-ups where fine detail was not essential.

(*B*) *Effect on Graininess of Printing with Diffuse Light.*—The gate of a motion picture step printer was fitted with a piece of pot opal glass in such a manner as to insure perfect contact between the glass and the negative during the printing operation. This arrangement permitted the printing to be carried out with diffuse light. Duplicate negatives and prints from these and from original negatives showed no appreciable difference in graininess, although printing with diffuse light slightly impaired the picture definition.

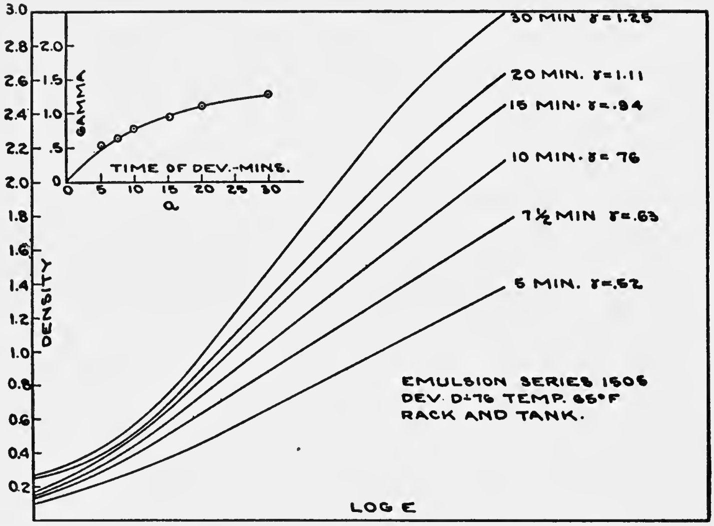

FIG. 3. Characteristic curves for Eastman duplicating negative motion picture film, series 1505. Developed in *D*-76 at 65°F. by rack and tank method.

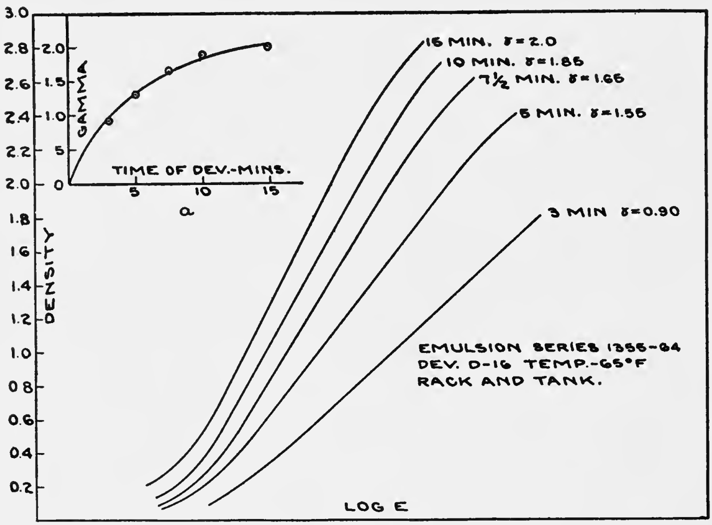

FIG. 4. Characteristic curves for Eastman duplicating positive motion picture film, series 1355. Developed in *D*-16 at 65°F. by rack and tank method.

VI. TONE REPRODUCTION

The photographic characteristics of emulsion series 1505 are shown in Fig. 3, from which it is seen that at the low gamma required for duplicate negatives (0.5–0.6), it was possible to print to a minimum density of 0.3 and still retain all the negative densities on the straight-line portion of the characteristic curve, which is the requirement for correct tone reproduction.[7,8] For higher gammas it was necessary to increase the minimum density values. A development time-gamma curve is also given in Fig. 3 (*a*).

Emulsion series 1355 (Eastman duplicating positive film) was

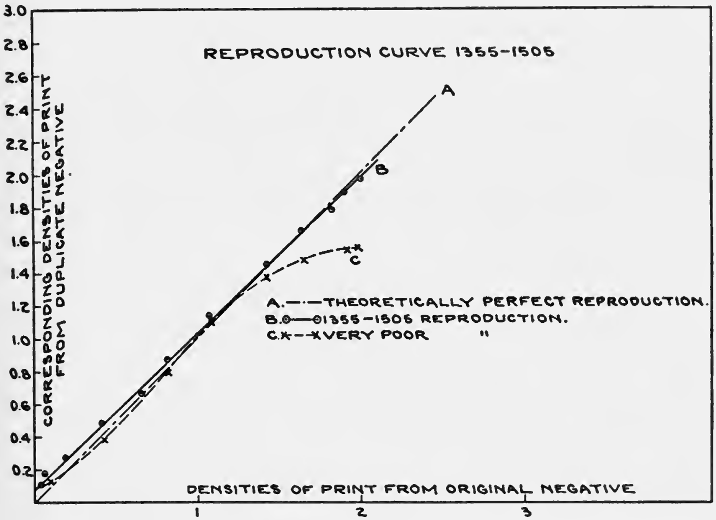

FIG. 5. Curves showing the degree of perfection attained in the duplication of negatives.

found to be the most suitable material for use in the making of the master positive. Its latitude permitted the use of the high gamma (1.85) without impairment of the tone reproduction. Owing to the great density range to be covered in the master positive for best gamma conditions, no other material was found which was entirely suitable in this respect. Fig. 4 gives the characteristics of emulsion series 1355, and it is seen from the curves that at a gamma of 1.85, it is necessary to print at a minimum density of not less than 0.40, otherwise a loss in highlight quality will occur. Fig. 4 (*a*) gives the development time-gamma relationship for this emulsion.

(*A*) *Reproduction Curve for the 1355-1505 Process.*—Fig. 5 is a tone reproduction curve for the 1355-1505 process, the densities of a print from the duplicate negative being plotted against the corresponding densities of the print from the original negative. The negatives and prints were perfectly matched and the prints from which the densities were taken received identical development.

It is obvious that with this method of representation, perfect tone reproduction is represented by a straight line at 45 degrees to the axis and commencing at the origin (Curve *A*). Curve *B* represents the tone reproduction with the 1355-1505 process, and it will be seen that when this curve is compared with Curve *A*, the process gives almost perfect tone reproduction, but only if care is taken not to print too low on the density scale when exposing the master positive and duplicate negative. Curve *C* (Fig. 5) shows the distortion that resulted when these precautions were not taken.

VII. THE DUPLICATION OF SOUND NEGATIVES

Frequency records with three modulation levels and frequencies varying from 100 to 6000 cycles were duplicated. Listening tests indicated that the upper frequency limit for duplicate negatives was approximately 6000 cycles, which frequency was only discernible at high and medium modulation levels. Tests also showed that a slight increase in ground noise occurred which became objectionable only in the frequency range from 5000 to 6000 cycles. Prints from duplicate negatives of piano records and vocal selections, for practical purposes, were indistinguishable from the original prints.

VIII. PRACTICAL INSTRUCTIONS FOR MAKING DUPLICATE NEGATIVES

Duplicate motion picture negatives may be made in the usual way without departing from ordinary methods of exposure and development. The quality of these duplicates will be better than could be obtained on other existing emulsions using similar technic.

(*A*) *The Master Positive.*—The master positive should be made on Eastman duplicating positive film, emulsion series 1355. The speed of this material is approximately the same as that of ordinary motion picture positive film. A lavender support serves the purpose of reducing halation effects and also for identification. The emulsion is capable of giving very fine grained images with good contrast on full development. Its latitude is such as to insure correct reproduction for the greatest range of tones likely to be met in an original negative. Also, it has the ability to reproduce the detail registered on the original.

(*B*) *Printing the Master Positive.*—When printing the master positive, the first requirement is that sufficient exposure must be given so that all the tones and fine detail of the original are recorded faithfully. *A good master positive appears denser than the average projection positive, and to the inexperienced eye seems to be overprinted.* The least dense portions ("catch-lights") of any master positive should have a measurable density—a graying-over of the highlight areas—otherwise the reproduction of tones in the final print will be unsatisfactory, giving the print a "duped" appearance. Timing of the master positive should be for the highlights, allowing the shadows to take care of themselves. Allowance must be made for the contribution of the lavender support to the density when judging exposure.

(*C*) *Development of the Master Positive.*—The master positive should be developed in any good positive film developer such as formula *D*-16. Developers of the borax type (*D*-76) are not capable of giving sufficient contrast.

The degree of development must be such that the contrast of the master positive is equal to or greater than that of a normal exhibition print (gamma approximately 1.8, for average good quality originals). This high contrast of the master positive permits the desired low degree of development of the duplicate negative which insures a minimum graininess of the image in the exhibition print. Using rack and tank methods, with fresh motion picture *D*-16 developer at a temperature of 65°F., development time for the master positive will be from 9 to 11 minutes, depending upon the manipulation technic. With continuous machines the time of development differs widely with their design. The fixing, washing, and drying processes are identical for master positives and motion picture positive films.

(*D*) *The Duplicate Negative.*—The duplicate negative should be made on duplicating negative film, emulsion series 1505. This film has sufficient printer speed so that enough exposure can be obtained through the dense master positive without changing printer lamps. The yellow dye in the emulsion, which absorbs the wavelengths of light to which the emulsion is most sensitive, reduces irradiation or scattering of light and, therefore, insures good definition; greatly extends the latitude (ability to reproduce a wide range of tones correctly); and lowers the contrast of the emulsion. Duplicating negative film must be handled in the darkroom with the same precautions as ordinary par-speed negative film, using the Wratten Series 2 safelight.

(*E*) *Printing the Duplicate Negative.*—As with the master positive, sufficient exposure must be given to the duplicate negative so that every tone and detail of the master positive will be faithfully reproduced. *Good duplicate negatives have no clear shadows, even when they are present in the original negative.* The shadows of the duplicate are always somewhat gray, and while those in some scenes may be more dense than others, depending upon the range of brightness in the subject, none of them should be glassy clear. Lack of exposure in printing the duplicate negative produces a lack of quality in the shadows of the exhibition print.

(*F*) *Development of the Duplicate Negative.*—The duplicate negative should be developed in the borax developer, formula *D*-76. The degree of development should be such as to reproduce the contrast of the original negative. If the master positive be fully developed, the average time of development for the negative when employing rack and tank methods will be approximately 7 to 8 minutes in fresh *D*-76 developer at 65°F. This degree of development corresponds to a gamma of approximately 0.5–0.6.

Original negatives may be divided into three general classes, according as they are normal, flat, or contrasty. In the process of leveling up the different scenes for the duplicate negative, so that the final printing operation can be carried out at a single light setting and that all the prints will require equal times of development, the first rigid requirement is to keep the degree of development of the duplicate negative at or below the specified degree (gamma 0.55 or less), for this insures minimum graininess in the exhibition prints. When it is desired to change the contrast of the duplicate negative from that of the original, it is best accomplished by changing the contrast of the scenes in the master positive by varying the times of development. In general, studio negatives are quite uniform in quality so that usually enough variation can be obtained through slight changes in the master positive.

The duplicate negative should be fixed for 20 minutes in a properly compounded acid fixing bath. If the film is fixed in an incorrectly compounded bath or is allowed to fix for too long a period, the rate of washing out of the dye will be retarded. After fixing, the film must be washed for 45 minutes. If the washing is incomplete or uneven, the dye which remains in the film will cause the print from the negative to be mottled and uneven. Rinsing for several minutes in water, before fixing, will greatly accelerate the removal of the dye.

(G) *Printing Precaution.*—It is *very* important when making duplicates to clean the original negative and master positive, because defects are cumulative. Dirt on the original negative or master positive will show up objectionably in the final print. After the original negative and master positive have been timed, they should be carefully cleaned to remove all traces of dirt.[9]

IX. SUMMARY

(1) As a result of tests with a large number of combinations of emulsions, the best duplicate negatives, with respect to both tone reproduction and graininess, were obtained with Eastman duplicating positive film, emulsion series 1355, and Eastman duplicating negative film, emulsion series 1505.

(2) In order to maintain the graininess at a minimum, it was necessary to develop the duplicate negative to a low gamma (0.55) and the master positive to a correspondingly high gamma (1.85). Since the graininess of a positive image of given density increases with increase of density of the negative from which it is printed, it is necessary to maintain the minimum density of both the master positive and duplicate negative as low as is consistent with good tone reproduction.

(3) It has been found that the graininess-gamma curve of the negative emulsion 1505 is straight and rather steep, but that of the duplicating positive emulsion 1355 has a long shoulder which runs almost parallel to the gamma axis. This explains why it is desirable to develop the master positive to a relatively high gamma so as to insure a low gamma and, therefore, minimum graininess for the duplicate negative. Although increasing the gamma of the master positive to a value greater than 1.85 would result in slightly improved graininess, the latitude of this material is diminished so that with fairly contrasty negatives it is not possible to obtain perfect tone reproduction.

(4) A fine grain borax type of developer was found to be most suitable for the development of the duplicate negatives, while any good positive developer was satisfactory for the development of the master positives. The low degree of development required for the duplicate negative tended to introduce certain development defects

which were at a minimum in the case of duplicating negative film, emulsion series 1505.

(5) Poor contact between the negative and positive during printing improved the graininess, but at the expense of loss in picture definition. The use of diffuse light caused a slight loss in picture definition without an apparent effect on graininess.

(6) Duplicating positive film, emulsion series 1355, has great latitude, so that when the master positive was printed on this material and developed to a gamma of 1.85 and the duplicate negative printed on duplicating negative film (emulsion series 1505) and developed to a gamma of 0.55, a practically perfect reproduction of the tones of the original negative was secured. It was necessary, however, to print the minimum densities of the master positive at a density of at least 0.40* and of the duplicate negative at a density of at least 0.3 to avoid distortion due to underexposure.

(7) Prints from duplicate negatives of sound records were practically indistinguishable, by listening tests, from the original prints, although tests with frequency records indicated an increase in ground noise and some losses at the frequencies of 5000 and above.

The authors are indebted to Messrs. H. A. Doell, A. J. Miller, and H. Parker, of this laboratory, for their assistance.

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* This value is that of the actual silver deposit. To obtain the total film density, the support density of 0.18 must be added to it.

THE SCREEN—A PROJECTIONIST'S PROBLEM*

FRANCIS M. FALGE**

Summary.—*The importance of the projection screen as affecting the visibility of the projected picture and the box-office receipts of the theater is briefly discussed. In addition, the paper presents various phases with which those who are concerned with the selection and installation of screens should be acquainted, points out the difficulties attendant on the deterioration of the screen surface, and the additional cost of operation produced thereby.*

Unlimited time and money are spent in improving, usually to a small extent, the many aspects of projection until, at length, the screen is taken into consideration. Here we stop; and yet, it is a fact that an improvement in projection of 100 per cent could be realized by making the appropriate corrections of the screen conditions. Not only would a large saving in electric current be achieved, but an improvement in box-office receipts would also be realized because of the better appearance of the picture, and the improvement as regards visibility of the picture and the attendant strain on the eyes.

In the average American theater, the manager, whether employee or owner, assumes full responsibility for all details of operation of the theater. Various departmental subdivisions are made, one of the most important, if not the most important, being the department of projection. The management sees that the proper film is delivered to the theater at the proper time, purchases such equipment as is needed for projection of the picture, and relies on the department of projection to coördinate all details in such a manner as to assure the best picture.

The projectionist, then, is answerable to the manager for problems connected with the picture. But how far does this go; where does his authority cease? An analysis of the facts shows that the projectionist is trained and equipped to assume direct responsibility for all problems pertaining to the picture, whether inside or outside the booth. His familiarity with the principles of light control and of the mechanical details of operation is needed to decide what carbons should be used or what screen should be installed.

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* Presented at the Fall, 1931, Meeting at Swampscott, Mass.

** Beaded Screen Corp., New York, N. Y.

The proper presentation of pictures, however, does not end with the placing of the responsibility on the projectionist. He must be provided with technically good film, of the proper density, and in the proper condition. Furthermore, his equipment must be in a satisfactory condition, and especially his screen must efficiently reflect the picture to the eyes of the patrons. Properly backed up by the manager, there should be no reason why a projectionist, with full responsibility for projection, should not have a picture at all times that is a real box-office asset.

It is a rule, rather than an exception, that the theater or maintenance manager of one or more theaters has, in discussing screens, said that he knew they were in a very bad condition, but that the condition of the business would not permit him to spend money now. Therein lies a fallacy, and a good reason why business is not so good. Furthermore, profits are lowered because a dirty or improper screen actually causes a waste of money.

A careful study of this situation has shown that the only method of correcting this unfortunate state of affairs is to face the issue squarely, and to place the responsibility on the proper person, the projectionist. This would result in bettering projection as a whole, and in simplifying the problems of the management.

Some of the facts with which the projectionist should be familiar are as follows:

(1) The selection of the correct type of screen is dependent upon individual theater conditions, and especially upon the type of lamp, the angle of projection, and the width of the house.

(*A*) White diffusing screens reflect light about equally in all directions. They are best for wide houses; houses having large projection angles, and using high intensity lamps.

(*B*) Beaded directive screens redirect light into a beam so that the light reaches a majority of seats in a house suited to this screen. A smaller percentage of light passes in all directions, so that a satisfactory picture can be seen from any seat not directly in the beam. These screens are best for medium width or narrow houses having projection angles under twenty degrees.

(*C*) Metallic reflective screens concentrate light into a narrow beam, with no diffusing element, and are suitable only for very narrow houses.

(2) When the type has been chosen, the most efficient of that type should be purchased, and it should be the one that will provide the best results throughout its useful life. The reputation of the manufacturer should be considered, and unusual claims should be carefully investigated.

(3) The proper size should be chosen:

(*A*) Minimum desirable width is one-sixth the distance of the screen from the farthest seats.

(*B*) Maximum desirable width is eight-tenths the distance of the screen from the front seats.

(*C*) Intensity of lamps is an important factor in limiting the size.

(4) The screen should be properly installed by following carefully the directions of the manufacturer. It should be masked in dead black. Screens should be placed not less than 18 inches from the stage floor, and as far from the front seats as possible.

(5) The projectionist should take note of the house lighting, and should suggest the elimination of glaring lights near the line of vision, and of spilled light on the screen.

(6) Great care should be taken to keep dust from settling on the screen.

(*A*) All overheads and maskings should be kept clean.

(*B*) Doors and other openings that cause drafts through the screen should be kept closed.

(*C*) A front curtain should close in the screen when it is not in use.

(*D*) In many cases, it is essential that the screen be backed up to the horns with a non-porous material.

(7) Screens should be cleaned regularly once a week by brushing, by using a vacuum cleaner on the back surface, or by blowing.

(8) If recommended by the manufacturer, screens should be cleaned according to instructions every three to six months, depending upon the local conditions.

(9) For diffusing screens, it has been shown that resurfacing by spraying is possible, though the process is still in the experimental stage.

(10) Screens should be replaced in nine to eighteen months, depending upon the local atmospheric conditions and the care given the screen. Screens constantly diminish in efficiency, and, as a result, the picture constantly grows dimmer. When the efficiency of a screen has decreased about 30 per cent, the cost of the additional electric current is usually greater than the cost of a screen.

To assure that a satisfactory and efficient projection surface is present at all times, it is not only necessary to observe the above recommendations, but to provide for proper inspection of the surface. This should be the duty of the projectionist. At weekly intervals, a white booth light should be projected on the screen and the surface inspected for streaks, clouds, and discoloration. Then a small sample of a fresh piece of material should be placed against the screen and the loss of light estimated. A decided difference should be a warning that the screen either needs brushing, or that, due to age, it has deteriorated beyond the useful economical limit.

Recent tests made by the Projection Screens Committee of the Society show a loss of about 50 per cent in reflectivity of screens after a year's use. This means that with a low intensity arc, 30 amperes produce the results of 15; with a hi-lo, 75 amperes produce the results of 37, and with high intensity arcs of 120 amperes, only 60 are really being used effectively.

Sound screens are porous and act as filters. The air passes through the screen, and the dust and dirt stay on the surface. Moisture and temperature conditions cause the dust to adhere to the surface in varying degrees causing streaks, cloudiness, and discoloration.

Taking a conservative 10 per cent loss of reflectivity for each three months' period, we find that at the end of the year, screens used ten hours a day, with electric power costing five cents per kwh., are causing a loss of light and money as follows:

Lamp Intensity	Loss Amperes	Effective Amperes	Daily Loss	Minimum 2nd Year's Loss
Low 25 Amps.	7	18	$0.37	$135.05
Hi-Lo 75 Amps.	20	55	1.10	401.50
High 120 Amps.	33	87	1.82	664.30

The second year's loss will be greater because of the cumulative effect on the loss of light.

Good business based on true economy will dictate that a screen that loses more than the cost of a new one should be replaced. The probable loss due to the patron's dissatisfaction with the dim, lifeless picture and its harmful effect on his eyes is even more serious, though less easily evaluated.

The steady progressive decrease in light is constantly compelling the projectionist to devise ways of increasing the brightness of the picture. This is especially true when a dense print is used. Constant forcing of the equipment causes inefficient burning of carbons as well as troubles with the light source; an increase in the cost of carbons; trouble with the automatic feed; trouble due to the increase of heat in the lamp house, especially in the reflectors, condensers, and meters. Furthermore, the feed lines may not be capable of carrying the larger load, and trouble and loss may result from this cause. All this can be eliminated by keeping the screen surface in good condition at all times.

PHOTOGRAPHIC EMULSIONS*

LEWIS W. PHYSIOC**

Summary.—*A short story of the evolution of the photographic process, describing the various stages of improvement in speed and quality. The historical development of the photographic process is treated briefly, from the camera obscura through the early experiments of the daguerreotype, the discovery and use of hypo, the use of collodion and gelatin emulsions, to the panchromatic emulsion and the reversal process.*

Those who are engaged in pursuits directly connected with the art of photography probably know that there is an interesting history represented in the development of this beautiful combination of art and science. When we compare our modern processes with the early experiments, our idea of mere history is enlivened by the elements of a thrilling romance. In fact, when we begin to study the various stages of development we see them unfold like the acts of a drama, reaching its climax in the most recent achievements.

For the benefit of those who have not the time to search through the many volumes devoted to the subject, it has been suggested that some of the salient features of this development be set forth in a brief, chronological order.

THE CAMERA OBSCURA

Although apparently known for a long time before, it was not until 1569 that the camera obscura was put to a practical use, when Baptista Porta devised a toy, later improved by Guyot, that was used for tracing natural landscapes and views to be reproduced. The various designs embodied the simple principle of passing rays of light into the darkened chamber through a pinhole aperture. W. H. Wollaston, in 1812, found that by using a single, meniscus lens in lieu of the pinhole, the image was rendered more brilliant and well defined, and after numerous developments of this principle the two Chevaliers of Paris made, in 1840, the first real photographic objective. It is interesting to contemplate that our most modern apparatus is merely an elaboration of this anciently observed phenomenon.

* Presented at the Fall, 1931, Meeting at Swampscott, Mass.

** Hollywood, Calif.

EARLY CHEMICAL EXPERIMENTS

With the chemical department, as with the camera obscura, we may revert to the ancient students, for as soon as men were capable of rational speculations they observed the effect of light upon various substances. A shield removed from a panoply after a long term of peace had left its outline upon the wall. The bleaching of hides was observed in very remote times. The early painters were well acquainted with the action of light upon various pigments.

The first important advance in this respect occurred when W. K. Sheele discovered that silver chloride became darkened by the action of sunlight. His experiments were interesting for three very significant reasons. In exposing the chloride under water he discovered that, as decomposition took place, a soluble compound was formed, and that by adding silver nitrate new silver chloride was precipitated. This was the first hint of the principles involved in the manufacture of an emulsion. Then, by adding ammonia to the darkened chloride, the insoluble metallic silver was left behind, a palpable suggestion of the developing process. Also, he noticed that the violet element of light acted more powerfully on the silver chloride, a condition that has placed a limit on the results of photography through many phases of its development.

From the time of Sheele's discoveries other experiments followed with an enthusiasm that reminds us of those who are working over a puzzle and are close upon the heels of the key, producing silhouette prints of various objects, reproducing the symmetrical outlines and delicate tracery of the venal structure of leaves, *etc.*

But, unfortunately, the same light that made them destroyed them, and they could be viewed only for a short time. We can appreciate the disappointment expressed by one of those experimenters when he said "nothing but a method of preventing the unshaded parts of the delineations from being colored, today, is wanting to render this process as useful as it is elegant."

FIXING THE CAMERA IMAGE

After considering these experiments, it may readily be seen that the paramount idea was to fix the camera image. The first record of any sort of success is accorded a young Frenchman, Nicephore de Niepce. He strayed a little from the efforts of his brother workers, and combined some mechanics with his chemistry. He found that asphaltum was also subject to the action of light, but in a somewhat different manner. He covered a metal plate with a solution of asphaltum and oil of lavender, and exposed it for several hours in the camera obscura. The parts exposed to the light became insoluble, and the unlighted portions were dissolved away with a solution of oil of lavender and petroleum. The metal could then be etched, and the picture so obtained was probably the first example of photoengraving. There is nothing that might furnish a more interesting comparison between those experiments and our modern developments than Niepce's statement that it required from seven to eight hours to expose a landscape in open light.

THE DAGUERREOTYPE

Coincidental with Niepce's operations, there was a scene painter who likewise was obsessed with the idea of fixing the photographic image. He was a good scenic artist; nevertheless he was not satisfied with his own efforts. Scene painters have ever been men who liked to look around. His interest in photographic processes was so great that he neglected his painting, and his good wife became concerned about his mental condition. In 1829 he entered into a partnership with Niepce. Let us pause here to consider the earnestness of a man so set upon a project as to acknowledge his limitations in prosecuting his designs and to call upon his competitor for help. Such a man seldom fails, for he is more interested in the actual achievement than in the glory usually attendant upon great accomplishments.

They plodded along together, not greatly improving their "heliography." They dipped in different chemicals and tried various metals for their plates—tin, copper, glass, and, finally, they knew not why, polished silver. There was a peculiar persistence about this idea of silver. Some say it was Niepce's idea, others that Daguerre insisted upon it. But the real truth had not dawned upon them. They were discouraged.

Finally Daguerre recalled some of the experiments of the earlier workers. They had shown that silver combined with iodine was sensitive to light, and he was convinced that Niepce's slow asphaltum should give place to the iodized silver plate. They tried it, but the images were so faint as to be useless. He and Niepce disputed, but soon Niepce died and his son carried on with the fanatical artist until accident solved the problem. The solution of the problem seems to have come about through the spilling of a bottle of mercury.

It is common knowledge that it is in the nature of some chemicals to give off fumes and of others to be greedy to combine with those fumes. So, when Daguerre returned to his investigations, he found that one of his old discarded plates had been acted upon by the fumes of mercury, and that each little particle of the faint silver image had become coated with condensed mercury. Daguerre discovered, to his joy and surprise, a well-defined delineation instead of the discarded failure. Here was another detail introduced into the foundation of the future structure of photography—a hint of the ultimate process of developing the "latent image."

The next development in the "fixing of the image" was introduced by another artist, Fox Talbot, a contemporary of Daguerre. He was out sketching, tracing a view from Wollaston's simple little camera obscura; and he, too, was inspired with the idea of capturing the fleeting image.

Talbot's experiments were important in having pointed off another period in photographic history. He substituted the paper support for the metal and the glass plates and raised the peg another notch in the scale of sensitivity, for, as he said, "Subjects such as white sails in full sunlight may be obtained in *half a second*," a great advance over Niepce's eight-hour exposure.

In the adoption of the paper support we also recognize the forerunner of our modern printing process.

HYPO: (SODIUM THIOSULFATE OR HYPOSULFITE)

In the discovery of the use of "hypo" our romance is given a dramatic mood. When we review the experiments already described we recognize one serious embarrassment. After having succeeded in fixing the camera image, the next difficulty was to make the reproductions permanent, "to make them as useful as they were elegant."

The requirement was a solvent, strong enough to dissolve the unlighted (or unchanged) silver salts, but not powerful enough to remove the metallic silver. The search was long and tedious, because of the distinction between a physical solvent and a chemical reagent, and most solvents are powerful reagents. Various solvents were employed but were found unsatisfactory. Ammonia was tried, but this required a very strong solution which affected parts that needed protection; cyanide of potassium nearly met the requirements, but was extremely poisonous and expensive.

It has been recorded that François Chaussier as early as 1799 discovered the salt. Sir John Herschel, in 1819, was probably the first to discover that hypo could dissolve the unreduced silver salts without attacking the metallic silver. However, it was not until 1837 that J. B. Reade used it in photography.

The remarkable feature of this hypo is the fact that from the time it was first used, and through its many stages of development, its position as one of the most important elements in the art has been unassailed by the most modern developments. We may be thankful that industrial chemistry and nature's stores have supplied us so bountifully with hypo. Its present price also furnishes an interesting comparison with that in the time of Reade, when it cost "half a crown an ounce."

THE WET PLATE

Despite the popularity of the daguerreotype, photographic enthusiasts strove for something better. They were probably spurred on by the agony of the victim who sat for a portrait, with body and head rigidly set in a brace, and whose face was covered with white powder make-up to reduce the lengthy exposure. Another item to be considered was the cost. The silver plates were expensive. It seems ridiculous when we consider how much more silver than was necessary was contained in one of those plates. Another undesirable feature was the limitation to a single picture. The natural induction, then, was to secure a *negative* from which could be produced many *positives*. In this conception lay the real germ of modern photography.

Paper negatives were tried, and were subsequently improved by waxing and soaking them in oil, to render them more translucent. Glass was the ideal support, but it involved new difficulties and demanded further experiments. It was necessary to find something that would adhere to the glass and would, at the same time, hold in suspension the sensitive silver salts. Albumen, starch, and serum of milk were tried, which for a while furnished a little hope.

Finally, Le Gray suggested collodion, a mixture of pyroxaline, alcohol, and ether. F. Scott Archer accepted the suggestion, and in 1848 announced the first real photographic emulsion. This marks an important period and involves several features. The virtue of the collodion is its nature to support the silver compound and yet not suffer from the effects of the silver nitrate necessary to form those compounds.

The collodion emulsion had one disadvantage, which led to the name "wet plate." Although the collodion held the silver salts, it entered into no compound with them and, when allowed to dry, the salts crystallized and destroyed the fabric and transparency. It was necessary to expose it wet. After development, the unexposed salts were then removed and the plate allowed to dry without the crystallization.

The use of *iodide* of silver was another feature. With the exception of Daguerre, other workers had used the chloride which blackened directly in the light. The iodide, except under specific treatment, gave no visual effect of light. Daguerre's mercuric accident probably suggested the development process. The most important feature, however, was the marked increase of sensitivity over that obtained previously, and there were introduced a quality and a practicability that startled even the most enthusiastic students. The wet plate combined such features as a fineness of grain that has never been excelled, crystalline transparency and brilliancy, and a broad range of values. Even at the present time, process workers in the publishing business use this method when excellence of reproduction is required.

While the sensitivity was low, compared to the modern dry plate, it was a great improvement over the Daguerre and Talbot processes, as the average exposure required was only ten to fifteen seconds.

THE DRY PLATE

Even the beauty of the wet plate could not long compensate for the tedious method of preparation and the inability to reproduce anything but still objects. In attempts to improve the process, it was observed that the soluble *bromide* salt entered into a finer solution with collodion and instead of floating the silver nitrate over the plate it could be introduced into the collodion solution drop by drop, forming an emulsified combination that could be spread on the plate; and that after washing out the solubles it could be allowed to dry. This is the first idea of what is properly termed the photographic emulsion.

The success of the collodion process naturally stimulated the search for other mediums for the suspension of the silver salts. Gelatin was selected as a substitute. Among the many experimentalists, Dr. R. L. Maddox is credited as being the first to produce really fine results.

The gelatin emulsion ushered in a period of extensive commercial developments, which continually demanded an increase of sensitivity. This sensitivity—or reduction of the time of exposure—influenced photography both as a profession and a pastime. The peculiar character of the gelatin emulsion is the remarkable combination it forms with the insoluble silver salts. The nature of this combination has been one of the most intriguing features of the art. But the important consideration is the speed. We have been shown that bromide and chloride of silver each has its individual maximum of sensitivity; the next discovery was that, when used together with gelatin under varying temperatures and under the so-called ripening and cooking treatment, there was formed a combination that created a tremendous increase in sensitivity.

The commercial stimulus resulting from the introduction of the dry plate was represented in a convenient product that could be placed into the hands of millions of enthusiasts; snapshot exposures, the fascination and mystery of the latent image, the magic of development; and we may include as a historic period in the evolution, the adoption of celluloid as the base, which made possible the advent of motion pictures.

PANCHROMATIC EMULSION

Ever since the experiments of Johann Wilhelm Ritter, in 1801, when he discovered that the violet and ultra-violet rays were apparently the more active agents in photography, experimenters had been worried by their inability to go but slightly beyond that section of the spectrum, and to render all colors in their natural, tonal values. Photography was always a sort of balance between two great evils: blue objects that reproduced too white and red ones that were rendered too black.

This difficulty has been overcome in the so-called *panchromatic* emulsion, which marks off the latest period in the development of photography. This emulsion is a modification of the ordinary gelatin emulsion, formed by incorporating in it particular elements which increase the sensitivity over the troublesome parts of the spectrum, particularly the red portion.

The latest development of this product exalts our idea of the beauty and dignity of scientific research, and induces speculation as to how much further it may be developed. It possesses a sensitivity never anticipated by the most sanguine workers; it embodies the revolutionary idea of a tinted base which greatly reduces the evils of halation; it has made possible every known process of natural color photography.

An interesting comparison between the speeds of the various emulsions may be found in the following table:

Niepce's Asphaltum Process	8 hours' exposure
The Daguerreotype	1 hour
Talbot's Calotype	3 minutes
Collodion Wet Plate	10 seconds
Collodion Emulsion (dry)	15 seconds
Early Gelatin Emulsion	$^{1}/_{15}$ second
Modern Emulsion	$^{1}/_{55}$ second

The above, under similar light conditions, at stop *f*/16.

REVERSAL PROCESS

The popularity of the sixteen millimeter film suggests the subject of the reversal process, or more correctly, direct positive, a process not generally understood. It is also involved in the operations of various color processes. In the case of the miniature film, it is designed to reduce the double cost of negative and positive, and to furnish only the single positive. The procedure depends upon the character of particular chemicals, such as potassium permanganate, potassium bichromate, and persulfate of ammonia. These chemicals have the power of reducing the metallic silver, but have no effect on the unexposed compound in the emulsion.

Reference to these chemicals again reverts to the peculiarity of hypo which has just the opposite function, that of dissolving the unexposed silver salts without attacking the free silver.

In conclusion, it must be acknowledged that no claims to originality are here intended. The paper results from the author's impulse to express something of the beauty, romance, and drama of photography not generally reflected in prosaic text-books and scientific disquisitions, but which are certainly inspired by a study of the developments of that fascinating combination of art and science.

BOOK REVIEWS

Cinematographic Annual—Vol. 2. *American Society of Cinematographers,* Hollywood, Calif., 1931, 425 pp.

This volume contains contributed material from all branches of the motion picture industry, ranging from highly theoretical papers to those dealing exclusively with modern practice. The year 1931, according to Arnold, marked a return to the older technic of letting the camera tell the story rather than making the dialog and sound effects the chief element of the picture. More compact camera housings, improved film, and better quality reproduction of sound represent a few of the new developments. The editor reviews the advantages resulting from the newer panchromatic emulsions, his opinions being supplemented by two articles prepared by Huse and Chambers, and by White, respectively. Camera lenses are treated adequately in three papers. Warmisham gives useful data on chromatic correction of Cooke ciné lenses. Westerberg discusses transmission losses in lenses, and a precise method of testing lenses is described by Rayton. Stull discusses the elements of lighting in a well-illustrated article which deals chiefly with portrait or close-up effects, whereas Howe treats of the broader subject of set lighting, emphasizing the value of light for enhancing dramatic sequences. Carbon arcs for set lighting are dealt with briefly by Kalb, who also joins with Downes in discussing the characteristics of projection arcs. The making of miniature sets and the design of costumes is treated adequately by Ree, a well-known supervisor of art direction. Rose tells of some of his experiences in using a small camera for preliminary tests of set lighting. Several papers are included on laboratory technic, such as the evolution of film processing apparatus, making a fade-out by after treatment, process photography, graininess of photographic deposits, and optical printing. In the field of sound recording technic, MacKenzie has presented a comprehensive discussion of the sensitometric characteristics of light valve records. Jones gives a brief summary of his extensive research in the theory of tone reproduction, and Sheppard presents data on the relative masses of photo-silver in latent image formation. There are several other interesting papers on various subjects and a well-illustrated section on new equipment. An appendix includes many useful formulas and practical hints. The pictorial section reproduces sixty-four beautiful stills made by cameramen.

G. E. Matthews

Photoelectric Phenomena. Arthur Llewelyn Hughes and Lee Alvin DuBridge. *McGraw-Hill Book Company, Inc.,* New York, N. Y., 1932, 531 pp., $5.00.

This work comprehensively covers the field of experimental photoelectricity and summarizes in an able manner the relevant prevailing physical theories. The authors have made a most complete study of the original papers in this field and have presented the results in a clear and logical manner. The complete references to the original work will be of special value to the worker in this field. For those interested in the technological applications of photoelectricity, the book should be a valuable guide to fundamental principles and to experimental methods and results.

The book is divided into fourteen chapters. The first chapter is an introduction to the subject and is followed by five chapters devoted to the emission of electrons from metallic surfaces when illuminated by visible and ultra-violet light. Four of these chapters are devoted to a presentation of experimental results and the fifth to the prevalent theories of photoelectric emission. The writers, who are primarily experimental physicists, have presented the theoretical material in such a clear and understandable manner that the applied physicist and engineer should be able to obtain a valuable insight into the theoretical aspects of the subject from this treatment.

Chapter VII presents the experimental results on ionization of gases and vapors by ultra-violet light. The photoconductivity of solids is treated in Chapter VIII. Photovoltaic effects and the rather uncorrelated work on the photoelectric effects in liquids and insulators are treated in the next two chapters. In Chapter XI is given a limited treatment of the very broad field of the photoelectric effects of x-rays and gamma rays. The material selected for this chapter is consistent with the general field of the book.

Chapter XII gives a valuable summary of technics that have been used in experimental photoelectricity. The last two chapters deal with applications of the photoelectric effect and with several unclassified subjects. The authors limit themselves to a very general statement of the technological applications and make no attempt at rigor or detail in discussion of the engineering problems involved.

This book is a most worthwhile contribution to the literature of experimental physics and through its comprehensive critical survey and review of experimental work has established a valuable milestone for the future worker in this field.

M. J. KELLY

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SOCIETY ANNOUNCEMENTS

NEW DIMENSIONAL STANDARDS

At the Washington, D. C., Convention, on May 9th, the Committee on Standards and Nomenclature presented to the Society its report covering the first half of the current year. This report included proposals for the standardization of thirty-five millimeter camera and projector apertures, and of dimensional layouts of sixteen millimeter sound film, the speed of travel of the film, and the interval of the film between the picture and sound gates.

The proposals relating to sixteen millimeter sound film, after considerable discussion, were returned to the Committee for further consideration, to be presented in revised form as soon as possible. The following recommendations of the Committee, however, relating to thirty-five millimeter equipment, were accepted by the Society as dimensional standards of this type of equipment:

35 mm. camera aperture	0.631 by 0.868 inch
35 mm. projector aperture	0.600 by 0.825 inch

In addition to this, the following recommendation of the Committee, relating to the performance of sound screens, was accepted by the Society, *viz.*, "that the data described on pages 445 to 447 of the September, 1931, JOURNAL, relating to test procedure and tolerances of acoustic performance of screens, be recommended by the Standards Committee as representing good practice in the specification and acceptance of screens."

SOUND COMMITTEE MEETING

At a meeting of the Sound Committee, held in New York on June 20, 1932, in addition to various unfinished subjects alluded to in the report of the Sound Committee, to be published in the August issue of the JOURNAL, there were discussed also the relations between the permissible time of reverberation in recording and in reproducing. The Committee is considering the advisability of conducting studies on the directional effects that are found in reverberation, and in the apparently growing tendency to record sound at high levels, perhaps to the detriment of quality, in the field of producing shorts.

SUBCOMMITTEE ON EXCHANGE PRACTICES

A meeting of the Subcommittee on Exchange Practices, of the Committee on the Care and Development of Film, was held at the General Office of the Society on June 22nd. The major part of this meeting was devoted to a consideration of the numerous phases of the work conducted by film exchanges, and of the problems with which they have to contend. After an enumeration of these subjects, they were assigned to the various members of the subcommittee for study and comment. The next meeting of the subcommittee is scheduled for July 20th. The subcommittee hopes to be able to present to the Society a study of conditions in film exchanges that will contain information of considerable value to the industry, but which was heretofore available only with great difficulty.

THE BOARD OF GOVERNORS

A meeting of the Board of Governors is scheduled to be held on July 7th, at which time nominations of officers for the year 1933 will be completed. Voting ballots will be sent to the Active membership of the Society about the middle of August, and the results will be announced at the Fall Convention, the date and location of which is also to be established by the Board of Governors on July 7th.

INTERNATIONAL CONGRESS OF PHOTOGRAPHY

Dr. Walter Clark has been appointed by Dr. Goldsmith to represent the Society at the next International Congress of Photography, to be held in Paris, France, in 1934. In addition, Mr. M. C. Batsel, chairman of the Committee on Standards and Nomenclature, has been appointed to serve on the American National Committee of the Congress, to represent the Society in matters of standardization and practice.

NEW YORK SECTION

The monthly meeting of the New York Section was held at the Institute of the Electrical Association of New York on Wednesday, June 8th. Dr. H. Sidney Newcomer presented an interesting paper entitled, "Wide Screen Photography with Cylindrical anamorphosing Systems, and Characteristics of Motion Picture Lenses and Images."

ACOUSTICAL MEASUREMENTS AND TERMINOLOGY

Mr. S. K. Wolf, Chairman of the Projection Screens Committee, has been appointed to represent the Society on the Sectional Committee on Acoustical Measurements and Terminology of the American Standards Association. The scope of this Committee is defined to be the "preparation of standards of terminology, units, scales, and methods of measurement in the field of acoustics."

WAYS AND MEANS COMMITTEE MEETING

At a meeting of the Ways and Means Committee, held in New York on June 3rd, further considerations were given to the possibility of revising the subscription list for the JOURNAL and various other fees of the Society. No action was taken in these matters, however, as the Committee felt that it would be desirable to allow sufficient time in which to judge the effects of the recent reduction of admission fees in adding to the membership of the Society.

The Society regrets to announce the death of

Leonard T. Troland

on May 27, 1932.

HONOR ROLL

OF THE

SOCIETY OF MOTION PICTURE ENGINEERS

By action of the Board of Governors, October 4, 1931, this Honor Roll was established for the purpose of perpetuating the names of distinguished pioneers who are now deceased:

LOUIS AIMÉ AUGUSTIN LE PRINCE
WILLIAM FRIESE-GREENE
THOMAS ALVA EDISON
GEORGE EASTMAN

JOURNAL

OF THE SOCIETY OF

MOTION PICTURE ENGINEERS

Volume XIX AUGUST, 1932 Number 2

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JOURNAL
OF THE SOCIETY OF
MOTION PICTURE ENGINEERS

SYLVAN HARRIS, EDITOR

Published monthly at Easton, Pa., by the Society of Motion Picture Engineers.

Publication Office, 20th & Northampton Sts., Easton, Pa.
General and Editorial Office, 33 West 42nd St., New York, N. Y.

Subscription to non-members, $12.00 per annum; to members, $9.00 per annum, included in their annual membership dues; single copies, $1.50. A discount on subscriptions 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 33 W. 42nd St., New York, N. Y.

Entered as second class matter January 15, 1930, at the Post Office at Easton, Pa., under the Act of March 3, 1879.

PROGRESS IN THE MOTION PICTURE INDUSTRY*

Summary.—*This report of the Progress Committee covers the period October, 1931, to May, 1932. The advances in the cinematographic art are classified as follows:* (*1*) *Production,* (*2*) *Distribution,* (*3*) *Exhibition,* (*4*) *Applications of Motion Pictures,* (*5*) *Color Photography,* (*6*) *Amateur Cinematography,* (*7*) *Statistics,* (*8*) *Publications and New Books.*

The past six months have been marked by severe retrenchment in operating expenditures of all sorts in the motion picture industry. This curtailment of operation naturally was reflected in the various industries supplying the studios and motion picture theaters. As a result, the six month period just ended has failed to produce any great advancement in new materials or equipment. However, in spite of the prolonged depression, consistent progress has been made in practically every branch of the motion picture industry. This progress has had two main motives: namely, improvement of the product and reduction in the cost of production.

The faster emulsions announced in a previous progress report have come into practically universal use for both exteriors and interiors, and have been extended to the field of amateur cinematography. Film laboratories have mastered the problems introduced by these emulsions, and handle them now in a routine fashion. The industry still awaits a suitable emulsion for sound recording purposes and, in the meantime, must utilize to the best advantage the emulsions at hand.

The industry continues to rid itself of the strait-jacket in which sound recording first placed it. This is being accomplished by developing high-grade portable sound recording equipment and silent or nearly silent cameras, by making improvements in methods of synchronization and prescoring, and in dubbing or re-recording technic and equipment.

The increase in the number of synchronized foreign sound versions has been phenomenal during the past six months, these versions en-

* Report of the Progress Committee. Presented at the Spring, 1932, Meeting at Washington, D. C.

tirely replacing those using separate foreign casts for each version. Recently, pictures have been synchronized in the oriental languages.

The standardization committees of the Society of Motion Picture Engineers and of the Academy of Motion Picture Arts and Sciences have been actively engaged during the past six months. A most notable contribution has been made by these bodies in finally setting forth dimensional standards for apertures of sound cameras and projectors. These standards will provide screen pictures of uniform dimensions irrespective of whether the picture is silent, synchronized to disk, or is a regular movietone print. The dimensions have been chosen so as to provide on the screen a picture of more pleasing proportions than was possible in the early days of movietone prints. The uniform projector aperture will simplify the problems of the projectionists by eliminating the necessity of using special masks for the various films being shown.

The popular interest in amateur cinematography continues to grow apace. The use of rental films and the growth of rental libraries are constantly increasing. In addition to the 16 millimeter film-disk equipment that has been available for some time for educational and business purposes, a new 16 millimeter sound-on-film projector has been placed on the market recently. It is understood that the quality of the sound reproduced from 16 millimeter film still leaves something to be desired, but progress in this field will undoubtedly be rapid.

Color processes have not been used to any great extent by the industry during the past year although consistent progress is reported by the color industry. Considerable activity is reported in amateur color cinematography, and a well-known firm has announced that its high sensitivity emulsions are now available in this field.

Improvements in acoustics, especially in theaters, continues as the public becomes more and more conscious of what constitutes good reproduction of sound. The electrical branch of the industry promises an improvement in this respect in the near future, laying particular emphasis on the reproduction of very high frequencies so as to add to the brilliancy and naturalness of dialog and music.

In the laboratory field, the sensitometric methods of control, so long followed in sound processing work, are now slowly but surely finding application in the work of developing the picture negative. In this latter field, the machine has practically eliminated hand development, and gamma control is replacing the ancient and wasteful method of basing the time of development on individual test strips.

To sum up the situation, scientific methods have continued to improve the foothold that they obtained when sound was introduced into the picture, and are paying dividends, not only in the form of an improved product, but also in developing a more sane and economical production technic.

The Committee wishes to thank the various individuals and companies that have supplied material for this report. In this connection, the reports of the Bureau of Domestic and Foreign Trade forwarded by Mr. N. D. Golden have proved invaluable.

The illustrations shown in the report were obtained from the Academy of Motion Picture Arts and Sciences, Bausch & Lomb Optical Company, Bell & Howell Company, Electrical Research Products, Inc., General Electric Company, General Radio Company, Metro-Goldwyn-Mayer, Inc., R.C.A. Victor Co., and R.K.O. Studios.

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SUBJECT CLASSIFICATION

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1. New Materials
2. Manufacture
3. Miscellaneous

B. Studio and Location
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2. Lenses and Shutters
3. Cameras and Accessories
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5. Special Cameras
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1. Equipment
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II. EXHIBITION

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I. PRODUCTION

A. Films and Emulsions

When the new high-speed panchromatic films were first introduced about a year ago, cameramen used them chiefly for interior work. During the past six months they have been adopted quite universally for making exterior shots, so that it can be stated that the bulk of the pictures being made at the present time in American studios are being photographed on the new improved films. Commenting on the improved films, Hall[1] reiterates the opinions previously expressed by cameramen that the significant property of the product is not so much the increased speed but the "tremendous improvement in photographic quality . . ." obtainable by using the new film.

New Materials.—A recent addition to the group of films is the Pankine G-Antihalo film supplied by Agfa. According to Schilling,[2] this film is said to be fine grained and to possess greater sensitivity to red, yellow, and green rays than the older Pankine F film. A bluish green anti-halation layer is incorporated between the emulsion and the support, which layer is unaffected by the processing solutions and necessitates only a slight increase in the printing light.

According to D. C. Dunham, Herr Kupfer has completed the development of an aluminum motion picture film band. Because the base is metallic, light must be reflected from it. Refining the clarity of the reflection and achieving in the emulsion combinations that would adhere to the metal have been the two greatest difficulties encountered in completing the invention. In projecting pictures from this metal-backed film, light from the arc is reflected from a mirror to the metal film as it passes over the projecting slot, the light falling on the film at an angle of incidence of 45 degrees. It is claimed that the film itself costs between one-fifth and one-sixth of the amount charged for the celluloid film, and it is also claimed that the metal is more durable than celluloid, does not stretch, and will not break so easily. It is claimed that the new film has been perfected for sound and color reproduction. One hundred and thirty patents covering the production and reproduction of pictures from this film have been taken out in the various countries of the world.

Gradually throughout the year 1931 and in the early months of the present year, film manufacturers have made the improved emulsions available to sheet film users, the ciné amateur, and the aerial photographer. For the user of small cameras making single exposures on 35 millimeter film, Kutzleb[3] describes a fast panchromatic film that makes possible snapshots in well-lighted rooms. The film is double-coated and has an anti-halation layer. It is now possible to utilize these new emulsions in almost every branch of photographic endeavor.

The Eastman Kodak Company has classified its panchromatic materials into three groups, known as Types *A*, *B*, and *C*.[4] Group *A* includes materials of the same type as those made prior to 1931; group *B* materials, known as "orthopanchromatic," have an extremely high color-sensitivity, corresponding approximately to that of the eye;

group *C* materials, called "hyperpanchromatic," have a high total sensitivity, and are extremely sensitive in the yellow, orange, and red portions of the spectrum. Eastman supersensitive panchromatic motion picture negative film is a material of Type *C*.

Manufacture.—According to a report from Soviet Russia, there are two film manufacturing plants in operation in that country having a capacity of 75 million meters of film yearly. A new plant, having a capacity of 150 million meters, is to be added this year. Three factories producing motion picture equipment are located in Moscow, Leningrad, and Samara, respectively.[5] Troubles encountered in manufacturing photographic materials in Russian factories were reviewed by Shkulin,[6] who pointed out the urgency of improving the quality of the raw materials, notably the gelatin.

Of theoretical, as well as practical, interest is the publication of several papers by members of the U. S. Bureau of Standards, on the subject of photographic emulsions.[7] These papers form a valuable addition to those published in recent years by workers in laboratories under the control of manufacturers.

As part of the work that resulted in the new panchromatic sensitizing dyes, the Kodak Laboratories have produced an entirely new series of sensitizers that enable high sensitivity to be obtained in definite regions throughout the whole visible spectrum and far into the infra-red.[8] The materials are made primarily for the use of spectroscopists and astronomers, and are available only as plates and not as film. A new dye called "xenocyanine" has enabled records to be made out as far as 11,250 Å with reasonably short exposures.[9]

Miscellaneous.—An interesting group of patents was issued to several firms in Great Britain, France, and the United States, relating to sensitizing dyes of the symmetrical and unsymmetrical polymethine series.[10] A patent was granted disclosing the use of a protein material as a sensitizer for silver halide emulsions.[11] A series of patents was granted relating to improvements in emulsions for the bleaching-out process.[12]

Four patents were published covering methods of incorporating non-halation layers in film.[13] Details of emulsions for sound recording were protected further by the granting of two patents.[14]

Two patents were issued dealing with means of minimizing fog formation in silver salt emulsions.[15] The continued interest in the diazotype process (as used, for example, on Ozaphane film) is shown by the large number of patents relating to this process that appeared during recent months.[16]

B. Studio and Location

General.—The current tendency is to photograph from one angle and to return, as far as possible, to the photographic technic of the silent picture. Generally, a scene is shot in an introductory long view, and then closer shots are made individually. There are fewer attempts to obtain simultaneous individual close-ups, and fewer

Courtesy of Metro-Goldwyn-Mayer Studios

FIG. 1. The traveling camera boom.

cameras are used, the trend being toward single camera shooting even in major studios, with rarely more than two cameras in use. This procedure is better for recording sound, as it necessitates less moving of the microphone, and, at the same time, is more economical of material and labor.

Moving shots are somewhat fewer, but more effective; enthusiasm for constant movement of the camera has abated. Crane shots, which afford greater flexibility of movement, have, to a considerable extent, supplanted "dolly" work on the stage floor. A crane boom used at the M-G-M Studios is shown in Fig. 1.

A marked step forward has been the introduction of the standard aperture, which facilitates production in several respects, and affords notable economies in constructing sets, recording, and in general speed of shooting.

There is a trend toward what is called "pre-cutting" of pictures; that is, arranging a script under the supervision of experienced cutters so that it is well adapted for final editing. In this way, less material is needlessly exposed and discarded in cutting. While this may not be considered a part of technical progress, it shows the tendency toward matching the mechanical efficiency of production to the artistic phases of the industry.

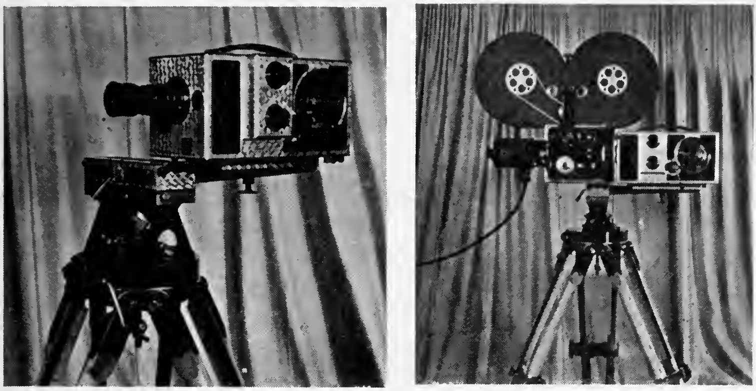
Lenses, Shutters, and Apertures.—Perhaps the most important advancement of the industry has been the promulgation and general acceptance of dimensional standards for the apertures of cameras and projectors.[17] The aperture dimensions agreed upon are 0.631 by 0.868 inch for cameras, the center line to be 0.7445 inch from the guiding edge of the film. The width of the sound track is set at 0.100 inch, provision being made for a black barrier of 0.017 inch between the picture and the sound track, and of 0.004 inch between the sound track and the sprocket holes. The standard aperture for projectors is to be 0.600 by 0.825 inch, the center line to be 0.738 inch from the guiding edge. It is claimed that the standardization of camera and projector apertures will remove the most vexing difficulties that have confronted studios and theaters since the introduction of sound. It is also claimed that the new aperture will give a picture that is much more pleasing to the eye.

One of the most interesting innovations that has appeared during the past six months has been a camera objective of adjustable focal length—the so-called "zoom" lens. Telephoto lenses of variable magnification have been known for a number of years. The novel feature of the new outfit is its mechanical construction, which permits the objective to remain in focus while varying the magnification; the diaphragm opening varies at the same time with the focal length so that a constant f value is maintained. Two makes of this variable objective have recently appeared on the market.[18]

It is claimed that the Varo lens gives range of magnification, speed, and other features, while yet assuring critical definition at any point along the "zoom," as it is called. The lens consists of three moving elements, comprising a total of seven glasses. The range of magnification extends from 40 to 120 millimeters, and the definition is critically sharp throughout the entire range. There is claimed to be no astigmatism or chromatic aberration.

When the elements are moved so as to change the focal length, the diameter of the iris diaphragm must be changed in corresponding proportion in order to maintain the f value (speed) of the lens constant throughout the entire "zoom." This is very important; otherwise the exposure would change during the "zoom" and the screen result would be very unsatisfactory.

The Varo lens is arranged so that the full range from 40 to 120 millimeters is obtained at stops of $f/8$ and $f/5.6$. At $f/4.5$ the range extends from 40 to 88 millimeters, and at $f/3.5$ from 40 to 50 millimeters (Fig. 2).



Courtesy of Bell & Howell Company

(*a*)   (*b*)

FIG. 2. (*a*) Varo "zoom" lens set up with visual eyepiece; (*b*) set up in photographing position.

The question of quality, in its relation to depth of focus and to the size of the lens aperture, has been discussed by Köfinger,[19] who points out the changes in the depth of field that are obtained with various diaphragm openings and discusses the advantages and disadvantages of large aperture lenses. There is little else to report on the subject of photographic objectives. A number of patents on new constructions have been noted.[20]

Camera finders are the subject of three recent patents,[21] and a considerable number of patents have been issued dealing with optical systems particularly adapted for color photography;[22] this in spite of the fact that there seems to be little interest in color productions at the present time, and that few of these processes have gone so far as to be applied commercially.

Stereoscopic effects seem to be of interest to a great many inventors, as evidenced by the number of patents that have appeared on this subject;[23] but in this field, also, the patent literature seems to be considerably in advance of practical application. The subject has been discussed by Prileshaeff,[24] who suggests a new method, depending on spectacles, of assuring that spectators distinguish properly the right and left eye images presented to them.

Patents dealing with distorting systems of cylinder lenses[25] designed to produce wide film effects by abnormal magnification in the horizontal plane are still appearing. Several reports give the results attained by these methods.[26]

Cameras and Accessories.—The chief advancement in camera construction has been in silencing the movements. Mitchell has produced a silenced movement, together with silenced magazines and new type of pull-down mechanism.[27]

The Bell & Howell Company has recently introduced a silent camera[28] that has many novel features, including a mechanism fitted with a means of focusing through the aperture. The cam stroke is reduced from 0.080 to 0.050 inch. It is claimed that this camera can be used within 15 feet of the microphone without a "blimp."

A novel design of camera blimp[29] is reported by the Educational Studios in Hollywood. It is made of cast aluminum, and it is claimed that it can be evacuated within 25 seconds. The Mitchell Camera Company announces a versatile rolling tripod for studio use, which is capable of supporting the heaviest silencing housings used, and with a triple extension support that provides for camera heights from three to eight feet from the floor.[30] A water-tight housing for an Eyemo motion picture camera eliminates the necessity of using diving bells in undersea photography.[31] Condensation on the interior parts is prevented by drying the air in the housing with calcium chloride.

Exposure and Exposure Meters.—It has been common practice for many years with the older types of panchromatic film to use yellow filters, especially under daylight illumination, to correct for the greater sensitivity of these materials in the blue and blue-violet spectral regions, as compared with their sensitivity in the green and red regions. The improved panchromatic films have a much higher green and red sensitivity than the older films. Hence, for certain kinds of illumination, it is desirable to use filters that absorb some red radiation in addition to some blue, in order to avoid the overcorrection of tones rendered by this color. Yellow-green filters are supplied by the manufacturers for this purpose and, in some cases, deep yellow filters have been discontinued as unsuitable for use with the new emulsions.

Emmermann[32] has published directions for preparing green filters, using various combinations of the dyes, Filter Yellow and Patent Blue, according to the nature of the illumination to be used. These filters absorb blue-violet and red, and are recommended for use with Agfa panchromatic films. With the more recently announced Pankine "G" film, Agfa filters Nos. 70 and 71 are recommended by Schilling[33] for use with light of tungsten quality and daylight quality, respectively.

For several years a fairly large percentage of scenes have been photographed by cameramen using the full aperture of the camera objective. In order to obtain, with anastigmatic lenses and under brilliant lighting conditions, the quality peculiar to such apertures, cameramen have used neutral density filters for reducing the exposure. Huse and Chambers[34] describe the use of a filter of 0.50 density in conjunction with two yellow filters, the Aero *1* and the Aero *2*. These new filters, known as *3N5* and *5N5*, respectively, are recommended for use in exterior photography with Eastman supersensitive panchromatic negative film.

For use with the improved panchromatic materials, two new Wratten filters have been introduced by the Eastman Kodak Company. These are known respectively as *X-1* and *X-2*. The *X-1* is a pale green filter, and is designed to give good orthochromatic rendering with the supersensitive panchromatic materials in daylight and white flame arc light; the *X-2* is a darker green filter, and gives satisfactory orthochromatic rendering with supersensitive panchromatic materials by incandescent tungsten and panchromatic carbon arc light. The *X-1* filter can also be used to give correct rendering with the Type B panchromatic materials exposed to tungsten illumination, while the older *K-2* yellow filter gives good correction with this class of material in daylight. The dark yellow *K-3* filter is now obsolete, the introduction of the new panchromatic materials having rendered its use unnecessary and, in fact, undesirable.[35]

Filter factors for use with du Pont special panchromatic film were published by White.[36]

Special Cameras.—A special Filmo *70-DB* camera[37] intended for taking golf pictures is announced by Bell & Howell. Seven speeds are available from 8 to 64 frames per second. It is claimed that, with a shutter opening of 110 degrees, sharp pictures of the club head at the bottom of the swing may be obtained. A slow motion camera driven by clockwork is claimed to expose 100 feet of 35 millimeter film with one winding of the mechanism.[38] The speed can be varied from 40 to 120 frames per second.

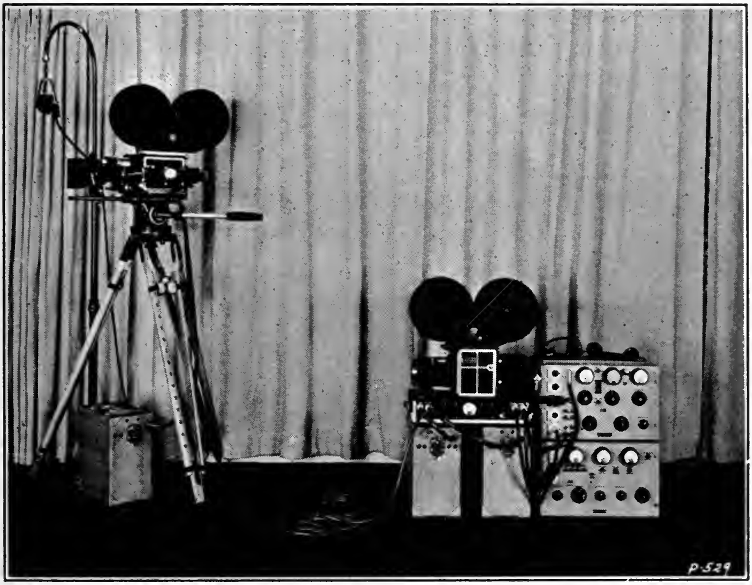
Studio Illumination.—During the past six months, "anti-spill-light" devices have come into general use. *Spill-light* is a term applied to the light radiated by a lamp in a more or less random and uncontrolled direction, and not in the form of a parallel beam along the desired axis, making it difficult to obtain the correct lighting effects and adding to the difficulties already encountered with microphone shadows, *etc.*

The method of eliminating this is to place a suitable shield in front of the incandescent bulb. This shield generally takes the shape of a metal spiral about five inches in outer diameter, its axis coinciding with that of the lamp beam. In this way, the filament and bulb, the latter acting as a lens for the spill-light, are blocked off from the set, while the desired beam is reflected from the mirror of the lamp. It is stated that a good spill-light shield eliminates practically all the random radiation, and causes a loss of less than five percent of the total illumination of the unit. Spill-light shields must be good heat radiators to prevent cracking the incandescent lamp mirrors and causing other defects.

A new form of high wattage incandescent lamp has recently been developed, in which the filament is supported directly by the prongs held in the socket, thus substituting metal-working precision for glass-working variables. The bulb plays no part in supporting the light source, merely serving as an envelope for the gas.

Composite Processes.—In the field of composite photography, the principal developments have been directed toward the perfection of the projection process. Instead of employing a special camera and differential lighting for producing the desired background, this method utilizes a technic in which the background is projected on the rear of a translucent screen, and then conventionally re-photographed with the foreground action. This is, of course, a well-known technic in still photography, and is by no means new in the motion picture field. Its present use has been broadened by the development of high-intensity light sources, synchronous electrical interlocks, and super-sensitive film emulsions. The principal advantages of the projection method are greater simplicity and lower cost. It is possible to see the background as the scene is photographed; whereas in the traveling matte and transparency methods, other means of judging the success of the photographic composition must be used.

Recording.—As reported in the JOURNAL, RCA Photophone, Inc., has placed on the market a readily transportable recording apparatus, and independent companies have also been active in this field. Most of the independent machines use the glow-lamp method of recording,



Courtesy of Electrical Research Products, Inc.

FIG. 3. Western Electric portable sound recording channel, including camera.

with d-c. interlocked motors. An example of the latter is the "Artreeves" recorder.[39]

The outstanding recent development in Western Electric sound recording equipment is the type F portable recording system consisting of an extension mixer unit, amplifier, film recorder, noise reduction unit, vacuum tube speed control, speed control motor, a variety of recorder and camera motors for use with various power sources, and uniform storage battery units consisting of aeroplane type of batteries in duralumin cases. All these units are designed to be extremely portable. The amplifier, the noise reduction unit, and the film recorder represent distinct departures from previous designs (Fig. 3). The amplifier weighs 80 pounds and has a frequency characteristic essentially flat between 40 and 9000 cycles.

Motors for this system normally are operated by the 12 volt storage batteries. Motors have been made available, however, for use with the standard Western Electric studio system, operating on 220 volt commercial distribution lines. Each unit weighs well under 100 pounds, and the total system in its simplest form weighs 396 pounds.

The use of acoustic reflectors has become quite general for outdoor pick-up under conditions where an unaided microphone is ineffective. These devices have not found much application in indoor recording, where reverberation is encountered.

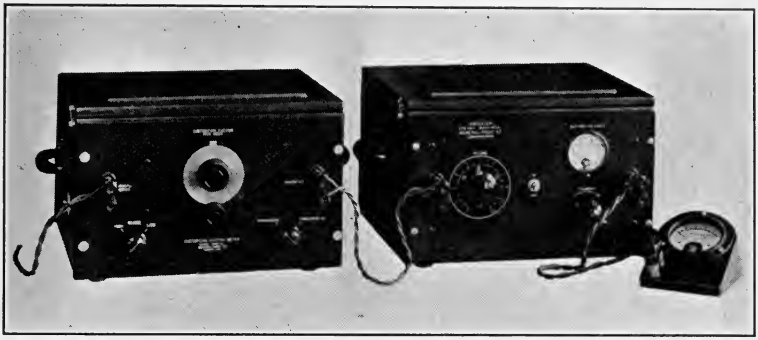
There is a tendency toward broadening the band of frequencies recorded and reproduced. Where formerly results were considered satisfactory when a range of, say, 60 to 6000 cycles was covered, the tendency now is to extend the range to a slightly lower limit at the one end, and to embrace considerably higher frequencies, up to, say, 10,000 cycles. The frequencies of recording galvanometer and valve peaks, formerly set approximately at 6000 cycles, are being increased to about 9000 cycles. Similarly, efforts are being made to extend the range of reproducing loud speakers, microphones, *etc.* Change of cavity shape and streamlining of condenser microphones have effected a substantial improvement in pick-up quality on the set.

An Austrian[40] reproducing machine is reported, which employs a tape record printed on glossy paper, the recording being done by the variable width method, with slit and selenium cell. The relatively high output of the selenium cell simplifies the amplifier requirements.

The use of a paper tape for the record permits editing on a convenient basis, and records playing 25 minutes or longer can be assembled. The device may find an application in providing records for the blind, as this type of record would be much cheaper than the Braille raised type book.

Several novel laboratory instruments that may be used for over-all improvement of sound picture recording and reproduction have been reported. The Bell Telephone Laboratories have announced[41] a special oscillograph, which was designed for making rapid records in sound picture studies. The oscillograph is briefly described, and illustrations are presented of records obtained in making the following studies: microphonic action of vacuum tubes; noise levels in amplifiers; investigations on rectifiers; studies on light valve clash; action of the biasing current of light valves as used in noiseless recording by the variable density method; acoustical studies showing the rise and decay of transients; loud speaker selection with regard to load carrying capacity, and investigations of mechanical flutter of reproducer sets.

The General Radio Company has announced a distortion-factor meter, which provides a simple and rapid means of measuring total harmonic distortion (Fig. 4). The same company announces a beat-frequency oscillator that has a power output of 50 milliwatts over a frequency range of 5 to 10,000 cycles, the harmonic content being of the order of 3 to 5 per cent.



Courtesy of General Radio Company

FIG. 4. Distortion-factor meter with amplifier.

Electrical Research Products, Inc., has made available a split beam monitoring unit for use in film recording, which also functions as a comparator for making determinations of light valve spacing. By means of this unit the various operations of adjusting the light valve are accelerated. In particular, it is of value in indicating immediately whether the valve ribbons have slipped, or whether in the picked up sound there are present frequencies so low that they are not reproduced audibly (see Fig. 5).

Re-recording—The only marked progress in re-recording has been in the field of foreign dubbing. Here, more precise methods of matching speech with the picture have been introduced. Previously, when it was necessary to produce a foreign version of an American picture, the track with the foreign version was made by actors who spoke into the microphones, after suitable adjustments had been made in the foreign script, while watching the characters on the screen. The addition of both auditory and visual aids to synchronization has afforded improved results.

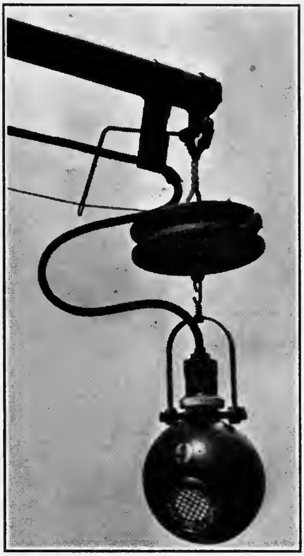
The auditory method consists of providing the foreign cast with individual headphones, which are fed from the English sound track of the picture. Thus, the actor is able to watch the screen for visual guidance and simultaneously to hear the English sentence while he speaks into the microphone the corresponding foreign words. Audible cues may also be supplied in this way.

Courtesy of Electrical Research Products, Inc.

FIG. 5. Split beam light valve comparator device.

Dubbing has been extensively practiced in Germany. There a visual adjunct, called the "Rythmographie," has been developed. This consists of an indexed paper tape moving synchronously with the film, but at lower speed. Individual tapes are prepared to cue each actor speaking the foreign lines. Several methods, likewise based on the use of such adjuncts, have been applied in Hollywood, but detailed information regarding them is withheld. The latest results, however, show quite exact synchronization, even with languages, like Chinese, which have little phonetic relation to the English.

Set Construction.—Development of the spark chronograph reverberation meter by the Bell Telephone Laboratories[42] has permitted the quantitative measurement of reverberation time, which is an important factor in room acoustics. The meter is an electro-acoustical ear with adjustable threshold sensitivity, and automatically plots the rate of decay of any given tone. The tone source generally used consists of a dynamic loud speaker supplied with a "warble tone" over the frequency range under consideration, thus eliminating difficulty experienced with standing waves.



Courtesy of Metro-Goldwyn-Mayer Studios

FIG. 6. The "bomb" microphone.

Klenke[43] describes a studio in which the floors, walls, and ceiling are loaded on steel springs within a second structure of solid masonry. The desired reverberation time of 0.6 second is obtained by using acoustical plaster on the ceiling and walls. The reverberation, however, may be varied by employing additional absorbing units or "gobos." A noise-proof ventilating system is obtained by using absorbing material in wooden ducts.

Microphones.—In a novel modification of a typical condenser microphone in a West Coast studio, the condenser and associated amplifier are incorporated in a bomb-like sphere as contrasted with the cylindrical form in common use (Fig. 6).

Three methods of calibrating a microphone and associated amplifier are described,[44] the amplifier later being separately calibrated to disclose the calibration of the transmitter alone. The methods described were respectively the Rayleigh disk, the actuator, and the thermophone.

The disadvantage of the actuator and thermophone methods is that the effect of pressure doubling and cavity resonance at the microphone diaphragm is not taken into account. The Rayleigh disk method is considered more truly representative of field use conditions.

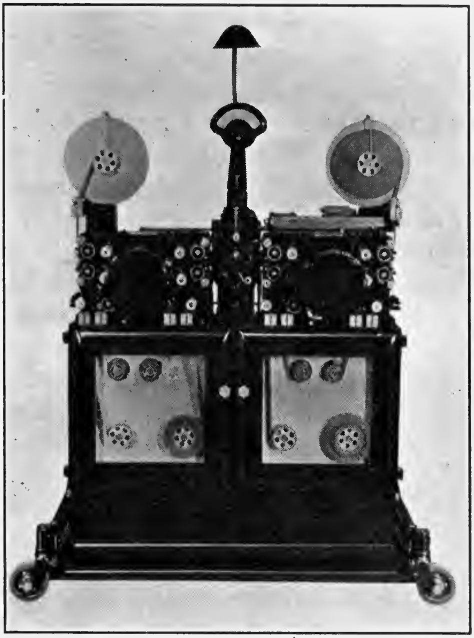
According to Ballantine,[45] the difference between open sound field and thermophone calibrations is shown to be caused by cavity resonance and diffraction phenomena.

C. *Laboratory Practice*

Equipment.—The introduction of a new printer capable of printing sound and picture simultaneously is probably the most important advancement in laboratory equipment. Advance in laboratory construction is evidenced by the new M-G-M West Coast Laboratory referred to in a previous report.

Photographic Chemicals and Solutions.—A French patent[46] has been granted, relating to a process of eliminating the silver salts from the picture area and substituting a bichromate process with dye mordanting. Another French patent[47] has been granted for the substitution of an alkali earth for the silver in the sound track image. A British patent[48] has been granted covering the process of depositing on exposed portions of the film an additional amount of silver from the developer. A British patent[49] has been granted a combined sound and picture film in which the sound record is opaque to ultraviolet rays but transparent to light within the greater part of the visible spectrum. Crabtree and Muehler have examined the properties of a large number of known intensifying and reducing solutions to determine formulas suitable for use with motion picture film.[50] The methods of intensification and reduction are applicable to sound film, with the possible exception of subtractive reduction which causes a loss of high frequencies.

Processing Technic.—There has been a marked increase in the use of sensitometry in motion picture development, especially the development of picture negative. Three of the largest studios in Hollywood have established the practice of developing all picture negatives to a fixed gamma. This practice at first caused confusion among cameramen, but after becoming familiar with the laboratory technic, they adapted themselves readily to the situation. Sensitometric control of the negative is said to reduce the cost of development and produce a product of high average quality. A British patent has been granted a method of rendering the sound track area smooth on a film having embossed striations.[51]



Courtesy of Bell & Howell Company

FIG. 7. The new Bell & Howell combined sound and picture printer.

Printing Machines & Methods.—Bell & Howell have announced[52] a new fully automatic 35 millimeter sound and picture printer (Fig. 7).

This device prints both sound and picture at one operation. Notches on the edge of the film, circuit interrupters, and similar devices, which are peculiarly liable to get out of order, are eliminated. The printer is fully automatic so that one operator can attend to a number of machines; all that he has to do is to thread the machine, push the lever, and pay no more attention to it. The machine stops automatically when a lamp burns out, or when by any chance a film breaks or the machine overheats.

The motor and printing lamp housings are water-cooled, and the drive embodies a specially designed mechanical filter. Oiling is automatic. Air pressure is used to insure good contact between negative and positive films and compressed air and vacuum devices tend to insure cleanliness of the picture and sound negatives, as well as of the positive and "traveling matte" films. The "traveling matte," which runs at one-fourth the speed of the negative, serves to control the printing light.

Several patents have been issued on printers and printing processes. Among those of interest are the following:

(*a*) Maintaining contact between negative and positive films by air pressure.[53]

(*b*) A printer for applying a sound record to a previously prepared picture film.[54]

(*c*) Photographically printing transparent composite sound record films from separate negative films on which the sounds to be combined are independently recorded.[55]

(*d*) In a method whereby a variable width[56] sound track is printed by means of a beam splitter on both sides of a double-coated film having an interposed non-actinic layer, the sound track is reduced in width by "folding back" the peaks in printing on the other side. The introduction of sound on 16 millimeter film has required the development of a continuous optical printer for reducing 35 millimeter sound negatives to 16 millimeter positives and of printers capable of printing directly from 16 millimeter sound negatives.

In order to minimize sound track printing losses, a patent has been issued covering the use of a parallel beam of light in printing.[57]

Tinting and Toning.—A British patent[58] has been issued covering a combined sound and multicolor cinematograph film wherein the colored pictures are produced as registering dye images in exposed silver emulsions on opposite sides of the film. The sound is recorded as a silver image in the emulsion on one side of the film, the latter being then treated in a bath which renders the images in each differentially absorptive to dyes, and finally being treated with a dye such that the resulting sound image is suitably absorptive for the light directed therethrough to the photoelectric cell used for reproduction. The emulsion on the opposite side of the film behind the sound image may be left clear or may be uniformly tinted with the used dye for the picture image on that side, provided such dye transmits freely the radiations directed to the photoelectric cell.

Film Treating.—A French patent No. 692,800 describes a process for protecting film and emulsion surfaces, comprising a coating of a thin layer of a transparent material having 4 parts of cellulose derivative and 96 parts of amyl acetate or other appropriate solvent. The practice of waxing movietone prints is being abandoned by some producers in favor of a protective coating to the emulsion and film base.

Sensitometry.—The French Committee[59] on the Standardization of Sensitometric Methods voted to accept the second and third recommendations of the American Committee. These recommendations provide that the light source be stated in all publications and that illumination be continuous, not intermittent. It is also recommended that exposure shall be varied by changing the time and not the intensity of the light source. The committee expressed a preference for the copper glycocoll filter to be used with the light source at 2360°K. to represent solar radiation.

F. von Goler and M. Pirani[60] review the proposals for a standard light for photographic sensitometry and present the results obtained by using a combination of three glow discharge tubes containing cadmium, mercury, and neon, together with suitable reflecting or transmitting filters.

II. EXHIBITION

A. General Projection Equipment and Practice

Projectors and Projection.—A description of the system employed in Trans-Lux rear stage projection has been published by Mayer.[61] This system involves two projectors placed close together behind the center of the screen, each inclined at an angle of $22^1/_2$ degrees to the center line of the screen and on either side of this line. A reflector is used for reversing the image, so that the projector and sound head are threaded in the usual manner. A patent has been issued on a system of this kind.[62] Dr. Joachim has published an outline of the historical development of projectors and has described the portable projectors now being made for sound film.[63]

Sixteen millimeter projectors have reached an interesting stage of development during the past year. The constant demand for more light has resulted in a number of new lamps of high wattage. These models have pushed to an extreme the amount of tungsten that can be put into a small lamp bulb, and it is hard to say how far this development will be carried. It may well be that new standards of lamp life and size will be established as a result of the present demand for extreme illumination. The optical principles of the 16 millimeter projector were discussed in a paper presented by Cook, at the October, 1931, meeting of the Society. In this it was pointed out that light sources, condenser systems, and projection lenses must all be properly proportioned to produce an efficient projection outfit.

Recently the lamp manufacturers have found it possible to make a commercially satisfactory lamp employing what is known as the biplane construction. This form of light source is made by placing an additional row of coils behind the front row, the rear row being so placed that its coils cover the spaces between the coils of the front row. Thus, an almost solid incandescent surface is presented to the optical system, resulting in a gain of 25 to 30 per cent in screen illumination over that obtained with the monoplane-mirror system.

The Bausch & Lomb Optical Company, of Rochester, New York, has recently made available a new 35 millimeter film slide projector. One interesting feature of the projector is that the mechanism for holding and operating the film is not connected in any way to the lamp house and condenser except in being mounted on the same base. Thus, the knob for moving the film, and the film itself, remain much cooler than is usually the case with such equipment. The projector uses the standard 200 watt, 115 volt lamp.

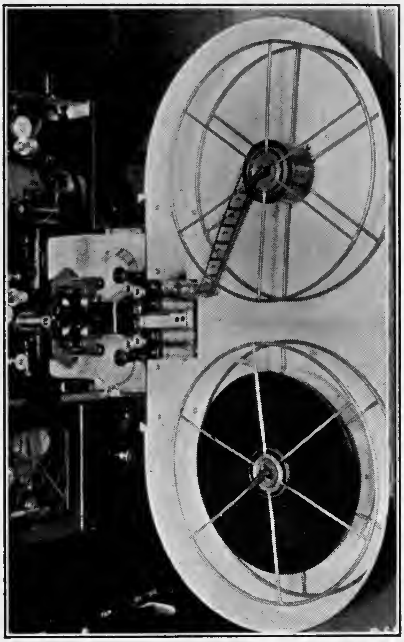
Sound Picture Reproduction.—The first 16 millimeter sound-film projector has very recently appeared on the market.[64] It is claimed to show a good 4 by 6 foot picture with excellent quality of sound reproduction.

Electrical Research Products, Inc., announces a double film attachment that has been designed for use on the Simplex head in projecting previews from working prints when the picture and sound are on separate film. This attachment embodies a take-up reel for the picture film and a pay-out reel for the sound track, both interposed between the picture and sound apertures. It is readily mounted in place of the blank plate at the back of the Simplex head (Fig. 8).

The tendency in reproducing sound from film is to extend the frequency range so that the higher frequencies are radiated from the loud speakers. It is understood that both RCA and ERPI are about ready to introduce this so-called wide band reproduction into the theaters.

Electrical Research Products, Inc., has developed a tool[65] for use in accurately adjusting lens tube assemblies in Western Electric sound-film reproducers under actual reproducing conditions in the field. This tool enables the average man to make a more accurate adjustment than was possible by the most skilled man using the older method.

A new photoelectric cell is announced which requires no auxiliary voltage.[66] A novel loud speaker is claimed to combine the principles



Courtesy of Electrical Research Products, Inc.
FIG. 8. Double film attachment mounted on projector.

of the piano and violin by providing a large tuned area for the dissemination of the sound.[67] It is supposed to provide a uniform response from 13 to 17,000 cycles per second. Increased use is claimed for selenium cells in sound film projection.[68] These cells were developed by Dr. Thorring and are claimed to be 1000 times as sensitive as gas-filled photoelectric cells.

Storage batteries are now being eliminated from Western Electric theater sound equipment, being replaced by rectifier-filter units.

The design of these units adapts them to any type of existing or new installation that would otherwise require storage batteries.

A marked improvement in disk sound records is reported from the Bell Telephone Laboratories.[69] The Laboratories claim that both theoretical and experimental investigations indicate that a phonograph record, cut with vertical undulations instead of the more usual lateral undulations, possesses fundamental advantages. The principal improvement is a marked increase in the volume and frequency range over which faithful reproduction may be obtained. A higher volume level can be recorded using the same groove spacing and speed. A greater playing time can be provided, with a given volume level,

Courtesy of Bausch & Lomb Optical Company

FIG. 9. Wide angle projection lens.

by a record of given size, since, for these conditions, both the groove spacing and the speed may be reduced. Improvements in methods of processing the stampers and in the record material result in a large reduction of the surface noise and hence a corresponding increase in the volume range. With these improvements, the frequency range that can be reproduced satisfactorily can be extended nearly an octave, to 8000 or 10,000 cycles. Incidental to these features are the great improvement in the quality of reproduction obtainable directly from the soft "wax" record and a great increase in the life of the hard record.

A number of patents have been issued covering sound reproduction.[70,71]

Projector Lenses and Optical Systems.—The Bausch & Lomb Optical

Company has designed a lens of 1 inch focus and a relative aperture of $f/2.5$ for the projection of standard 35 millimeter film. This is of interest, principally, for projecting film behind a translucent screen. The lens requires a condenser mounted immediately behind the aperture plate of the projector in order to obtain uniform illumination of the field (Fig. 9).

Burt describes[72] an optical system that uses positive and negative cylindrical lenses having their axes at right angles. The image of a source is optically elongated and flattened by these cylindrical lenses to the proportions desired, and is then focused on the film. Advantages are: maximum possible brilliancy with a given source temperature; insensitivity to the position of the lamp filament; sharpness of the image; and perfectly uniform brilliance throughout the length of the beam.

Fire Prevention.—Several patents have been issued [73,74] covering safety devices for film reproduction. A detailed description of the requirements of a safe and efficient film storage cabinet is given in an article in *Theater Management.*[75]

B. Special Projection Methods

Effect Projection.—According to H. Picard,[76] a wide screen picture can be obtained with film of normal width by compressing the width of the image by using an auxiliary cylindrical lens both in making the negative and in projecting the positive. This method is open to the objection that the graininess of the negative is evident in the magnified image of the positive. It is proposed to overcome this fault by using wide negative film and compressing the image with the auxiliary lens in the process of printing by projection on the fine-grained positive. The illustrations with the article show pictures of the French Colonial Exposition buildings made in this manner. Other applications using this scheme are mentioned, such as that of producing narrow vertical pictures, and color and stereoscopic processes requiring two or more pictures in the standard frame.

Stereoscopic Projection.—H. E. Ives has considered the problem of projecting motion pictures in relief,[77] summarizing as follows:

"The essential conditions for producing pictures in stereoscopic relief are twofold: first, separate pictures must be made from different points of view, corresponding to the two eyes; second, each eye of the observer must receive its appropriate view. No compromise with these fundamental requirements appears possible.

"If stereoscopic projection is to be achieved in such a form that a large group of observers may simultaneously see the projected picture in relief, the distribution of the appropriate views to the two eyes must be accomplished for each observer. There are two places where the distribution may be made: the first is at the observers' eyes; the second is at the screen on which the picture is projected.

"If the first method be employed, two separate images must be provided on the screen, and every observer must have a means of directing one image to the right eye and one to the left eye.

"If the distribution of the images is to be made at the screen, two images are no longer sufficient. Theoretically, an extremely large number must be provided, a separate one for each position that can be occupied by any eye in the audience."

Several methods of utilizing the parallax panoramagram method are discussed. It appears from the theoretical standpoint that the problem of projecting motion pictures in relief is entirely soluble, and experimental tests of still picture projection have been successfully made. Practically, the accomplishment of projecting motion pictures in relief will depend upon apparatus operating at excessive speeds, a great multiplicity of taking or projecting units, projection screens containing minute ridged reflecting or refracting elements of extreme optical perfection, projection lenses of extraordinary defining power, microscopic accuracy of film positioning, and photographic emulsions having speeds at present unknown.

Non-intermittent Projection.—An account of a new continuous projector of French design was published in the January issue of the JOURNAL.[78] This particular outfit is small in size, and is fitted with an optical compensator that is claimed to reduce wearing of the film and to be extremely silent in operation. F. Tuttle recently presented a paper before the Optical Society of America that summed up, very thoroughly, the various types of continuous projectors, the optical means used in fixation of the image, and the advantages of each type of construction.[79] A few patents on continuous projectors have been noted.[80]

A new type of non-intermittent motion picture projector is described by Huc.[81] The principle involved is one that required the film to pass over a cylindrical drum having an aperture through which the single frame or picture is projected upon an oscillating mirror which, in turn, reflects it into the objective of the machine. During the movement of the film over the aperture, the adjacent frame is isolated by means of a movable window behind the aperture, which moves at the same angular velocity as the film. When the projection phase is terminated a shutter masks the objective during the return of the mirror and window. It is claimed that such a projector is capable of projecting a film 3000 times without injuring it.

C. *Theater Design and Installation*

Screens.—According to Schlanger,[82] the claim is made that with the exception of the progress made in projection engineering, the art and science of exhibition have advanced very little. The position of the screen, for example, is still determined by the stage floor of the dramatic theater. The average life of a theater should be at least 15 years in order to amortize the initial cost of construction and to show a reasonable profit on the investment. Physical comfort of the patron is considered of primary importance in theater design. A maximum screen size having the ratio 1 to 1.67 is considered preferable to satisfy various requirements.

The new specifications for camera and projector apertures should do much to place upon the average screen a picture of more pleasing dimensions than has been obtained with movietone prints. In order to project to the screen the complete picture as photographed in the studio, and not cut off the top and bottom of the picture, the projector aperture should be carefully measured to the specific height, 0.600 inch, and the screen masks adjusted accordingly. The ratio of the height of the picture to its width will then be approximately three by four at medium angles of projection, and will vary slightly with greater or smaller angles.

Theater and Stage Illumination.—A novel departure in theater lighting is announced by Burke.[83] He states that the development of thermionic tubes has opened an entirely new phase of theater lighting control. This development has made possible the feature of preset dimming and proportional dimming, and a small compact switchboard such as has been heretofore impossible.

The preset dimming feature allows an operation whereby a control board may be adjusted for any desired number of effects in advance, so that these effects may be called for by the operator at will, merely by operating a single control.

Proportional dimming, a new feature, allows the lights to be controlled in such a manner that they may be dimmed in combinations, while retaining the same color tone throughout the dimming process.

The third desirable feature is that a small compact control board may be so arranged that it can be placed as desired in the orchestra pit, or in some similar location, so that the operator becomes a light artist, taking his place in the performance along with the organist or other artists.

Theater Acoustics and Construction.—A series of interesting articles dealing with theater acoustics and construction have recently appeared, a few of which are abstracted briefly here.

E. Petzold[84] advocates the regulation of the acoustics of an auditorium just as its lighting and heating are regulated. He explains a method by which the change in acoustical absorption caused by the presence of an audience may be compensated for. He describes acoustical controllers consisting of a series of rotatable triangular columns, the walls of which consist of three types of materials: reflecting, absorbing, and resonating.

According to Hopper,[85] the necessity of determining acoustical coefficients of absorption at frequencies up to 8000 cycles has been brought about by the improvements being effected in increasing the frequency range of recording and reproducing sound pictures and in radio broadcasting. Naturalness and intelligibility are enhanced by the addition of these higher frequencies, which further increase the effect of realism.

Several methods of measuring sound absorption are in use, but these methods require rather large samples on which to conduct the tests. The Norris-Andree[86] method of measuring reverberation theoretically lends itself to the measurement of sound absorption, permitting relatively small samples to be used and necessitating no reference absorption material.

C. F. Eyring[87] presents a theoretical and experimental analysis of the relation between the rate of decay of sound in the main body of the theater and that in the balcony. For an ideal theater, if the average coefficient of absorption of the balcony is less than that of the main auditorium, the rate of decay of sound in the balcony, after the first drop of a few decibels, is essentially the same as though the balcony were coupled by its opening to out-of-doors. If the average coefficient of the balcony is as great as or greater than that of the main body of the theater, the time of reverberation will be constant throughout the theater, this being the usual case. On the other hand, as the average coefficient of absorption of the balcony exceeds that of the main room, the rate of decay of sound in the main room very quickly approximates the value calculated on the assumption that the coupling surface is an open window to which a weight of 0.9 has been assigned.

According to Friend,[88] the audience affects only the reverberation time. It is desirable to maintain the reverberation constant, a difficult feat under the varying conditions of the audience. Such a condition may be approximated by using seats of sufficiently high acoustical absorption that the total absorption will remain nearly constant whether the seats are occupied or not. Some other general rules concerning acoustics are mentioned. Among these are: the importance of avoiding curved surfaces that can focus the sound, the necessity of proper balance between the size of the room and the sound output, and the avoidance of unusual shapes that make satisfactory distribution impossible.

III. APPLICATION OF MOTION PICTURES

A. Education and Business

As will be noted in Section V, there has been considerable activity in the 16 millimeter field, especially as regards portable projectors. The great drawback at present is the lack of suitable libraries of films for educational purposes. However, progress is being made in this respect by several manufacturers of this type of equipment.

W. Lewin, basing his claims on tests conducted on classes in high-school physics, states[89] that motion pictures impart more information in a given time and contribute more to the retention of information, than most orthodox methods of instruction. An interesting use of "silent talkies" is being made in teaching lip reading to the deaf at Ohio State University.[90]

The use of motion pictures in scientific work continues. E. Adolph, of the University of Rochester, has photographed individual bacilli and yeasts at the rate of 2 to 30 times per minute for several hours as they grew in a suitable medium, and thus has been able to determine their rate of growth. In Germany, the first motion picture of a total eclipse of the moon was photographed on April 2, 1931.[91] In this work, an $f/10$ objective, having a focal length of 65 centimeters, mounted on an Ernemann *E* camera, was used. The use of motion pictures to obtain views of rapidly moving objects is reported from Massachusetts Institute of Technology.[92] An intermittent source provided flashes of high intensity having a duration of the order of 0.00001 of a second, the film being run continuously in the camera, and exposures being made at the rate of 480 per second.

A patent has been granted for a burglar alarm system that includes a camera, a flashlight, and a synchronous means of setting off the flash and exposing the film in the camera, upon the operation of suitable light-sensitive devices electrically connected so that any obstruction of the rays of light falling upon selected parts of the system will cause the system to operate.[93]

B. Medical Films, Radiography, and Cinephotomicrography

Motion pictures continue to be used extensively in medical research and practice. Jasper and Walker[94] report a camera built for simultaneously recording horizontal and vertical movements of both eyes by the corneal reflection method. They claim that the record is positive, easily read, and can be made at low cost. Schwarz[95] presents an illustrated description of the pin-hole apparatus used in the clinic of the University of Vienna for photographing the internal walls of the stomach. The illumination, lasting about 0.001 second, is obtained on exploding a tungsten filament with a condenser discharge. The exposures are stereoscopic, and are made on a set of four pieces of film, 6 by 12 millimeters in size.

A brochure on "Roentgen-Kymographie" by P. Stumpf[96] describes the author's experiments in studying the movements of internal organs by means of the shadows cast by x-rays upon the film as it moves slowly past a series of parallel slots.

Linke[97] describes a survey of the best known cinemicrographic equipment, and describes the Askania apparatus in detail. In this assembly, the microscope, the camera, and the light source are mounted on independent supports. A 55 ampere, self-regulating arc is used and the appliances available render it possible to cover a range of frequency of exposure from 100 a second to one every 10 hours.

C. Television

The literature on television grows, but the advent of television into the realm of practice still appears very remote. Using a 10 by 10 foot screen in conjunction with a receiving disk having 900 rpm., in a television demonstration that opened on October 22, 1931, at the Broadway Theater, New York, N. Y.,[98] a few short talks, a vocal solo, and part of one act of a Theater Guild production were televised from the Theater Guild Studio, a few blocks distant from the receiving station.

The De Forest direct pick-up television camera is described,[99] in which light is reflected from the performer, through the lens and a 60 hole scanning disk, to the photoelectric cells located in a box on top of the camera.

A Television Talkiola[100] incorporates, within a single cabinet, mechanisms for producing six different kinds of entertainment; namely, television with synchronized sound, talking motion pictures (16 millimeter or silent pictures), phonograph, short-wave radio, and broadcast radio. A $^1/_5$ horsepower synchronous motor operates the perforated scanning disk used for television, giving a 6 by 8 inch picture. The principle of rear projection is used for the 16 millimeter projector.

A number of patents have been issued covering scanning disks and methods.[101]

D. Miscellaneous Uses

An interesting innovation in electroöptical transmission is described in U. S. Patent 1,826,812. It involves a system for transmitting electrical impulses into light impulses of varying intensities, and is comprised of two plane mirrors having their planes intersecting at right angles and controlled by the incoming picture current at the receiving station, these mirrors taking the place of the usual light valve. This "90 degree mirror" rotates about an axis at the line of intersection. The surfaces consist of alternately reflecting and non-reflecting strips, which gradually increase in width from the line of intersection. The rotation of the 90 degree mirror is controlled jointly by picture currents received from a transmission line, these currents passing through a movable coil attached to the 90 degree mirror, and by current from a local source which passes through a stationary coil, the position of the 90 degree mirror varying in accordance with the amount of current received from the line.

IV. COLOR PHOTOGRAPHY

The growth of a color consciousness is evident in the motion picture industry, and comes as a welcome departure from the recent period during which little interest in color was evinced by the producers. Since the last meeting of the Society, one feature comedy drama has been released in color, a mystery drama is now in production which promises to be enhanced by the additional dramatic effects available, a number of short subjects both for amusement and advertising have been released to an approving public, and additional subjects now in the form of negatives are awaiting printing.

Adequately faithful reproduction in color postulates color processes that are inherently stable throughout the several steps of manufacture on a scale yielding in a short time a large number of prints of uniform quality in color balance, register, contrast, definition, and sound reproduction. Material advance is reported along these lines, notably by Technicolor, whose improved printing process, announced at the Spring, 1931, Meeting of the Society, and demonstrated at the Fall, 1931, Meeting, has produced a uniform product having little apparent graininess, and showing good long-shot definition.

According to Kershner, under the poor weather conditions in the Arctic, satisfactory monochrome motion pictures were more difficult to obtain than color pictures, as the slight chromatic differences were more readily recorded by the latter film. This cameraman exposed about 20,000 feet of film last summer, using a bi-pack process.[102] The Autochrome color screen, so popular for many years but available only on plates, was marketed during 1931 on a film support.[103] A new bi-pack roll film from which prints are made on paper by inbibition was introduced under the name "Colorol Film."[104]

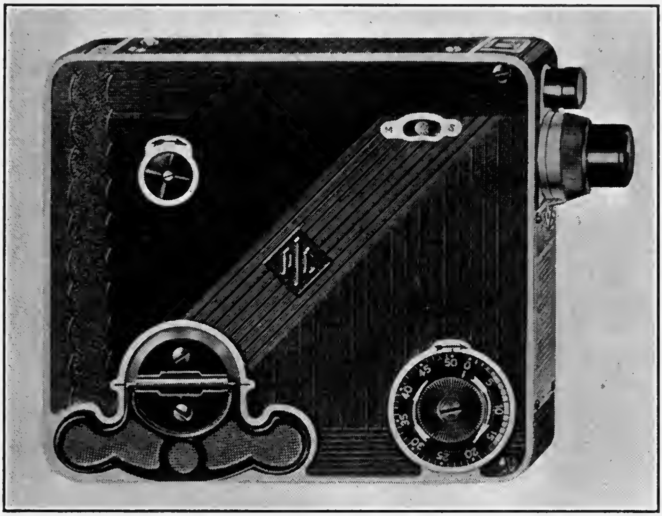
Technically, no fundamental developments of importance have been disclosed during the past six months. Such developments as are noted fall into two classes: (*a*) improvements and modifications of the lenticulated film additive process, particularly in methods of printing and projecting, but ranging from machines for goffering the film surface (U. S. Pat. 1,844,418) and coloring agents in the emulsion for reducing the effects of reflected light (U. S. Pat. 1,843,595) to projection (U. S. Pat. 1,836,787); and (*b*) improvements and modifications of the three-color screen plate process described in the previous report of the Progress Committee. Additional patent references of these two classes, as well as miscellaneous disclosures of interest in the color field, are listed.[105]

A useful summary of the patent literature of color photography was published by Grote.[106] Additional patent protection was granted on improvements in making Multicolor screens for cinematography.[107] Two Canadian patents were issued to Mannes and Godowsky, Jr., relating to the use of a plurality of emulsions in separate layers, each being sensitized to record different color values producible on development.[108]

V. AMATEUR CINEMATOGRAPHY

A. General Equipment and Uses

A new answer to the question of film libraries for the use of the amateur has appeared. This library, which serves southern California at the present time, but which is planned for wider service in the near future, offers films for free use. The cost of the films is defrayed by an advertiser, who "sponsors" it in the manner in which radio broadcast programs have been sponsored. A leader on



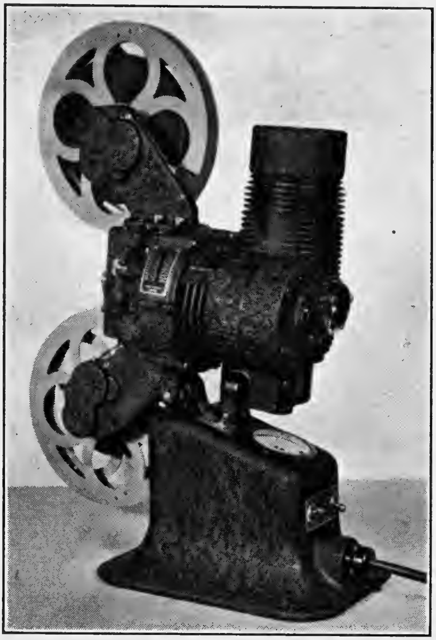
Courtesy of International Projector Corporation

FIG. 10. Simplex-pockette camera.

the film bears the advertisement and the sponsor bears the expense. The scope of this experiment will be extended to include other parts of the United States as rapidly as results justify doing so. At the present time more than three hundred subjects are available in the first unit established.

Additional films synchronized to disk records are now available for the Filmophone. Five hundred films are ready, others being added regularly. A catalog has been issued[109] which lists 450 medical films now available from various sources.

Cameras.—The most recent addition to the amateur standard size cameras on the American market is a very compact one manufactured by the International Projector Corporation. This is known as the Simplex-pockette camera and incorporates a radical change in the method of loading from those previously employed[110] (Fig. 10). The fifty feet of film, representing the capacity of the camera, are supplied in a ready-threaded magazine which is simply inserted into the camera. The film may be removed at any time, in which event only one frame will be fogged, allowing films to be interchanged without

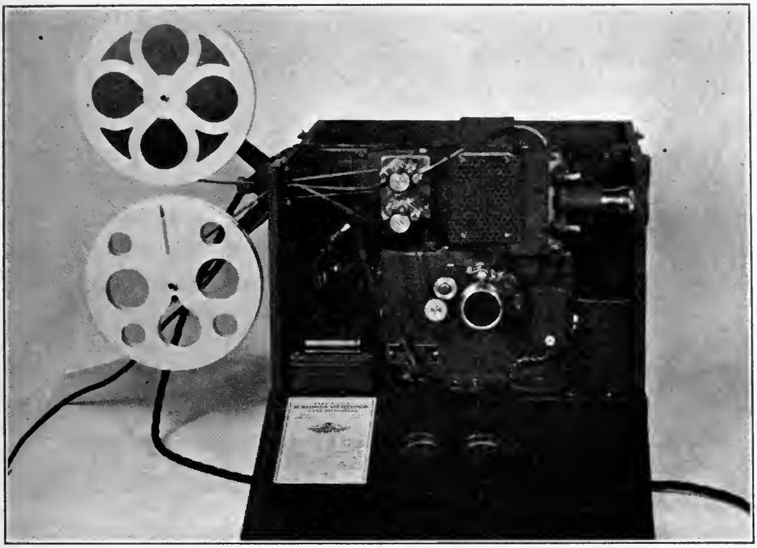


Courtesy of Bell & Howell Company

FIG. 11. The new Filmo model *J* projector.

having to make the changes in a dark room. The camera is equipped with a fixed focus *f*/3.5 lens. The spring motor drives twenty-five feet of film at one winding, and is wound by a non-detachable key that folds into a recess in the side of the camera. The speed may be varied between 12 and 16 pictures per second, or single frame exposures may be made by a release provided for the purpose. This makes possible animated pictures or titles.

Projectors.—Two Filmo projectors are now supplied which are completely gear driven.[111, 112] The model *J* is equipped with a number of unusual features and represents a decided advance in the design of small amateur projectors capable of showing pictures up to 16 feet in size. The main features of the projector are as follows (Fig. 11): entirely beltless; fully automatic gear-shift rewind, automatically lubricated; improved lamp, lens, and condenser, giving about 30 per cent more light than previously available; aero type cooled lamp housing, with radiating fins to reduce heating; lateral micrometer reflector adjustment for critically focusing the lamp filaments—especially efficient for Kodacolor; centralized lubrication—only five oil cups.



Courtesy of RCA-Victor Company

FIG. 12. 16 Mm. sound-on-film projector.

This projector uses the new 400 watt biplane filament projection lamp, which is specifically adaptable to Kodacolor projection. The advantages of the biplane filament lamp, in conjunction with the reflector adjustment on this machine, admit of a considerable improvement in Kodacolor projection. Kodacolor pictures, 3 by 4 feet and even larger, have been shown to audiences of one or two hundred persons with this machine.

Three models are available in the new Victor projectors, which differ among themselves principally in the light sources used.[113] Following the trend evident in all new projectors, the higher wattage lamps are operated at 120 volts.

Both the Filmophone and Animatophone projectors, synchronized with disk records, are now available with "blimps" similar to those used with professional cameras.

The long awaited announcement of an amateur sound-on-film process finally appeared in January, when a projector using such film was stated to be on the market[114] (Fig. 12). A film 16 millimeters wide, having only a single row of perforations, is used. The sound track is located in the area normally occupied by the second row of perforations. Another process uses a variable density sound record printed at an angle along the edge of 16 millimeter film.[115] The angular recording of the sound is claimed to increase the sound volume available from the track.

Accessories.—A new mounting is supplied on a 25 millimeter *f*/3.5 lens for use on the Filmo *70* which makes the distance setting and lens aperture markings visible in the finder in the manner long familiar to the professional user of the Eyemo.[116] A 15 millimeter *f*/2.5 wide-angle lens is also supplied for this camera. A $4^1/_2$ inch telephoto lens is now available for the Model *K* Ciné-Kodak, in addition to the 3 inch lens previously listed.

A new exposure meter has been placed upon the market which, similarly to others previously available, is operated according to a judgment of the least perceptible brightness in a photometric field.[117] A physical photometer, known as the "electrophote" employing a light-sensitive cell, is offered in a case similar in size and shape to a roll of film. The lens aperture is indicated directly on the scale when the unit is pointed toward the scene to be photographed.

A new title board for use with any model Ciné-Kodak is very compact. A supplementary lens is so mounted as to focus the camera on a very small area, allowing the use of typewritten titles.

For making interior shots, a new lamp, called the "Photoflood," similar in appearance to the standard 06 watt, inside-frosted lamp has recently been marketed. When operated on 115 volt circuits, it consumes 250 watts, has a visual light output equal to that of a 500 watt lamp, and a photographic light output approximately that of a 750 watt lamp. Its life is about two hours. A special socket, in which a resistance is incorporated, is available for use with this lamp. The lamps are operated at 65 volts with the resistance in the circuit until the moment of shooting, when the resistance is cut out. This allows preparations for the shooting to be completed without unduly shortening the life of the lamp.

Films and Film Processing.—A new panchromatic reversal film has been placed on the market by Agfa. It is said to have about twice the speed by daylight of Agfa's older panchromatic reversal film, and nearly three times the speed by tungsten light. The film is stated to be more sensitive to red radiation and to possess equally as fine grain as the older film. An anti-halation layer is inserted between the emulsion and the support.[118]

Patent protection was granted a scheme for avoiding the use of paper leaders on ciné film by dyeing both ends of the film on the emulsion side with a dye impermeable to actinic light rays.[119]

B. Color Processes

Many of the obvious limitations of the Kodacolor process were eliminated or greatly reduced when it was announced in March, 1932, that supersensitive Kodacolor film was available for public use.[120] The full aperture of $f/1.9$ is still used; neutral density filters are placed before the lens when exposures are made in direct sunlight. Pictures in dull light or open shade are stated to be possible with this film at half cranking speed.

VI. STATISTICS

Motion Picture Theaters throughout the World

	Equipped for Sound	Unequipped	Total
Europe	11,217	18,099	29,316
United States	13,500	6,500	20,000
Latin America	1,379	4,056	5,435
Far East	1,529	3,396	4,925
Canada	705	395	1,100
Africa	271	419	690
Near East	16	69	85

France.—George R. Canty, American Trade Commissioner at Berlin, submits the following estimate of capital invested in the French film industry during 1931, as recently appearing in the French trade press. The total amount is estimated at 1,350,000,000 francs ($53,-300,000), composed of the following items:

Equipment of cinemas for "talkies"	250,000,000 francs
New houses and transformations	280,000,000 francs
Studio construction and sound equipment	150,000,000 francs
Investment in companies, *etc.*	175,000,000 francs
Production costs (all films)	495,000,000 francs
	1,350,000,000 francs

During 1931, it is reported that new companies, capitalized at 83,000,000 francs, were formed in France, while the increases of capital by established firms amounted to 24,600,000 francs.

According to the German trade press, reports George R. Canty, American Trade Commissioner at Berlin, the association of French raw film manufacturers is reported to have applied for restrictive measures against the import of foreign material in view of the fact that Germany, America, and Belgium have succeeded in increasing their sales to an alarming extent in the last few years.

The following figures may be of interest:

Total Raw Film Imports

1927	8,120,000 meters
1928	15,000,000 meters
1929	19,000,000 meters
1930	25,000,000 meters
1931	28,000,000 meters

In 1931, Germany (Agfa) participated with 13,101,582 meters, America with 10,415,824 meters, and Belgium (Gevaert) with 4,428,-414 meters.

Germany.—What are claimed to be the most up-to-date and lavishly equipped sound-film studios in Europe have been erected in Germany by Tobis, in conjunction with Klangfilm, on the site of the Jofa studios. They are now being perfected by the installations of Topoly (Tobis-Polyphon-Film G. m. b. H.), which company is planning to concentrate its entire management and production there in the beginning of February. The studios are equipped with the most technically advanced apparatus, constructed under Topoly patents; and two post-synchronization studios and a number of other studios and laboratories are still in process of construction.

The production of high-class shorts is the object of the formation of a new film group at the Berlin State Theater. The society is to be called Tonfilm und Theater-Arbeitsgemeinschaft G. m. b. H. Under the management of Dr. Halewicz, it will collaborate with Tobis-Melofilm on a profit-sharing basis. The entire artistic personnel, including actors and directors, will be provided by the new group, while Tobis will be responsible for the technical equipment.

U. S. S. R.—Trade Commissioner George R. Canty, Berlin, states that the German trade press reports that the Soviet Trade Delegation in Berlin has made an agreement with the Weldfilm Company of

Berlin regarding the distribution of Russian films reprinted on narrow-gauge stock. For the beginning, it is intended to reprint 20 Russian full-length features, which have already met with success outside Russia, such, for example, as: *Potemkin*, *Blue Express*, *Storm over Asia*, and so on. It is further reported that the agreement in question also includes the exclusive rights to the distribution of pictures in all important European territories.

Great Britain.—According to the *Cinematograph Times*, the official organ of British exhibitors, 522 feature films were shown to the trade in Great Britain during the first eleven months of 1931. Eight hundred applications for patents in cinematography were made to the British Patent Office last year.

Canada.—Canada has more Canadian dollars invested in the motion picture industry and more Canadians employed in it, receiving higher wages and salaries, than in the automobile industry. According to a local authority, 94 cents out of every dollar taken in at Canadian box-offices are spent in Canada. It is declared that but 6 per cent of these receipts go to motion picture producers in France, Great Britain, or the United States. Although the bulk of the profits remains in Canadian hands, the development of the industry in Canada is of particular interest to American producers mainly because 95 per cent of the films exhibited were produced in the United States.

From 1907 to 1929, approximately 1100 theaters were built throughout the Dominion, but after 1929 the number declined steadily. The motion picture industry today represents an investment in theaters alone of approximately $60,000,000.

Actual production of motion pictures is limited for the most part to government, scenic and nature films, industrials, and newsreels. The proximity of the United States, the domination of the Canadian industry by American interests and the lack of a local market due to this foreign competition, hindered the development of other films, although there have been sporadic and unsuccessful attempts by locally financed organizations to make features.

Foreign sound pictures are charged $6 for each reel of film censored. The fee for similar British reels is $3. Silent films, whether British or foreign, are examined at a rate of $3 per reel. Each sound "trailer" that offers pre-exhibition advertisement, costs $3 to censor, while the silent "trailers" are subject to a 50 cent fee.

South America.—In Bogota, Colombia, more than twelve different taxes are collected on motion pictures, adding considerably to the burden of the exhibitors in meeting their problems.

VII. PUBLICATIONS AND NEW BOOKS

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7. *Talking Pictures and Acoustics*, by C. M. R. Balbi, London.

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9. *Disk Sound Film* (*Der Nadeltonfilm*), by C. Borchart, W. Knappe, Halle.

10. *Seeing—A Partnership of Lighting and Vision*, by M. Luckiesh and Frank K. Moss, Williams & Wilkins Co., Baltimore.

11. *Television*, by Edgar H. Felix, McGraw-Hill Book Co., New York.

12. *Artificial Sunlight*, by M. Luckiesh, D. Van Nostrand & Co., New York.

13. *Patent Law*, by Fred H. Rhodes, McGraw-Hill Book Co., New York.

14. *Ciné Photography for Amateurs*, by J. H. Reyner, Chapman & Hall, London.

15. *Cinematic Design*, by L. Hacker, American Photographic Publishing Co., Boston.

16. *Ciné Titling and Editing*, by H. C. McKay, Falk Publishing Co., New York.

17. *Yearbook of the Ciné Amateur* (*Jahrbuch des Kino-Amateur—1931/32*), edited by F. S. Frerk, Photokino Verlags, Berlin.

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REPORT OF THE SOUND COMMITTEE*

The Sound Committee purposes to encourage any advancement that will bring about improvements in the recording and reproducing of sound. To facilitate an orderly procedure and also to present to the Society a comprehensive picture of the problems involved, an outline has been prepared which shows the major elements on which faithful reproduction of sound depends. Opposite each item in the outline are given references to pertinent discussions in technical literature. While this bibliography is not complete, the Committee feels that it is sufficiently inclusive to permit ready reference to fairly wide and varied sources of useful information. It appears as an appendix to this report.

The Sound Committee has confined its specific considerations to four timely and important subjects appearing in the outline and presents to the Society the results of its studies.

I. AUDITORIUM ACOUSTICS

The ultimate aim in reproducing a sound picture is to achieve naturalness. The characteristics of the theater in which the sound is reproduced affect materially the degree of naturalness that will be obtained. Because of the growing recognition of the importance of acoustics in sound reproduction, a rather complete consideration of this problem follows. In discussing the factors involved, there is presented the opportunity of pointing out some deficiencies of the present theory or available data that indicate the need of further study.

Reverberation.—One particularly important phenomenon, which is a function of the theater's characteristics, is the possible distortion due to the presence of reflected energy from the surfaces of the auditorium. In considering reflected energy, there must be known both the intensity of the reflected energy relative to the direct energy at a given point, and the time lag or phase relation between the reflected energy and the direct. The cumulative effect of these two factors may, as a general premise, be evaluated as reverberation time.

* Presented at the Spring, 1932, Meeting at Washington, D. C.

Reverberation time is specifically defined as the time required for the steady-state energy density in an enclosure to decay to one one-millionth of its value when the source is cut off. This definition does not state, however, what the initial value shall be, and apparently assumes that the decay will always occur linearly. By the earlier methods of measuring reverberation time, using the ear, the shape of the decay curve could not be determined. Since instrumental means of plotting the decay curve have become available, it has been found that this curve is frequently not linear and, further, that the excellence of the acoustical conditions may not be expressed solely by the reverberation time. There is an obvious need of further study to assist us to recognize fully the import of the shape of the decay curve, so that we may more exactly determine the acoustical conditions that are now expressed only partially by the reverberation time.

The familiar reverberation time formula of the late Prof. W. E. Sabine has been found to be inadequate under certain conditions. Extensions of the original formula have recently been developed, tending to overcome this inadequacy. While the use of the reverberation formulas is probably well understood by many engineers, their correct application is frequently not made.

For computational purposes a number of authorities have established optimum reverberation times, most of which have been determined empirically and which assume certain types and sizes of auditoriums or certain classes of performance. In some cases the optimum value must be selected as a compromise, because several types of performance, each having its own optimum, may be given in one auditorium. The most commonly used optimum reverberation times have been discussed by Wolf[1] in a previous paper. Absorption in excess of that which gives optimum reverberation time is not necessarily prejudicial to speech reproduction, and might be desirable in special cases where excessive ambient noise can not be otherwise controlled. Extreme damping is, without question, undesirable from the musical standpoint.

A reverberation time known as the "maximum acceptable time" has also been empirically determined. This is considered to represent the outer limit of acceptable quality consistent with the present state of the art, and takes recognition of the fact that a reasonable variation from the optimum curve is tolerable.

Such acoustical phenomena as echoes, dead spots, and sound concentration, which result in an uneven distribution of acoustical energy, can be avoided by the engineer either by employing proper methods of design or by treating the reflecting surfaces.

The theory of reverberation has been undergoing modification, although it must be admitted that it still involves approximations and is incapable of explaining completely all the known experimental facts. For example, in 1931 V. O. Knudsen showed that the absorption of air has a marked effect on the decay of sound at frequencies greater than 2000 cycles. Prior to this, C. F. Eyring had reported a modification of the original Sabine formula, which should be more generally true and should be susceptible of a special application to "dead" rooms, such as stages for recording sound motion pictures. At the last meeting of this Society, S. K. Wolf reported that the computed reverberation times for large auditoriums are far in excess of those actually measured. No completely satisfactory explanation of the reason for this is evident from existing theories. The computation of reverberation times in theaters is complicated by the presence of balcony spaces and large back-stage volumes, the effect of which was discussed by Eyring in 1931.

While it is evident that certain discrepancies exist and that compromises must be accepted, it is fortunately true that sufficiently concrete data are at hand to permit handling the acoustical problems in a reasonably satisfactory manner. It is important to emphasize, however, that a complete and expert knowledge of the subject is essential, lest immature and erroneous judgment, together with an indiscriminate use of scraps of data, produce most unacceptable results.

Absorption.—To study acoustical problems effectively, it is necessary that statistics on the absorption qualities of materials be available. At the present time there are several laboratories that make absorption measurements, and many manufacturers who offer a wide variety of absorbing materials from which may be chosen those that best suit the individual theater. Unfortunately discrepancies exist among the tests on the same material performed in different laboratories. The existence of these discrepancies is common knowledge among acoustical engineers who through their familiarity with the subject are in a position to form some judgment of the reliability of published figures. So long as discrepancies exist, however, the subject is not on a thoroughly sound basis.

Absorption *versus* frequency curves of a single type of material commonly show differences when tested by several laboratories, as great as 15 per cent or more. As the differences are not uniform for the various frequencies, the case does not appear to be one of constant error or of a single neglected factor. A given piece of material, mounted in various ways, evidences a variation in absorption characteristics, particularly at the lower frequencies. Some slight variations may be caused by the non-uniformity of the physical characteristics of materials manufactured in large quantities. One reason for the observed discrepancies is undoubtedly that different testing methods are used. Some laboratories use organ pipes as sources of sound, a stop-watch as a timing device, and the ear as a detector. Others employ oscillographs, and others the chronograph reverberation meter with warble frequency tones as sound sources.

The Acoustical Society of America, realizing the importance of establishing a uniform practice, has appointed a committee to investigate the causes of these differences and to make recommendations for standardization. It is expected that several laboratories will successively measure a given sample of a selected material so as to eliminate one variable element. Specific note will be made of the method of mounting the material for the test. Whether or not the methods used materially affect the results can be determined directly by making repeated tests on the same material in any given laboratory, varying only the method.

Ambient Noises.—Naturalness of reproduction is materially affected when full advantage can not be taken of the musical and dramatic effects that are conveyed by changes of loudness or intensity level. While some difference in loudness between the front and rear seats of a theater is naturally expected, it is normally possible, by properly using the amplifying and loud speaker facilities, to distribute the sound adequately to all sections of the house. But even with good distribution, ambient noises are often sufficiently great to annoy patrons seated in parts remote from the screen. Incident upon the reduction of the background noise in the sound record, stricter requirements are imposed upon the allowable disturbances emanating from ventilating systems, projection rooms, and from the lobbies and streets.

While the noise of the audience is an important factor, over which there can be little control, it is possible to treat other sources of annoyance that too often are present. It is desirable, but not always possible, that theaters be located in comparatively quiet localities, but in any event, steps should be taken to isolate the interior from whatever external disturbances may exist. Such methods of isolation that are provided for in the technics of building construction will not be elaborated on here, but will merely be mentioned as important factors to be considered when constructing new houses. In existing theaters, when the noises can not be prevented or excluded completely, they can be minimized by increasing the absorption within the theater itself.

Noise originating within the building may be transmitted through the air directly or through the walls housing the apparatus. Steel and concrete sometimes conduct vibrations that may be transformed into sound at points remote from the apparatus causing them. Both air-borne and solid-transmitted sounds can be reduced by adopting precautionary measures. Obviously, the first essential of the operation of machinery used in the theater is silence. If carefully designed and properly operated and maintained, such devices should normally give little trouble. When disturbing vibrations are present, however, their effect will be greatly reduced if the machinery be mounted on elastic supports having the proper resilience. The elastic material must be carefully chosen lest conditions be aggravated. As a rule, the natural period of the mounting when loaded by the machine should be less than one-fifth the vibration frequencies to be eliminated. Where noises are air-borne, they may be absorbed by acoustical materials and their transmission sufficiently hindered by enclosing the machines in sound-proof structures.

The most common producer of disturbing noises in the theater is the projector, especially when its vibrations may be transmitted through an improperly designed projection room floor or directly through walls that are not sound-proof. Treatment of the room itself is usually desirable in any case, not only to reduce transmission of the sounds to the audience, but to contribute to the comfort of the projectionists.

Where noise is transmitted through air-conditioning ducts, the ducts may be lined with sound absorbing material. Where these ducts are rigidly attached to blowers, canvas joints may be inserted to take the place of solid joints, so as to reduce the transmission of the vibration.

It will be seen that disturbing noises originating in the theater may in most cases be readily and inexpensively eliminated once the source is discovered. Noises external to the theater are much more difficult to reduce, once the building has been constructed. It may be noted, however, that in many cases that would be simple to correct, little effort has been made to relieve the condition.

Effect of Increased Frequency Range on Acoustics.—As the frequency range of recording and reproduction becomes greater, the query arises whether our present ideas of acoustical standards will change. It is believed that since an increase of the frequency range introduces no novel acoustical elements, such a change will involve merely a more extensive analysis of the same factors demanding consideration heretofore. Owing to the increased directivity of many loud speakers at high frequencies, the problem of sound distribution in the theater may assume certain new aspects.

Since most sound absorbing materials are comparatively ineffective in the low frequency range, it might be feared that some difficulty from reverberation might ensue if there is any marked extension of the lower frequency spectrum. Data indicate, however, that more reverberation is tolerable at low frequencies; that is, the optimum reverberation time is greater. It is likely, therefore, that theaters heretofore satisfactory in this respect for speech and music will remain so.

The phenomenon of resonance may be somewhat more bothersome with extended low frequency range, simply because the natural vibration period of some elastic element or body of air may be reached, which period previously was outside the range of the transmitted frequencies. Correction of resonance is usually simple, however, either by clamping the vibrating body so that it is incapable of motion or by treating it with absorbing material. The requirements against noise, an objectionable feature at all times, will certainly be no less strict than at present.

Many of the general observations made regarding theater acoustics apply equally well to recording. A studio that has been properly constructed should present a suitable space in which to make recordings of extended frequency range. Problems of set construction and microphone placement, which even now confront the studios for solution, will be of greater significance than in the past.

II. RELATION OF STUDIO ACOUSTICS TO THEATER ACOUSTICS

There has been too great a tendency to consider recording and reproducing as separate problems. Even among the recording studios themselves, there can not be said to exist any consistent practice as regards acoustical conditions. These conditions range from the extreme deadness of cloth-walled sets to the hardness of painted plywood flats. Many of the studios entertain the opinion that their own particular methods of constructing sets provide acoustical conditions appropriate for the most favorable reproduction in the theater. Since the recording conditions vary so widely, the conclusion is inevitable that some of the studios are wrong.

While there have been published a number of papers that state the desirability of establishing certain acoustical conditions surrounding the microphone in recording, these are by no means universally accepted as correct or desirable. This is due to a difference of opinion as to what constitutes desirable theater quality and to the unfortunate results experienced when the methods have been incompletely applied under the limiting conditions obtaining in the studio.

The relation of studio acoustics to theater acoustics and their psychological effects can not be simply expressed, and much divergent opinion is encountered. The Committee feels that as a first important step toward agreement on the relation between studio and theater acoustics, the review rooms and preview theaters should be adjusted to have the acoustical characteristics now considered optimum for auditoriums of their size. Reproducing equipment in the review rooms should also be as free from distortion as possible, so as not to impart to the reproduced sound its own idiosyncrasies. With present methods, previews are heard under such varying conditions that a concerted opinion is difficult.

There is a definite tendency toward the elimination of so-called "dead" recording in the case of music, but by no means is this universal in the case of speech. There appears to be only one point on which agreement is unanimous, and that is that excessive low frequency reverberation relative to the high frequencies, while most easily obtained, is also most objectionable in both recording and reproducing.

III. COMPENSATION FOR LOSSES

Recognizing the importance of extended frequency range, it is believed that a standardized method of compensating for such losses as those arising from film processing and recording and reproducing slits should be determined, and the proper points of the circuit at which such compensation should be made should be decided upon. The Committee recommends that all losses incurred up to the release print, such as recording slit loss and film and printing losses, should be compensated for in the recording operation. The frequency characteristics of the reproducing apparatus should be made flat except for a correction for whatever slit is used.

It is an incidental but important observation of the Committee that the azimuth of recorders should be continually checked in order to assure good response at frequencies greater than 5000 cycles. One preferred method has been suggested whereby the slit azimuth may be checked by adjusting for maximum output, running a frequency film through the recorder in both directions and noting the difference between the two settings required for the maximum output.

IV. DESIRABLE VOLUME RANGE

It is believed that greater volume range follows closely in importance the extension of the frequency range, upon which considerable stress has already been placed. In giving thought to this important subject, the Committee was confronted with the inadequacy of the commonly used term, *volume range*. Volume range may be used to refer to the difference in level, usually measured in decibels, between the maximum sound and the minimum sound actually recorded on a given sound record or reproduced therefrom, regardless of whether this range is the maximum that might have been employed without objectionable ground noise ratio. A second conception refers to the range that can be effectively used between the overload point and the noise level. The term *volume range* has also been applied as an engineering term to mean the difference in level between the overload point and the noise level. The first definition is measurable for a given recording provided that the period over which the loudest and weakest sounds are to be averaged is specified; while the second definition is readily determined, since it depends on judgment as to how far the recording should be kept from the upper and lower limits. The Sound Committee has requested the Standards Committee to define specifically and to suggest distinguishing terms for these three conceptions of volume range. In the discussion in this report we have attempted to avoid ambiguity, using the expression "overload to ground noise ratio," whenever this quantity is meant.

Measurements by Messrs. Sivian, Dunn, and White indicate a range of 68 decibels between the loudest and softest music that might be produced by a large orchestra. Messrs. Wolf and Sette recommend an average intensity for the loudest sustained speech sounds, of about 70 decibels above threshold, with an additional allowance of about 5 decibels for the peaks. A further allowance of at least 5, and preferably 10 decibels, should be made for special sound effects, bringing the maximum to 80 to 85 decibels above threshold. About the same value is recommended for loud music. The same authors also give 20 to 40 decibels above threshold as the ordinary range of audience and other auditorium noises. This gives 40 to 65 decibels as the ratio of the loudest useful sound to the auditorium noise. Since the recommendations for maximum sound are based on providing naturalness of speech and satisfactory music, the complete desired volume range could be attained only under the best conditions of quiet in the auditorium. It should be borne in mind that because of the ability of the listeners to concentrate their attention on sounds coming from a certain direction, general auditorium noise does not interfere as seriously as ground noise of equal intensity emanating from the loud speakers. Therefore, the ratio of maximum sound to auditorium noise is practically usable as the actual volume range.

Reproducing equipment should have ample capacity to produce the desired intensity levels in the auditorium without overloading, and reproducing amplifiers should have sufficient gain to attain these levels from a fully modulated record.

Background noise due to reproducing equipment should be so low that more than full advantage can be taken of all the range that the record itself will permit, allowance being made for substantial future improvements in the overload to ground noise ratio in records.

Disk and film records that have been in use during the past few years have an overload to ground noise ratio of the order of 30 to 35 decibels. Recent improvements in both film and disk recording have extended this by 5 to 10 decibels, but the available range is still far short of what is needed, both for full expression in music and for the range required for satisfactory dramatic effects and sound perspective, as well as for making allowance for special loud sounds.

In considering the use of an extended overload to ground noise ratio, it should be observed that safety margins at either extremity must be provided so as to afford a net effective volume range. At the upper limit it should never be necessary, except for possible momentary peaks, to reach the overload point lest quality suffer. The faintest recorded sounds should also be at a level sufficiently above the ground noise so that the latter will not be obtrusive. A margin of from 10 to 20 decibels between the average power of the faintest words or music and the ground noise that emanates from the loud speakers is necessary, in order to be sure that the audience will be oblivious to the background disturbance.

H. B. SANTEE, *Chairman*

M. C. BATSEL	E. W. KELLOGG	H. C. SILENT
P. H. EVANS	C. L. LOOTENS	R. V. TERRY
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DISCUSSION

DR. GOLDSMITH: It is my impression that yesterday, during a discussion of one of the papers, a statement was made with reference to 16 millimeter recording and reproducing equipment which, it was stated, was to be substantiated in the forthcoming report of the Sound Committee. The statement, as I understood it, was to the effect that it was satisfactory to make sound track negatives and positives by methods that resulted in the reduction of the high frequency level, and afterward to correct for this loss by corresponding compensation in the reproducing equipment. It appeared astonishing that the Sound Committee, according to the statement, would recommend a procedure that placed the burden of correction for high frequency losses on reproducing equipment. This is uneconomical, since it requires that the greatest possible number of pieces of apparatus shall carry the compensating means, and that each of these pieces of apparatus (sound projectors) shall have the necessary excess audio-frequency output capacity in certain of the amplification stages which is required for this method.

I have noted with approval that the Sound Committee has made no such recommendation, and it appears evident that there has been a misconception relative to the views of that Committee in the discussion in question. A preferable and recommended point of view, in my opinion, is that each step in recording or reproducing sound, from the original studio rendition to the final theater or home reproduction, shall be carried out with, as nearly as possible, a flat audio-frequency response characteristic, from the lowest to the highest desired frequency. Any inevitable deviations from this ideal should assuredly be compensated for prior to the final reproducing apparatus, which should be, as nearly as possible, flat. Any other adopted solution of the problem of accurate sound reproduction will impose undue burdens on the industry and lead to confusion. If compensation were to be made in the reproducing apparatus, it would presumably be of a different degree for the product of each recording studio, and no general agreement would seem feasible as to the extent of such compensation. Experience in older fields substantiates the idea that each stage of acoustical recording or transmission up to the ultimate auditor should have a flat audio-frequency characteristic, if possible; and that compensation (if unavoidable) should certainly be executed other than at the ultimate point, which, in our field, is the sound projector.

Has the Sound Committee any data as to the extent to which reverberation times, for a given frequency in the recording studio and in the theater, are additive? That is, if the reverberation time for a frequency of 1000 cycles were one second in the studio and one second in the theater as well, would the effect on the theater audience (at the measurement point) be that of a two-second reverberation time for a 1000 cycle note? A quantitative knowledge of this relation would be of help in determining proper methods of recording and reproduction.

MR. SANTEE: There must be, of course, some relation, but I hardly think that the effects are directly additive. The Sound Committee might study this subject and incorporate its findings in future reports.

MR. RICHARDSON: I am not convinced that there is any necessity of punching a screen full of holes, or of placing the horn behind the screen. The average audience would not be able to notice anything wrong if the horns were moved to the side of the screen instead of being placed at the center. Besides, the screen is difficult to clean when perforated.

DR. GOLDSMITH: Experiments in moderately sized rooms in the home with 16 millimeter sound projectors indicate that the exact position of the loud speaker is a matter of comparative indifference. Assume a room approximately 15 by 20 feet, with the audience seated from 8 to 12 feet from the screen, the screen being 30 by 40 inches in size. The loud speaker is placed on the floor. Under such circumstances, the loud speaker can be directly under the screen, to either side thereof, or as much as 4 or 5 feet forward of the screen toward any individual in the audience without any protest or any apparent impression on the part of the members of the audience that the sound is not emanating from the characters on the screen. The small dimensions of the room, the short times of acoustical transmission involved, and the general acoustical characteristics of the room no doubt contribute to this convenient result. Something of the same effect is found in large theaters for that portion of the audience who are not close to the screen. The exact location of the loud speaker seems to make less difference in this case.

MR. DOWNES: The holes in the screen are responsible for the loss of a great deal of light, and we have demands for more and more light. We are reaching the point where it is difficult to obtain more light from the source, and if these holes could be removed, some of this difficulty would be avoided.

MR. KELLOGG: I assisted in experiments at the General Electric Laboratories in some of the first efforts to make sound films. Perforated screens were not available. The loud speakers were either both on one side of the screen, or one on each side. This arrangement was very satisfactory for music, and at that time the reproduction of music was regarded as the chief requirement. When, at a later date, speech had become the chief requisite, some difficulties arose, especially when the effects of poor recordings and reverberant theaters were compounded. In the course of a series of tests for the purpose of improving the situation, we found that there was a definite improvement in the clarity of speech, when the sound came from a single source, instead of from two or more sources. With a single source, it becomes more important to locate it behind or over the screen. Although an audience may not in general be extremely critical of the location of the source, there are unquestionably times when the illusion will be marred if the sound comes from 10 to 15 degrees to one side.

MR. EDWARDS: In the case of combination houses, the screen is raised and the horns are moved to provide stage room for vaudeville. As the vaudeville ends, the curtain and screen must be lowered, and the horn towers moved back to their original position.

These operations have to be performed in semi-darkness in about 30 seconds, and it should be perfectly obvious that errors in placement can, and do, occur.

In ordinary picture houses, where the horns are supposedly permanently located, in numbers of cases the angles of the horns have been altered unintentionally by cleaners and others working back stage. These conditions are responsible for nine-tenths of the unsatisfactory sound distribution in theaters today. If it were possible to build the horns into the proscenium arch, it would obviate these difficulties without destroying the illusion and at the same time permit a much more satisfactory picture on the screen.

MR. DAVEE: The ability to locate sound is binaural. Most people are unable to hear equally well with either ear, and the ability of an audience to locate a sound is probably not accurate. It would be interesting to examine the ability of an average audience to locate sound sources and to apply the results of the study in locating the horns.

MR. SANTEE: Perhaps that is why the location was determined as it is. While some persons could not tell whether the horns were behind the screen or not, others were able to do so. It was agreed that it was easier to listen to the sound when it emanated as closely as possible from the image of the characters on the screen. Otherwise, there would probably be an unconscious but continued mental effort exerted by the listener to make himself believe that the sound was emanating from the speaker's lips. The conclusion was reached that the logical place for the loud speakers was as nearly as possible behind the image of the head of the speaker.

MR. GREENE: If no complaints are made, it does not necessarily follow that everything is all right. I have never forgotten the remark of Mr. E. T. Clarke before this Society years ago: "Indignation and lack of interest take the same form; people stay away."

As for the perforated screen—it may be clean, it may be white, yet if it is compared, from any normal viewing distance, with an unperforated piece of the same material, the latter will appear cleaner and whiter than the perforated sample. The perforated screen produces a sort of "half-tone" effect to even a sharply defined picture, and when this effect is compounded with a soft-focus effect that may look very artistic on a solid screen, the result is something that must be decidedly conducive to eye-strain.

As regards horn placement: some time ago, when the matter of attachment sound systems was being discussed in committee, one of the engineers exclaimed, "The trouble is that we are attempting to fit a precision instrument to a machine that is not a precision device." He spoke very truly. The trouble is that a precision industry is trying to fit itself to an industry—the exhibition of motion pictures—that is not a precision industry, and that apparently strongly resents any and all attempts to make it so. Almost any service engineer will admit that practically all the coöperation he receives from the exhibition phase of the industry comes from the projectionists. The majority of exhibitors are either apathetic or antagonistic. Many want service abolished altogether, want to sever all connection with the precision industry. Therefore, any recommendations that the Society may make as regards the placement of horns or speakers will receive but scant coöperation from the exhibition phase of the industry unless it effects a considerable saving. Quality will not be considered.

REPORT OF THE PROJECTION PRACTICE COMMITTEE*

The report of the Projection Practice Committee for the Spring, 1932, Convention is devoted to:

(1) A description of a method of testing the output level of several projectors during the performance for the purpose of maintaining them in an equalized condition.

(2) A description of a method of checking the continuity of the speech circuits of individual loud speaker units during the performance. Such an arrangement can also be used for equalizing the sound volume before each performance.

(3) A study of theater problems of the release print dealing with processing of film, buckling of film, density of positive prints, cutting film for change-overs, uniformity of volume level, and use of the present standard release print. A paper dealing with these matters, presented during the session on the release print, at the Washington, D. C., Convention, on May 12, 1931, will appear in a succeeding issue of the JOURNAL.

(4) The Committee's comments on the problems of projection and on the importance of maintaining competent supervision of projection, as regards the maintenance of high quality of performance and as effecting the economies of operation.

(1) As regards the first topic, no method has heretofore been available that would permit testing the output level of an idle projector while the performance was being conducted on a second projector. Whenever a difference of output level between projectors developed, it was necessary to wait until the end of the day's run in order to check and correct trouble of this nature. Meanwhile, the projectionist was obliged to compensate for inequality of sound level between projectors each time a change-over was made. As a result of this procedure, faulty control of sound volume occurred in a great many cases.

The Committee realizes that there should be provided some means of correcting this inequality of volume output immediately after being discovered, one that would permit a check to be made at any

* Presented at the Spring, 1932, Meeting at Washington, D. C.

time when the existence of this trouble was suspected. A brief description of a device designed for this purpose follows:

The general wiring of the output level indicator circuit is illustrated in Fig. 1, which shows a jack *A* bridged across the output of

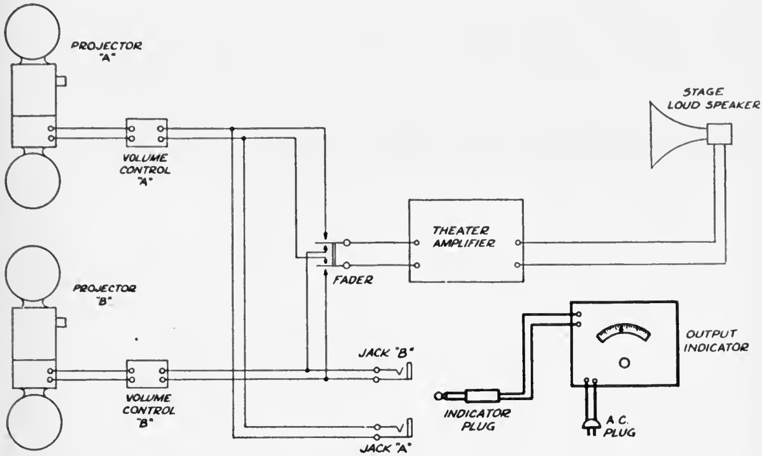

FIG. 1. Output indicator for equalizing the outputs of two or more projectors.

one projector *A*, while a jack *B* is bridged across projector *B*. This arrangement can be extended to include three or more projectors. Attached to the output indicator is a plug to be inserted into the several jacks, and also a plug to be connected to 110 volt a-c. circuit.

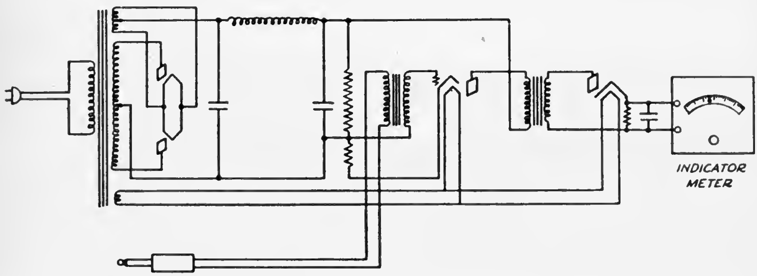

FIG. 2. Output indicator for use on a-c. power supplies.

Fig. 2 gives the details of wiring of a vacuum tube voltmeter and an associated amplifier. At the left is shown the power transformer and rectifier tube and filter.

For use with the output indicator, the Committee recommends that several lengths of test film carrying 1000 cycle, 90 per cent modulated, sound track be furnished to each projection room as a part of the regular equipment, to be kept on hand at all times. These lengths can conveniently be attached to the beginnings or the ends of the reels, or can be run separately on the idle projector, thus affording a check on the output whenever desired during the performance.

(2) As regards the second topic mentioned above, a method is desired of determining the continuity of the speech circuit of each

FIG. 3. Testing panel for detecting inoperative speech coil circuits in theater reproducing systems.

individual loud speaker unit during the performance. The speech coil in certain types of loud speakers is a delicate piece of equipment, and is subject to occasional breakdown, noticeably affecting the distribution of sound in the theater.

A device, such as shown in Fig. 3, may be used to provide the projectionist with a ready means of determining which of several loud speakers is inoperative owing to a defective speech coil. Each speech circuit is provided with a jack placed in one side of the line between the output of the horn panel and the loud speakers back-stage. This permits plugging an a-c. milliammeter in series with each speaker. Zero deflection indicates an open circuit.

This equipment can also be used to check the equalization of projectors by plugging the a-c. milliammeter into one of the speech coil circuits, and running the 1000 cycle test film in each projector while noting the deflection of the meter.

There are several factors that adversely affect the quality of the picture and the reproduced sound. At the present time the projectionist has a poorer view of the screen than any one else in the theater. He should be provided with facilities that would enable him to see the picture as clearly as the patrons in favorable locations, so that he could discover and remedy visual defects and not be dependent upon observations made by others. The projectionist should be able to hear the reproduced sound as well as any one in the audience. Assistance in the solution of the problem of improving the projectionist's perception of reproduced sound in the theater is requested, and any practical suggestions along this line will be carefully studied by the Committee.

These problems naturally present technical and commercial difficulties, but are sufficiently important to merit intensive study for the purpose of improving the present conditions, which impose a severe handicap upon projectionists in the presentation of sound pictures. In the interim, before high-quality sound can be provided in the projection room, volume indicating instruments should be furnished as a partial substitute.

The Committee has received the coöperation of one manufacturer who is attempting to improve the visibility of the screen from the projection room. As a temporary measure, the Committee advocates the use of high-powered glass that will bring the screen apparently within twenty feet of the projection room.

The Committee wishes at this time to stress particularly the need of competent supervision of projection. Although this need has existed since the time when the first pictures were shown, its importance has always been underestimated. Competent supervision is even more vital to the industry under present conditions. There has never been a time when the "sales resistance" of our public has been as great as at the present, or a time when its critical faculties were so highly developed. It is doubly important, under such circumstances, that entertainment be presented upon the screens of the theaters under the most favorable conditions and in a flawless manner, as the projected picture and sound are the closest contacts the public has to the industry. This is best accomplished through supervision by qualified men who have become familiar with the many projection problems through years of experience.

Supervision includes (1) the instruction of projectionists in the proper presentation of the picture; (2) the proper method of handling the film so as to reduce damage and degree of wear of prints and thus to extend their useful life; (3) the institution of working routines to provide for smoothest performance; (4) the provision of instructions relating to the uses of equipment so as to obtain various projection effects for the purpose of enhancing the entertainment value of the performance; (5) the periodic inspection of projection equipment, including the checking of adjustments, so as to prevent film damage; (6) the correcting of all possible causes of trouble before breakdown occurs with its consequent possible interruption of the show; (7) the training of projectionists so as to acquaint them with methods of handling emergency situations, instructions for quickly locating causes of trouble, and the methods of making repairs.

The supervisor is in close contact with practical projection problems in the theaters; he is able to discover remedies for the correction of the difficulties encountered, and to initiate or aid in the development of new appliances for this purpose, or to accomplish improved or more economical operation. He is also able to pass upon the necessity of making repairs, and is often able to point out a more economical method of making them. He is familiar with the methods of testing under practical operating conditions the many appliances offered to the theaters. He is frequently able to suggest methods of improving such devices, making them more valuable to the theater.

As an example of the need of supervision, a recent court decision ordered an exhibitor to pay damages of more than two hundred dollars to a film exchange for injuring a print while in the possession of the theater. The amount awarded was based upon the footage that was scratched, at the rate of $3^3/_4$ cents per foot. It is quite probable that such a decision might lead to similar actions against exhibitors in the future. Even when exhibitors are *not* ordered to make direct payment to exchanges, the industry is obliged to absorb the cost of all film damaged through mishandling, most of which could be prevented.

The Committee directs attention to the fact that many large companies have in the past few years enormously improved the projection and sound reproduction in their theaters by providing competent supervision. Supervision of projection constitutes the only means of assuring economical and high-quality results.

Lack of proper supervision in projection has already accounted for a substantial loss of the industry's money, and this waste will continue until the importance of competent supervision is realized.

H. RUBIN, *Chairman*

J. O. BAKER	C. GREENE	P. A. MCGUIRE
T. BARROWS	H. GRIFFIN	R. MIEHLING
W. H. BELTZ	J. HOPKINS	F. H. RICHARDSON
G. C. EDWARDS	W. C. KUNZMANN	M. RUBEN
S. GLAUBER	R. H. MCCULLOUGH	P. T. SHERIDAN
J. H. GOLDBERG		L. M. TOWNSEND

DISCUSSION

MR. EDWARDS: One of the great difficulties that the Projection Practice Committee has encountered is the lack of adequate coöperation between all the firms interested in the problem. By obtaining the point of view of all the manufacturers we can be assured of presenting a well-rounded report. The cost that the industry has to bear because of the mutilation of film is enormous, and we need perfect coöperation in order to reduce it.

MR. MCGUIRE: I should like to state that the study of the causes of film mutilation and their remedies has not been dropped by the Projection Practice Committee. It was impossible to collect all the requisite data in six months and report adequately on the subject. However, I sincerely trust that the industry can be made to understand the importance of this particular phase of the activities of the Committee.

MR. CRABTREE: I noticed that the Committee regards the waxing of film as undesirable. With the early method of waxing, when the wax in the waxing machine became too cold, it accumulated on the blades and was applied too thickly to the film. It then caused trouble at the projector gate. But I should like to recommend a change that has been made—to use a solution of the wax, the concentration of which controls the amount of wax applied, so that it is impossible to apply too much wax unless the solution is too concentrated. I made a survey of the different laboratories in New York, and found that 95 per cent of them are using a solution of wax for edge waxing. To what extent is wax accumulating in the gates of projectors today? Does the accumulation consist of wax, dirt, gelatin, or a mixture of these? What is wrong with the present method?

MR. RICHARDSON: The chairman of the Committee is a supervisor of projection, and every one on the Committee engaged in practical projection made the statement that no method of waxing has yet been used that would not allow some deposit in the sound gate. Yesterday we were told that waxing of film to be used in the Navy's projectors is taboo. It was said that there is no waxing process that is not objectionable.

MR. EDWARDS: I agree with Mr. Richardson. Our experience in a first-run film house has shown that it is necessary to take out the sound gate and clean out the accumulation of wax after every running. If this is not done we soon find that we have a "frozen" film in the gate.

MR. CRABTREE: Yet 95 per cent of the laboratories are using this process of waxing. I feel that if trouble is being experienced, the laboratories are using a stronger solution of the wax than is recommended.

MR. EDWARDS: It is quite possible that the fault lies not so much in the process as in the application of the process. In laboratories and in projection rooms we have to depend upon such labor as we can get, and probably as much care is not taken in applying the wax as was intended by the inventors of the system. We have to dig out the wax from the grooves in the rollers up to the tenth run. If neglected for one reel, we often find that the heat of the plate will melt the wax and the film will adhere to the gate.

REPORT OF THE PROJECTION SCREENS COMMITTEE*

New Types of Screens.—Since the last report of the Committee, there have appeared several new developments in screens that deserve notice. Those that have come to our attention are the following:

Screens of embossed material coated with ordinary white pigments have been introduced by several manufacturers. The indentations are about $^1/_8$ inch square with a spherical contour, either convex or concave, and of about $^1/_{16}$ inch relief. The purpose of this treatment is to obtain more uniform light distribution than is usually possible with an ordinary, flat, diffusing surface. Even diffusing screens with smooth surfaces frequently exhibit some loss of brightness at angles of 50 degrees or more from the screen normal, and also in some cases have a slight glossiness at the specular angle which is undesirable because of the tendency to glare. The embossed screen tends partially to overcome these two deficiencies according to tests submitted by one manufacturer. However, it should be pointed out that a good flat screen is relatively free from such defects also

Another interesting development is the metal mesh screen. From the rear, the screen resembles ordinary metal mesh material; on the front, one sees small squares approximately $^1/_8$ inch wide, consisting of white diffusely reflecting material. At each corner of the squares, there is a minute open space for sound transmission. One outstanding advantage of the screen is that there are no seams. The optical properties are similar to those of the fabric base screens.

A very recent type of screen attempts to combine the properties of diffusing and specular type screens. This is done by means of a combination surface (on a fabric base) which has small diffusing and metallic areas, side by side, the areas being small enough to be indistinguishable at a distance from the screen. The Committee has no data on its reflection or other characteristics and, hence, can not further describe the screen.

Another screen may be made of tiny glass beads held together by a

* Presented at the Spring, 1932, Meeting at Washington, D. C.

suitable binding agent. The combination has sufficient tensile strength, and is porous enough for sound transmission. The screen is not at a practical stage of development as yet, but is merely mentioned as a possibility.

Standardization.—In previous reports, the Committee made recommendations on acoustic ratings, light reflection measurements, and sizes for installation.[1] Relevant material on these subjects has been referred to the Committee on Standards and Nomenclature for action.

Maintenance.—In the following table are shown measurements made by one of the members of the Committee in his laboratory on the light reflection of screen samples procured from field installations. These supplement data previously published, and are given to emphasize further the importance of surface maintenance and the harmful effect of dust and dirt on projection.[2]

TABLE I

Total Reflection Factor

	Per cent
(1) Diffusing Screen	
New	85
Used 2 years	60
Used 8 months; washed	69
Refinished by exhibitor	65
Refinished by manufacturer	82
Sprayed; cellulose coated	76
(2) Beaded Type Screen	
New	70
Used $3^1/_2$ months	50
Used 4 months	61
Used $4^3/_4$ months	38
Used $9^1/_2$ months	59
Used $15^1/_4$ months	47
Used 16 months	60
Used 18 months	51
Used 19 months	57

It will be noted that the results are in terms of total reflection factor and differ, therefore, from data published previously, which gave the reflection at a single angle. It is believed that the present method is more informative of the effect of aging on screen reflection at all angles of observation. It was possible to make the observations so because they were made in the laboratory with facilities available for the measurement of total reflection. With screens in place in the theater, it was feasible to determine only the reflection at a single angle.

The loss of light caused by the dust is obtained by comparing the values for the used and the new screens. It is evident that the loss is often considerable, and also that there is no consistency. Some screens used only a few months are much poorer than those used for a year or more. The conclusion is obvious that conditions under which screens are used vary the rate of deterioration. It is highly important that dust and dirt be kept from the screens; they should be covered when not in use; air that carries dust should be prevented from circulating through them; and they should be cleaned periodically with vacuum cleaners or by some equally effective method.

The Committee has had the opportunity to study the results of resurfacing as done in the theater. At first, it was hoped that surfaces could be renovated satisfactorily by spraying and painting screens when in place. However, it is the present opinion that the process of resurfacing has not been generally successful. It requires skill and experience, and even with much care still leads to ununiform reflection and cloudy effects that are obtrusively apparent. Whether or not methods will be later devised to eliminate these difficulties is problematical.

Dust and dirt also cause deterioration of the acoustical properties of screens by clogging the perforations and pores which aid sound transmission. The remedy is quite simple. The screen may be either cleaned with a vacuum cleaner possessing strong suction or subjected to a bath of compressed air to drive the dirt from the pores.

Pigments.—Yellowing of screen surfaces is another problem that is of interest to both the manufacturer and the exhibitor. Old screens acquire a yellow tinge, which causes a loss of reflection and imparts a dull tone to projected pictures. There is not a great deal known about the causes of such discoloration and methods of preventing it, although it is the general opinion that the vehicle, and not the pigment employed, is usually the ingredient that yellows. With the scant knowledge available, it is impossible to make specific recommendations.

The following general rules concerning vehicles have been furnished in response to an inquiry to the National Lead Company:

"While in search of the type of pigment or bead for most efficient reflectance, do not overlook the importance of the vehicle with which application and continued adherence of these surfacing mediums is made possible. In considering the selection of a vehicle, the following precautions might well be observed:

(1) Do not employ a vehicle that will cause premature yellowing.

(2) Do not employ a vehicle that will too rapidly impair the tensile strength of the fabric, causing premature rotting of the screen.

(3) Do not employ a vehicle of such high elasticity that it will remain 'tacky,' occasioning excessive retention of dirt.

(4) Do not employ a vehicle that dries to a point of brittleness, as failure to bind the bead or pigment will result.

(5) Do not employ a vehicle of so bodied a type as to bridge over or unduly clog the small apertures in perforated screens."

Light and Reflection Measuring Devices.—A simple device for measuring screen illumination and reflection would be a valuable asset to the projectionist. At present, there exists no such aid to assist judgment as to the amount of light available for the motion picture observer. Judgment is based on past experience of the individual manager or projectionist, and is subject to human limitations. It would be desirable to minimize or at least to supplement the human element by means of instruments as convenient and trustworthy as voltmeters. In this way, the reflecting properties of the screen could be checked monthly and the illumination from a projector checked as frequently as is necessary.

In the past the outstanding instrument for this work has been an illuminometer involving the comparison of a standard light source with the test object. The method requires skill and practice on the part of the observer and, for this reason, does not readily lend itself to theater use, except in the hands of a trained engineer. Its use is complicated by variation of reflectivity with angle of observation and by the factor of color, which, while real and important, is not simply evaluated. On the whole, without discounting its value, necessity even, it does not appear to meet the requirements for simplicity and practicability necessary in a device to be used by laymen.

More recently, there has been introduced a compact photo-cell type of photometer, which eliminates some of these difficulties. At the same time, other difficulties arise that reduce its value in its present state. Before discussing this instrument further, some analysis of the general problem of light reflection measurement is necessary.

To determine the reflection factor of a diffusing type of motion picture projection screen, we compare the ratio of the light reflected to the light incident. This is what the comparison illuminometer can do for any point. The photo-cell photometer is dependent upon the average brightness of the entire screen rather than upon the brightness of a small section, and will give accurately the reflection factor for the screen only if the screen illumination and brightness are uniform throughout. The value obtained for the brightness, *i. e.*, for reflected light, will be in error because of unequal response of the sensitive element to light at different angles of incidence. For a uniformly bright screen, a simple correction factor is applied to obtain the true value; for an ununiformly bright screen no general correction can be applied. In practice, the screen illumination will vary from place to place, the variation extending over a wide range, being frequently 50 per cent and in some cases as much as 100 per cent or more. The incident light may be measured over the entire screen surface in order to offset the effect of ununiformity in determining the incident light. The ratio of reflected to incident light gives a figure related to the total reflection factor of the screen. It will be seen that measurement would be simple if screens were uniformly illuminated, whereas in practice complications are introduced that make strict accuracy difficult, if not impossible.

The photo-cell device may, however, be of practical use in measuring relative values of screen brightness over a period of time. Thus it can be used to regulate screen illumination by providing a measure of its constancy and uniformity. In the hands of an expert, it will also yield information that may be valuable in determining the depreciation of screen surfaces. One of its main assets is that it indicates directly and avoids human uncertainty. More research is being done to eliminate present handicaps and, in the near future, it may be made more generally applicable to theater uses.

A simple, yet reliable, method of determining screen reflectivity in one direction is to read the reflection factor from a reflection gauge at that point where the brightness of some part of the gauge matches the brightness of the section of the screen between perforations, then deducting the loss of light caused by the presence of the holes. This loss is usually in the neighborhood of 6 to 10 per cent. The advantage of such a measurement is that it can be made without the projector in operation, the house light or even a portable lamp being sufficient. The reflection gauge is a small disk having a graduated scale of reflecting portions ranging from approximately 0.05 to 0.85.

None of the above-mentioned methods is readily applicable to determinations of reflection factor of the specularly reflecting screens, such as metallic or beaded surfaces. For these types of screens, reflection factor measurements should be made in accordance with regularly established methods.

Selecting a Screen.—Choice of the type of screen to employ in a theater will depend somewhat on the shape of the theater. For wide houses, in which wide distribution of light is required, the diffusive type is recommended as most uniform. For narrow houses the choice will depend on whether or not a balcony is present. It is seen from the curves shown in a previous report[1] that the beaded screen directs a large portion of its light back into the projector. In this way, the balcony is favored somewhat at the expense of the orchestra. A metallic screen would favor the orchestra. Both these last screens would favor seats on the screen axis, penalizing those at the side. They would also exhibit a lack of uniformity of brightness from top to bottom and side to side, and a projected picture would exhibit "fade out" across the screen. In a theater of small width and height this drawback may be outweighed by the advantage of concentrating the light on the axis, without diffusing it to the side walls.

The main optical considerations in choosing a screen are efficiency of reflection, distribution of light at the angles of observation existing in a theater, uniformity of brightness across the screen as viewed from various points, and invisibility of seams. To be quite satisfactory, a screen must fulfill the requirements imposed upon all these properties and, in addition, must fulfill requirements directed toward ease of maintenance, sound transmission, and mechanical properties. A screen with the highest initial reflection is not necessarily the best from the optical standpoint. Reflecting ability must remain good over a period of time under such conditions as may exist in the field. The pigment and vehicle composing the surface should meet the specifications outlined above. A hard, smooth surfaced screen would be easiest to clean and less apt to collect dust but, on the other hand, may not be so uniform in its distribution of light. No tendency toward glossiness must be present, as it would be likely to cause the seams to be prominent and mar a projected picture by dividing it into vertical sections.

As regards acoustical properties, a screen should be of a type approved by manufacturers of sound equipment, as stated in a previous report[1]. In general, the lighter the material used for the screen, the better it will transmit sound. There are many screens among which there is little to choose as regards sound, many being made from the same or similar basic fabrics. As the weight per square foot is increased, sound transmission is less efficient, especially at the higher frequencies.

From time to time, there has been exaggeration in statement made by individual manufacturers concerning the superiority of their product. Screens have been claimed to remove distortion, create three dimensional effects, and heighten illusion. The Committee would like to go on record, stating that there is little or nothing to these claims. A picture projected on a plane screen when viewed from an angle will appear foreshortened horizontally, and the type of reflecting surface on the screen will not alter the situation; if projected at an angle, the figures will be further elongated. As for stereoscopic effects, it is impossible that a flat surface, reflecting pictures made in the ordinary manner, will reflect anything but two dimensional views, and in any case only what is projected upon it. Judging from recent papers on the subject, three dimensional projection is possible only with special prints and probably special projection or viewing apparatus. A screen has no power to differentiate between background and foreground objects, influence their relative position, or produce binocular vision from monocular photography. Its quality must be judged by the nature of its reflecting surface (of course, also, by mechanical, acoustic, and maintenance considerations, these being extraneous to this particular discussion). As for illusion, a screen, that reflects an image that can be comfortably observed, will probably be said to heighten illusion in the sense that it does not cause distraction.

Rear Projection Screens.—As yet, the Committee has not been able to obtain a release for data on the light transmission properties of rear projection screens. There are relatively few manufacturers in this field, and they are unwilling to release information more detailed than what has already been published.

Screens for 16 Mm. Projection.—The requirements for 16 millimeter screens for home or demonstration use are not as severe as those for screens for theater use. They are usually metallic or beaded, in order that great values of brightness may be obtained over a limited area, immediately in front of the screen. The sizes vary from 22 by 30 inches to 9 by 12 feet. They are made to be rolled into convenient wooden or fabrikoid cases.

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REFERENCES

[1] Report of Projection Screens Committee, *J. Soc. Mot. Pict. Eng.*, **17** (Sept., 1931), p. 437.

[2] Report of Projection Screens Committee, *J. Soc. Mot. Pict. Eng.*, **18** (Feb., 1932), p. 242.

REPORT OF THE NON-THEATRICAL EQUIPMENT COMMITTEE*

The Non-Theatrical Equipment Committee was formed early this year for the purpose of investigating matters relating to 16 millimeter film cameras and projectors, accessories such as screens, film splicers, *etc.*, film slide projectors, glass slide projectors, and 35 millimeter portable and semiportable projectors.

The membership of the Committee is largely composed of representatives of the various manufacturers of 16 millimeter equipment and 35 millimeter film portable and semiportable projector equipment, since the work of the Committee very largely concerns these people.

The function of the Committee is twofold: to study and to make available information relating to non-theatrical equipment, and to recommend to the Committee on Standards and Nomenclature proposals for standardization on matters which this Committee is in a better position to study because of its close contact with the non-theatrical field.

It might properly be assumed that this Committee should undertake the problem of establishing 16 millimeter sound film dimensions. Since many 16 millimeter sound films will be printed from 35 millimeter negatives by reduction, the problems associated with the smaller film can be better handled by a subcommittee of the Standards Committee, as is now being done. The Non-Theatrical Equipment Committee must, however, keep in close touch with the work of the Standards Committee, contributing its opinion whenever necessary. This close coöperation has been well carried out, as several members of the Non-Theatrical Equipment Committee are members of the Standards Committee.

Upon investigating the interchangeability of lenses for 16 millimeter cameras, the Committee found that complete interchangeability already exists among those cameras, where it is at all possible. Mechanical considerations, such as rotating shutters and the necessity for compactness, prevent the use of other lenses in those cameras

* Presented at the Spring, 1932, Meeting at Washington, D. C.

not included. It has been found that manufacturers of these small cameras appreciate the desire of many users of 16 millimeter cameras to increase the range of their equipment, and are making their lenses interchangeable wherever possible. For spring-operated 16 millimeter cameras with speed controls, the Committee recommends that a speed of 24 frames per second be provided so as to permit photographing a picture to which sound may be added later.

Sixteen millimeter film projectors, originally intended for home use, are being used to a greater extent in schools, small auditoriums, *etc.*, with larger pictures and longer throws. This usage requires high values of light output, which have so far been provided by projection lamps of increased wattage and improved design. Material increases in illumination can be obtained by using improved devices, such as larger lenses with greater spacings. Such changes, of course, demand projectors having greater over-all dimensions and weights, qualities that projector manufacturers are reluctant to provide because of the competitive situation. The Committee feels that both the home field and the semiprofessional field can not be served by a single style of projector, designed to serve both purposes, and recommends that a so-called "super" 16 millimeter projector, incorporating the recent developments in projector optical systems as well as in lamps, be made available.

It has been proposed that this Committee recommend a maximum size for pictures projected from 16 millimeter film in order to discourage the use of excessive magnification and inadequate illumination. The Committee feels little would be gained by making such a proposal, and consequently has not made such a recommendation.

The Committee recommends as good practice that all 16 millimeter film and lantern slide projectors, as well as 35 millimeter portable and semiportable projectors, be equipped to use some form of prefocused base lamp, since it has been well demonstrated that the use of such a base and socket results in a higher average screen illumination than is obtained when the user merely adjusts each lamp to the optical system.

As regards standardization of screen size for home and other non-theatrical applications, the Committee has found that a high degree of standardization already exists. For home use the 30 by 40 and the 36 by 48 inch screens are the most popular, and practically all manufacturers make screens of these sizes. For auditoriums the 6 by 6 or the 6 by 8 foot screens are most generally used.

It has been proposed that a $^3/_8$ inch spindle be made standard for the 1200 and 1600 foot 16 millimeter film reels; $^5/_{16}$ inch is now the standard for these and the smaller sizes of reel. Since the $^5/_{16}$ inch spindle is also used in 35 millimeter projectors and rewinders, for reels up to 3000 feet, there was no need of the $^3/_8$ inch spindle from the standpoint of strength. Projectors provided with extension arms to take the 1200 and 1600 foot reels would also be used with the 100, 200, and 400 foot reels, and the larger spindle would be a serious handicap. The Committee favors the use of the $^5/_{16}$ inch spindle for the larger 16 millimeter film reels, and also recommends a minimum hub diameter of approximately 3 inches for these reels, to lessen the strain on the film that might occur with a take-up stiff enough to turn the large reel.

The Committee does not feel that the advent of 16 millimeter sound film, even with a single row of sprocket holes, should limit the Society's recommendation of both the diagonal and straight splice.

Both the Society of Motion Picture Engineers and the Academy of Motion Picture Arts and Sciences have adopted the 0.600 by 0.825 inch aperture for projectors instead of the 0.900 by 0.680 inch aperture, formerly the standard for motion picture projectors, and even yet standard for film slide projectors. All manufacturers of film slides and film slide equipment have been canvassed, and report that it would impose a great hardship upon them and the users of their equipment to change to the smaller aperture. Furthermore, there is no necessity of making such change since these two 35 millimeter film applications are quite independent of each other. Several manufacturers expressed the need of a larger aperture instead of a smaller one.

Automatic film slide projectors, sound-on-disk film slide projectors, and three-color film slide projectors were discussed briefly, but no proposals regarding these devices have come before the Committee.

The Committee has recommended to the Standards Committee, in respect to the dimensions of the lantern slide mat opening given in the report of dimensional standards ASA-Z22-1930, that the specifications be changed to include the word "maximum," reading as follows:

4. Lantern Slide Mat Opening

3.0 inches (76.20 mm.), maximum, wide by
2.25 inches (57.15 mm.) high.

The inclusion of the word "maximum" makes the dimensional standard consistent with practice, as other shapes and sizes are frequently used. However, they must not exceed the values shown above.

The Committee recommends for adoption by the Standards Committee the four following definitions:

Sixteen Millimeter Silent Projector.—A projector capable of projecting only 16 millimeter silent film; usually provided with variable speed control so as to operate faster and slower than 16 frames per second.

Sixteen Millimeter Sound-on-Film Projector.—A projector for showing 16 millimeter sound track film, operating at the fixed speed of 24 frames per second; it may or may not operate at lower speeds.

Sixteen Millimeter Sound-on-Disk Projector.—A projector for projecting 16 millimeter film with sound-on-disk, operating at the fixed speed of 24 frames per second, together with a synchronously operating turntable, the turntable to operate at $33^1/_3$ revolutions per minute. Projector speeds less than 24 frames per second and turntable speeds of 78 and 80 revolutions per minute may or may not be included.

Sixteen Millimeter Sound Projector.—A general term designating either the 16 millimeter sound-on-film projector, the 16 millimeter sound-on-disk projector, or a projector capable of performing both of the above functions.

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REPORT OF THE MUSEUM COMMITTEE*

The Museum Committee was formed for the purpose of preserving the relics and traditions of the motion picture; with this purpose in mind, the Committee set about to choose a suitable museum for the deposition of all available relics. A museum on either the East or West Coast was considered. After due consideration, it seemed more feasible to start the exhibit on the West Coast, as a number of collections are available only for a West Coast museum.

The Committee succeeded in locating and bringing together a number of available relics, and placed these relics in glass cases, labeling them accurately, stating the history and points of interest of the exhibit, and giving credit on this label to the donor. For the deposition of these relics the Los Angeles Museum was considered, and, after a consultation with Dr. W. A. Bryan, Director of the Los Angeles Museum, the Committee was assured the coöperation of that institution, and the requisite display room and glass cases, in addition to a custodian, were assigned for the exhibit.

The Los Angeles Museum is maintained by the county, is open seven days a week, and occupies a pretentious building in Exposition Park. The exhibits are arranged, as far as possible, in chronological order, in such manner that the pioneers represented are given credit for the influence they exerted upon subsequent screen history. The labels on the exhibits are accurate, the authority for them being obtained from the Patent Office Records or by referring to the pioneer who made them. They are so labeled with the view of making greater use of the exhibit. Correspondence concerning the priority claims of the outstanding pioneers is displayed after being authenticated, and is displayed in such a manner that it may be read by the visitor. A prominent sign placed in the exhibit reads: "This Exhibit of Motion Picture Relics is being brought together through the coöperation of the Society of Motion Picture Engineers."

Among the exhibits represented are: Muybridge's "Horse in Motion" experiments, conducted for Leland Stanford University;

* Presented at the Spring, 1932, Meeting at Washington, D. C.

various models of projectors, including the Edison, Pathé, Armat, Edengraph, Motiograph, Kinemacolor, *etc.*

One exhibit, representing about six years' work, is a collection of authentic specimens of film made by various pioneers. Each specimen is a frame or two in length and is bound between plates of glass in order to protect it. These specimens of film show in a concise manner the evolution of the industry, and accompanying each is a historical notation concerning the pioneer who made the specimen. There are about twelve hundred specimens in this collection, and among them can be seen films of any width from four millimeters up to four inches, representing various attempts to

FIG. 1. General view of the S. M. P. E. motion picture exhibit at the Los Angeles Museum.

establish other than the thirty-five millimeter width. There are some two hundred different color attempts recorded. This collection includes, besides color and the various attempts at wide film, sound, third dimension, processes, and outstanding pictures; in fact, everything that is made on film, including the first piece of film made on the celluloid supplied by George Eastman to Edison in 1889, and the transparent paper used prior to the advent of celluloid. The first piece of film made for Edison by Dickson is included in this collection, as well as a piece of George Eastman's raw stock of 1889. Other pioneers such as Jenkins, Rector, Lumière, Urban, Lauste, Ruhmer, and others too numerous to mention, are represented. Over a thousand specimens are shown.

Another display is a series of early projector models such as the Edison, Armat, Lumière, and Kinemacolor, as well as a series of the basic movements. There is also a collection of early cameras. There is a collection of over three thousand stills, handbills, posters of the Nickelodeon Theaters, props used in pictures, miniatures, and photographs of prominent people.

Besides the technical relics of the industry, there is a display of stills, handbills, and personal memoirs that represent the growth of the motion picture industry. Exhibited here is a display showing the drawing and photographing of cartoons step by step, and minia-

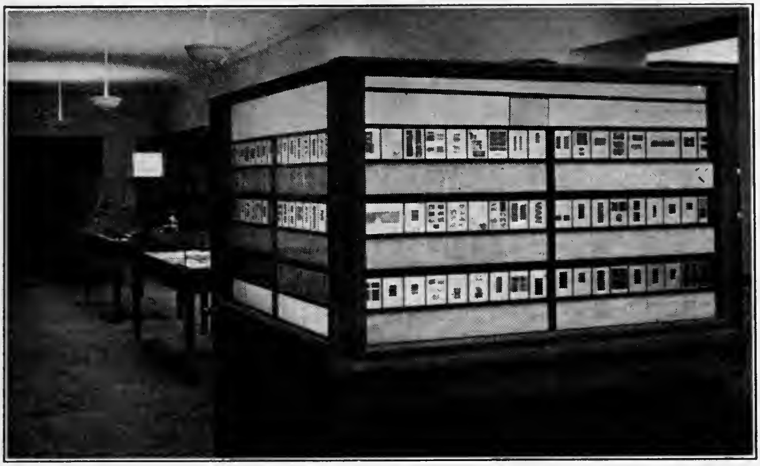

FIG. 2. Another view of the exhibit, showing in the foreground the case containing about 1200 historical film specimens, each with its history or that of its maker. The white placard announces the sponsorship of the exhibit by the S. M. P. E.

tures and props used in outstanding pictures. These are displayed so as to have an educational value.

There can be seen in this exhibit some of the personal possessions of outstanding personalities of the screen, including costumes used by Mary Pickford, Charlie Chaplin, Douglas Fairbanks, Lon Chaney, as well as such equipment as William S. Hart's "six-shooter;" a lariat used by Tom Mix, Harold Lloyd's original pair of glasses, and objects used by Mabel Normand, Wallace Reid, Rudolph Valentino, Mack Sennett's Keystone Cop, and others. Accompanying these exhibits are labels giving the history of the personalities represented, giving to the exhibit an educational value, in addition to the interest that it holds for contemporary motion picture "fans."

Mrs. Alice Herbert, the widow of the late Thomas H. Ince, has deposited at the Museum a collection of ninety-four albums containing the complete collection of synopses of the pictures directed by Ince. Accompanying these synopses is a complete set of stills of each picture. These date back to 1909, when Mr. Ince first made motion pictures for the Biograph Co.

Another interesting collection was made by David Horsley in 1920 and is on exhibit. This is a collection of hand-colored transparencies of famous stars of 1915 to 1920. The value of this collection can not be appreciated without being seen. Mr. Horsley, who was an outstanding independent producer, formed the Centaur and Nestor Film Companies, and assisted in forming Universal.

All these exhibits are accurately labeled, well displayed, and carefully preserved. The Museum Committee desires to enlarge the exhibit and increase the number of pieces on display, so that those who have material available are requested either to lend or donate it to the Society, and in turn it will be loaned to the Los Angeles Museum for display. The Los Angeles Museum officially acknowledges everything received, and credit is given the donor on the label accompanying the exhibit.

The Committee wishes to show its appreciation to Messrs. W. Kennedy, Laurie Dickson, Thomas Armat, W. V. D. Kelley, Mark Larkin, Alfred Reeves, Joe Reddy, Mary Pickford, Douglas Fairbanks, Mack Sennett, Louis B. Mayer, Eric von Stroheim, Lee de Forest, Wallace Clendenin, and a host of others for their coöperation and valuable help.

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SOCIETY ANNOUNCEMENTS

BOARD OF GOVERNORS

At a meeting held on July 7, 1932, at the Hotel Pennsylvania, New York, N. Y., the nominations of officers for the year 1933 were completed; upon receiving the formal acceptance from the nominees of their nominations, voting ballots will be mailed to the Active membership.

Considerable time was spent in revising the operating budget of the Society in order to make it conform to changing conditions, and various economies in the administrative procedure were instituted. In addition, it was deemed advisable not to hold a Fall Convention in the usual manner, but that, instead, a business meeting of the Society should be held, as the Fall Convention, in New York on October 5 under the auspices of the local New York Section, at which meeting several papers would be presented, the voting ballots would be counted, and the new officers for the year 1933 would be installed. It is probable that arrangements will be made to hold an informal dinner preceding the meeting in the evening. Further particulars concerning the meeting will be announced to the membership later.

As regards the advertising policy to be pursued in connection with sustaining memberships, the Board of Governors decided that various combinations will be acceptable: *viz.*, that any company may become a sustaining member of the Society by contributing $100.00 or more annually; that any advertiser may become a sustaining member by contributing at least $100.00 more than the cost of the advertisements; or that any company may simply buy space without becoming a sustaining member.

The Membership Committee is conducting a campaign for new members and it is hoped that the recent reduction of admission fees will assist materially in this work.

A revised method of validating and approving standards was adopted by the Board, and is as follows: that the Board will consider proposals for standardization supported by the recorded affirmative votes of three-fourths of the members of the Standards Committee, received within thirty days from the date on which the proposals to be voted upon were mailed to the members of the Committee; the Board of Governors will then either accept or reject the report of the Committee containing the proposals; if accepted, the report will be published in the next succeeding issue of the JOURNAL accompanied by an invitation to all members to submit their comments in writing to the Editor-Manager. At the next meeting of the Board of Governors, not sooner than thirty days after the publication of the report in the JOURNAL, the Board may consider the comments and take final action toward approving the proposals for publication as recognized standards of the Society, or may reject them.

The Standards Committee is at the present time communicating with the standardization bodies of societies in foreign countries for the purpose of cooperating with them in establishing international motion picture standards.

EMPLOYMENT ADVERTISEMENTS

In order to assist members of the Society who are desirous of obtaining positions, the Board of Governors decided to establish in the JOURNAL an "Employment Page." Advertisements on that page will be available to members of the S. M. P. E. and to manufacturing concerns who wish to secure trained men for positions. Material for publication is subject to editing and must be sent to the General Office of the Society by the 10th of the month prior to publication. Manufacturers and others seeking engineers are invited to address replies to these advertisements at the box number indicated. All replies will be forwarded directly to the advertiser.

Each employment advertisement shall not exceed one-sixth page in length; a charge of $2.00 will be made for a single insertion, or $5.00 for three consecutive insertions.

PACIFIC COAST SECTION

At a meeting held on June 16, 1932, at Hollywood, after the usual routine business, a communication directed to the president of the Academy of Motion Picture Arts and Sciences was read, inviting members of the Technicians Branch of the Academy to attend meetings of the local S. M. P. E. section. In his reply, Mr. Levee, president of the Academy, stated that the matter was being referred to Mr. Lester Cowan, executive secretary, for further action. After a brief address by Dr. Lee de Forest, Mr. Elmer Richardson described to the section the activities of the Convention held in Washington, D. C., on May 9 to 12. The following papers were then presented: "Sixteen Millimeter Movietone Equipment," by Mr. J. Cass; "The Varo Lens," by J. A. Dubray; "Recording Lamps," by Bert Delaray. These papers were attended by demonstrations and an exhibition of sample equipment.

OPEN FORUM: HOW CAN THE SOCIETY OF MOTION PICTURE ENGINEERS BE OF GREATER SERVICE TO THE INDUSTRY?

The following is an abstract of suggestions made at the Open Forum at the Fall, 1931, Meeting of the Society at Swampscott, Mass.

(1) Sound reproduction in theaters needs greater refinement as the public has become much more critical of both sound and picture quality. The standard for projectionists should be raised in order to effect improvement in their work. (H. B. Franklin)

(2) More papers dealing with the fundamentals of the optical, physical, and electrical aspects of the industry are needed for the JOURNAL and fewer papers on descriptions of miscellaneous mechanisms. (D. MacKenzie)

(3) The Society should encourage more fundamental research in universities. An effort should be made to increase our membership among the staffs and the post-graduate students of colleges. Lower entrance fees would help to encourage such memberships as well as to make the JOURNAL more accessible to these members who now rely on the "library copy." (A. C. Hardy)

(4) Greater emphasis should be placed on the importance of increasing our membership among executives of the larger producing and manufacturing com-

panies. A special branch of the Membership Committee should be appointed to do this work. (G. E. Matthews)

(5) Papers on specific subjects should be segregated as much as possible in order that members attending the convention may hear all the papers of interest to them on one or two days and get away again if it is desired to do so. (H. H. Strong)

(6) An effort should be made to increase the Society's membership among projectionists, theater managers, and theater technicians. If the managers could be shown that membership in our Society indicated a better type of projectionist, it should help raise the standard of projection. (D. T. McNamara)

(7) It is a reflection on the engineers of the industry that the director should outstrip them in doing his job better than the engineer. Our Society can be of greater service to the industry by making every effort to improve existing conditions in the recording and reproduction of sound and in the technic of processing the film. It is our job to educate the producer as to what constitutes good sound and to show him the fallacy of using poor equipment. (W. H. Carson)

(8) Our Society could certainly be of much greater service to the producer than it has been in the past, and indirectly we could win his confidence and have more of his problems referred to us. A section of our JOURNAL might be devoted to the subject "Inventions Needed," wherein the nucleus of new ideas could be suggested. Many useful ideas regarding equipment are being worked out constantly in the studios; these ideas should be collected and a description of them published. Standards on materials used for set construction would be helpful to the producer. As an example, a certain medicinal mineral oil is used to produce fog effects in the studio. A less expensive oil might be found which would be equally as effective. Engineering data could be obtained from the manufacturers of lamps, motors, *etc.*, and published for consultation by the producer. Committees should study the problems confronting the producer and make recommendations for better practice. For example, a graphic method of monitoring sound might be worked out which would be more effective and accurate of interpretation than the present method of relying on the opinion of the monitor man. Our Society should also investigate the design of sound studios. (M. W. Palmer)

(9) A chief aim of our Society during the coming year should be to convince the producer that we are in a position to be of real service to him in the solution of his engineering problems. This was shown very clearly on the wide film problem in connection with the work of the Standards Committee under the chairmanship of A. C. Hardy. Another example of the type of salesmanship needed was that given by our past president, J. I. Crabtree, who personally obtained many of the sustaining memberships and thus made possible the establishment of our permanent executive office and our monthly JOURNAL. Every effort should be made by every member to coöperate fully with the producing organizations. (E. I. Sponable)

ACADEMY OF MOTION PICTURE ARTS AND SCIENCES

A meeting of the Academy was held on June 15 at Hollywood for the purpose of discussing the methods of adapting sound recording and processing equipment to a new technic described as *split film recording.* This technic permits the recording of sound on one-half the width of the standard 35 millimeter positive. In a method adopted by one studio, the sound track film is run through the recorder once, and is then turned over and run through again, placing a sound track along each side. After developing and drying, the film is split so as to separate the two sound tracks, which may then be matched with their corresponding picture negatives in the subsequent synchronizing and editing processes. Methods by which $17^1/_2$ millimeter stock may be used for original recording and editing processes were also discussed.

NEW AMENDMENTS

Of the amendments proposed by the Constitutional Committee, and submitted to the Board of Governors, the following were approved by the general Society on May 9 at the Spring, 1932, Meeting at Washington, D. C.

BY-LAW I
Membership

Section 3. Applicants for active membership shall give as references at least three active members in good standing, and for associate membership, at least one active member in good standing. Applicants shall be elected to membership by the approval of at least three-fourths of the board of governors.

BY-LAW III
Board of Governors

Section 2. A majority of the board of governors shall constitute a quorum at regular meetings.

Section 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.

BY-LAW IV
Meetings

Section 1. The location of each meeting of the Society shall be determined by the board of governors.

Section 3. A quorum of the Society shall consist in number of one-tenth of the total number of active members as listed in the Society's records at the close of the last fiscal year.

BY-LAW VII
Dues and Indebtedness

Section 1. The admission fee for applicants to the grade of active membership shall be $10.00, and for the grade of associate membership, $5.00.

Section 2. The transfer fee from the associate grade to the active grade of membership shall be the difference between the above-mentioned fees, or $5.00.

BY-LAW X
Local Sections

Section 8 (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.

Section 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.

SUSTAINING MEMBERS

Agfa Ansco Corp.
Bausch & Lomb Optical Co.
Bell & Howell Co.
Bell Telephone Laboratories, Inc.
Case Research Laboratory
Du Pont Film Manufacturing Co.
Eastman Kodak Co.
Electrical Research Products, Inc.
Mole-Richardson, Inc.
National Carbon Co.
RCA Photophone, Inc.
Technicolor Motion Picture Corp.

HONOR ROLL

OF THE

SOCIETY OF MOTION PICTURE ENGINEERS

By action of the Board of Governors, October 4, 1931, this Honor Roll was established for the purpose of perpetuating the names of distinguished pioneers who are now deceased:

LOUIS AIMÉ AUGUSTIN LE PRINCE
WILLIAM FRIESE-GREENE
THOMAS ALVA EDISON
GEORGE EASTMAN

JOURNAL

OF THE SOCIETY OF

MOTION PICTURE ENGINEERS

Volume XIX **SEPTEMBER, 1932** **Number 3**

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JOURNAL
OF THE SOCIETY OF
MOTION PICTURE ENGINEERS

SYLVAN HARRIS, EDITOR

Published monthly at Easton, Pa., by the Society of Motion Picture Engineers.

Publication Office, 20th & Northampton Sts., Easton, Pa.
General and Editorial Office, 33 West 42nd St., New York, N. Y.

Subscription to non-members, $12.00 per annum; to members, $9.00 per annum, included in their annual membership dues; single copies, $1.50. A discount on subscriptions 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 33 W. 42nd St., New York, N. Y.

Entered as second class matter January 15, 1930, at the Post Office at Easton, Pa., under the Act of March 3, 1879.

THE LAPEL MICROPHONE AND ITS APPLICATION TO PUBLIC ADDRESS AND ANNOUNCING SYSTEMS*

W. C. JONES AND D. T. BELL**

Summary.—*Many speakers find it difficult to use the conventional type of microphone, because of the restrictions that it imposes upon their freedom of movement. A microphone, known as the lapel microphone, designed to be attached to the speaker's clothing, has been developed for overcoming these limitations.*

The vibratory structure of the lapel microphone is designed to have low mass and stiffness, and to resonate at a comparatively high frequency. The resilient support of the diaphragm adds sufficient mechanical resistance to prevent the occurrence of a prominent peak in the response at the resonance frequency. Means are provided for reducing extraneous noise to a minimum. A part of the sound reaching the microphone, due to body vibration, is rich in low frequencies and must be attenuated, otherwise the quality of transmission will be unnatural. This attenuation is accomplished in the coupling transformer, which, together with the apparatus required for suppressing clicks, for indicating when the circuit is in operation, etc., is mounted in a control cabinet. A flexible cord connects the microphone to this cabinet.

It is expected that the lapel microphone will find application in theaters, churches, convention halls, lecture and banquet rooms, and the like, where public address systems are now employed. It also can be applied in connection with other sound recording and reproducing equipment where the background noise, characteristic of carbon microphones, is not a limiting factor.

It is not unusual for a person who is unfamiliar with the use of the conventional form of microphone to move sufficiently relative to the microphone, to affect seriously the results obtained. Many speakers find it difficult to employ their characteristic mannerisms and to inject their personalities into their messages when their freedom of movement is restricted. It is also necessary for a lecturer often to turn from a stationary microphone in order to explain a lantern slide or to use a blackboard. A microphone, known as the lapel microphone, has been developed to overcome these limitations. It is shown in use in Fig. 1.

The lapel microphone is attached to the speaker's clothing. It is slightly less than an inch and a half in diameter, and weighs about one

* Presented at the Spring, 1932, Meeting at Washington, D. C.

** Bell Telephone Laboratories, New York, N. Y.

and a half ounces. Obviously, it would be difficult to meet the requirements of size and weight of a microphone to be worn on the clothing, if it were constructed in accordance with the conventional form of stretched diaphragm instruments now in use.[1] Another, but equally fundamental, method of attack therefore has been employed in designing the lapel microphone in order to secure the desired response characteristics. The stiffness and mass of the diaphragm have both been made small, and sufficient mechanical resistance has been added

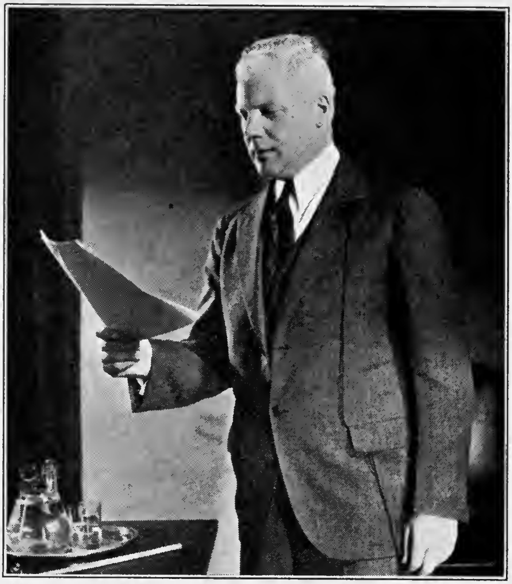

FIG. 1. Lapel microphone in use.

to assure the required degree of uniformity of response in the region of the resonance frequency. A cross-sectional view of the microphone, Fig. 2, shows the means adopted to accomplish these results.

The mass is made small by constructing the diaphragm of thin aluminum, formed into a cone so as to provide sufficient stiffness to cause it to vibrate essentially as a piston throughout the frequency range of interest. A number of thin impregnated paper rings support the edge of the diaphragm. These rings fit into a recess of such dimensions that they are permitted to separate slightly from one another. This mode of construction not only provides a support of little stiffness for the diaphragm, but also introduces resistance due to the viscosity of the films of air between the adjacent layers of paper. The resonance frequency of this vibratory system is approximately 5000 cycles per second. The damping, however, is sufficiently high to prevent the introduction of a sharp peak in the response at this frequency.

Unlike the carbon microphones now used in public address systems, the diaphragm of the lapel microphone is insulated from the granular

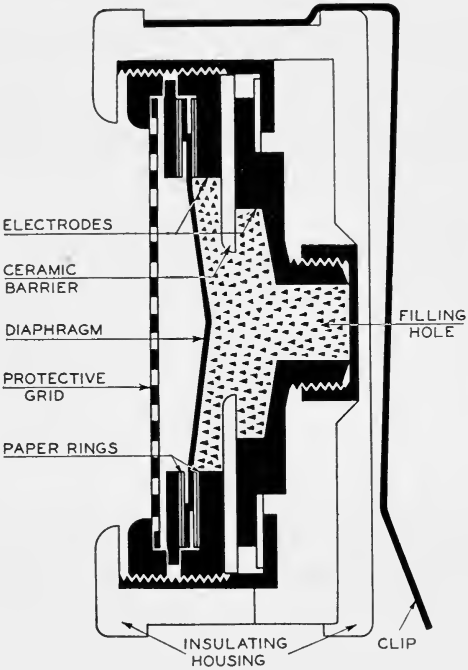

FIG. 2. Cross-sectional view of the microphone.

carbon, and both of the electrodes are stationary. The surfaces in contact with the carbon are cylindrical in shape and are gold plated. They are insulated from each other by a ceramic barrier that causes the current to take a path through the carbon, which assures effective modulation of the resistance and a substantially uniform distribution of voltage between the contacts. The dimensions of the electrodes and the opening in the barrier have been proportioned so as to provide a sufficiently large number of contacts in series, to minimize carbon noise and to reduce materially the electrical aging of the carbon, which results from excessive temperatures at the points of contact between the granules. Mechanical aging of the carbon, caused by abrasion of the contact surfaces as the microphone is moved and the granules change their positions relative to one another, is reduced and the life of the instrument is increased by filling the chamber almost completely with carbon.[2] The latter procedure also reduces considerably the noise caused by moving the microphone about. Many of the design features of the lapel microphone are identical to those of a transmitter recently developed for the use of telephone operators.[3]

A rubber covering for the microphone materially reduces the noise caused by the rubbing of the microphone on the speaker's clothing or

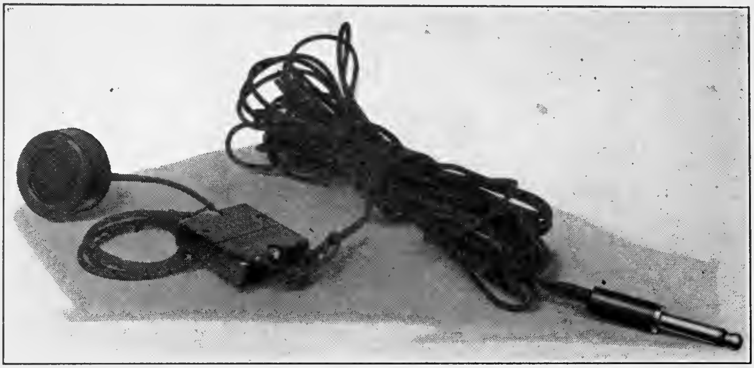

FIG. 3. Microphone, cord, and plug.

that which is picked up through the clip provided for attaching the microphone to the speaker's clothing. The clip is so designed that the microphone can be attached either to the breast pocket of a coat or to the lapel. The latter position is preferable for it is nearer the speaker's lips and hence increases the intensity of the speech relative to the noise. The difference between the speech and noise levels under these conditions is approximately the same as that obtained with the conventional form of stationary carbon microphone.

A flexible cord provides the electrical connection to the microphone. This cord is approximately thirty feet long, and is provided with a plug for connecting it to the jacks in the control cabinet. A plug and jack, shown in Fig. 3, are provided at a point about two feet from the microphone so that the latter may be connected and disconnected at this point if desired. The circuit should not be disturbed at this point, however, when current is passing through the microphone, because the means for suppressing clicks, described below, is not effective under these conditions. The plug contains a small condenser having a capacitance of a few thousandths of a microfarad. This condenser is bridged across the conductors leading to the microphone and, although it has no measurable effect on transmission at voice frequencies, it prevents the cohering of the carbon granules and the consequent loss in output that would otherwise result were the plug withdrawn from the jack while the microphone is connected in circuit.[2] When the microphone is in use, the plug and jack should be placed in the coat pocket, thus preventing mechanical vibration from being transmitted through the cord to the microphone and introducing noise.

At present, most public address systems are designed to employ either a push-pull carbon microphone or a condenser microphone and associated amplifier. It is therefore quite desirable that the lapel microphone be adapted to these systems with the least possible additional apparatus. The output of a lapel microphone, when fastened to the coat lapel, is approximately the same as that of a push-pull carbon microphone located about three feet from the speaker. No additional amplification therefore is required when the lapel microphone is used with an amplifying system designed for the push-pull type. The resistance of the lapel microphone, however, is higher than that of the push-pull microphone, and an additional transformer is therefore required for coupling the microphone to the amplifier in order to obtain the best results. This transformer also prevents the direct current supplied to the microphone from flowing through the primary winding of the input coil of the amplifier.

If the frequency characteristic of the coupling transformer were flat over the frequency range of interest, the quality of the sound reproduced from the lapel microphone would be "deep" and unnatural, due to the fact that a part of the sound reaching the microphone results from the vibration of the body. Sound picked up in this way is rich in low frequencies. The coupling transformer, therefore, has been designed so as to introduce a loss at low frequencies. The discrimination against the low frequencies due to the combined effect of the microphone and its coupling circuit, amounts to approximately 20 decibels at 100 cycles per second referred to the response at 5000 cycles per second. This range of response is based upon a field calibration of the microphone, corrected for the angle of incidence of the sound wave. Data obtained in a number of measurements of the angle of incidence showed the average value to be approximately 70 degrees when the microphone is worn on the coat lapel and the speaker faces directly forward. Obviously, this angle is subject to considerable variation when the speaker turns his head from the position in which it was held when the measurements were made. The diameter of the microphone, however, is so small that the effect of variations of the angle of incidence is confined to the comparatively high frequencies, being only 6 decibels at 10,000 cycles per second for an angle of

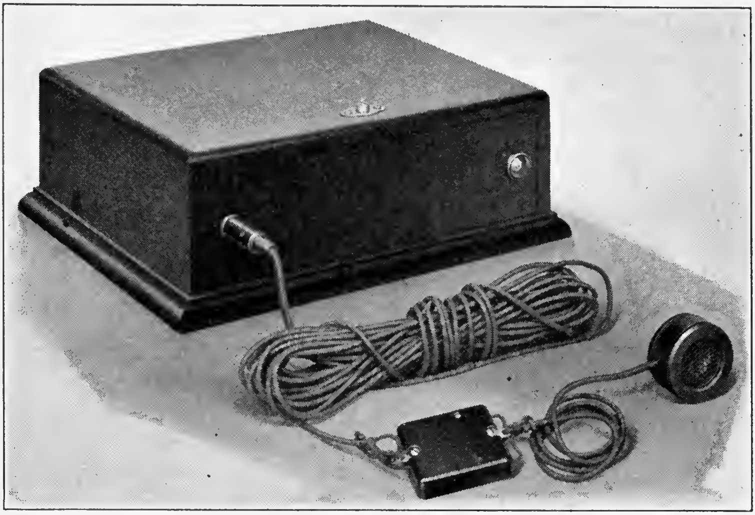

FIG. 4. Single-unit control cabinet.

70 degrees. No correction was made for the baffle effect of the body, owing to the difficulty involved in establishing a representative condition. The directive properties of the voice also affect the frequency characteristics of the output of the lapel microphone.

It is evident from the discussion in the preceding paragraph that simple field calibrations of the lapel microphone do not take into account many factors that affect its performance in actual use and are difficult to interpret. Response curves based on field calibration data, therefore, have not been included in this paper. These data, however, have shown that the response range of the lapel microphone includes frequencies as high as 10,000 cycles per second, and there are no sharp or prominent resonance peaks in the curve.

In order to avoid very disturbing clicks in the loud speaker when switching from one microphone to another, the output of the coupling circuit is momentarily short-circuited until the switching transients have disappeared. The necessary apparatus for effecting this delay is mounted in a unit known as a control cabinet. This cabinet also contains the coupling transformer, the jacks for connecting the microphones, *etc.*

Two types of control cabinet are available, namely a single-micro-

FIG. 5. Five-unit control cabinet.

phone type, Fig. 4, to be used when only one person is to address the audience, and a five-microphone type, Fig. 5, to be used when several speakers take part in a program and means must be provided for switching quickly from one to another. The operation of both types has been made as simple as possible so that an experienced operator will not be required. Two relays, operating automatically, open the circuit between the transformer and the output of the coupling circuit when the microphone is not in use, and short circuit the output of the control cabinet for a short interval after the microphone is connected to the cabinet. All that is necessary to connect the microphone to the single-microphone cabinet is to insert into the jack the plug on the microphone cord; shortly thereafter the lighting of a pilot lamp indicates that the relays have performed their functions and that the microphone and cabinet are operating. The five-microphone control cabinet is operated similarly; five jacks are provided, and a key is associated with each jack for switching the microphones in and out of circuit. Microphones may be connected to all the five jacks, but

FIG. 6. Arrangement of apparatus in the five-unit control cabinet.

only one can be connected to the amplifying system at one time. In case two or more keys are operated simultaneously, the cabinet becomes inoperative, and remains so until all keys but one are returned to their inoperative positions. As in the single-unit cabinet, a pilot lamp indicates when the circuit is operating. The arrangement of the apparatus in the five-unit control cabinet is shown in Fig. 6.

During the development of the microphone, field trials were made under a variety of conditions typical of those that would be encountered in practice. The information obtained indicated that the size and weight of the microphone had been so reduced that it could be worn without inconvenience or discomfort. In fact, it was found that most speakers were less conscious of the lapel microphone than they were of the conventional form of microphone. The quality of the program was improved as a result of the greater freedom permitted the speaker and the improvement in the transmission. The cord extending from the microphone to the control cabinet did not raise an important problem except in so far as it reacted on the technic of using the instrument. In this connection, it is of interest to note that methods were developed that made it feasible to handle even the more complex types of public address programs without difficulty.

It is expected that the lapel microphone will find application in theaters, churches, lecture rooms, convention halls, banquet rooms, and the like, where public address equipment is employed. It also has a field of application in connection with other sound recording and reproducing equipment where the background noise, characteristic of the carbon microphone, is not a limiting factor.

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[2] JONES, W. C., AND INGLIS, A. H.: "The Development of a Handset for Telephone Stations," *Bell System Tech. J.*, **11** (Apr., 1932), No. 2, p. 245.

[3] BENNETT, A. F.: "An Improved Transmitter for Operators' Use," *Bell Laboratories Record*, **10** (Feb., 1932), No. 6, p. 182.

A 16 MM. SOUND-ON-FILM PROJECTOR*

H. C. HOLDEN**

Summary.—*A description is given of a talking picture equipment suitable for application in the non-theatrical field. The factors influencing the selection of a satisfactory form of film are pointed out, and a short review is presented of the problem involved in obtaining a sound record of good quality on this film.*

During the past few years public interest in the motion picture as a means of entertainment and instruction has been greatly stimulated by two important developments. The first and most universal appeal has been the introduction of talking pictures into the theater. Second, the introduction and standardization of 16 mm. safety film and the marketing of suitable cameras and projectors has brought an increasing number of persons into personal contact with the making and projection of motion pictures.

In view of the success of talking pictures in the theater, it is not unreasonable to expect that the addition of synchronized sound to the 16 mm. film will in a similar manner add to the appeal of home motion pictures. Also, there must be considered the effect of such a development on the value of the smaller film in the educational and industrial fields.

The requirements to be met by projection equipment intended for these applications differ in many respects from those encountered in theatrical practice. For greatest utility the apparatus must be extremely compact, free from fire hazards, and capable of producing consistently good results in the hands of inexperienced operators.

The sound-on-film system is especially adapted to fulfill the requirements of this application. Synchronization of sound and picture is very nearly automatic, and there is no problem of reëstablishing synchronism in case of film breakage. Furthermore, in operating the equipment no care is required to be assured of associating the proper sound record with the particular reel of film being shown.

Projection equipment utilizing this system has been developed, and

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* Presented at the Spring, 1932, Meeting at Washington, D. C.

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

is now in production by the RCA Victor Co. This apparatus consists of a 16 mm. sound-on-film projector with the associated amplifier and loud speaker. The complete equipment is contained in two carrying cases of remarkably small size and light weight.

The initial stage of the development of this apparatus was concerned with the selection of a suitable type of film. The requirements of safety, small size, and small cost appeared to be met by the standardized 16 mm. safety film which had come into extensive use in the amateur field; for which reason attention was directed toward this or a similar film as showing the greatest promise for our application.

The solution of the problem resolved itself into the answering of two questions: first, to what extent would the quality of the sound record suffer because of the slower linear speed of the small film? Second, how to place a sound track of adequate width on the narrow film without sacrificing too much in picture area?

The linear speed of 16 mm. film at a projection speed of 24 pictures per second is 36 feet per minute as compared with a speed of 90 feet for 35 mm. film. The ratio of these two speeds is a measure of the relative difficulty of obtaining a satisfactory record on the large and small films. The limiting factors are, of course, the resolving power of the emulsion and the finite width of the recording and reproducing slits in relation to the highest frequency required for acceptable quality. Experiments carried on over an extended period established conclusively that a frequency range very nearly equivalent to that encountered in the average radio receiver could be readily obtained, and this was considered adequate for our needs.

In approaching the problem of establishing a standard form and size of film it was necessary to keep in mind the following requirements:

(1) It is considered desirable that the sound projector be capable of showing the 16 mm. standard silent film without resorting to the use of interchangeable aperture plates. Also, the size of the picture must not be reduced to such an extent that graininess of the emulsion becomes an important factor in picture quality. Again, we do not desire to attempt the establishment of an additional standard width of film. Therefore, the 16 mm. width of film and picture size should be adhered to.

(2) The sound track had to be sufficiently wide to provide assurance that the ratio of ground noise level to signal level would remain

within certain prescribed limits. Or, expressing the same thought in other words, the ground noise level should not be high enough to limit seriously, in decibels, the range that can be recorded. It can be demonstrated that in those cases where the recording is made with the aid of anti-ground noise devices the ratio referred to is a function of sound track width, becoming greater as the width is reduced. Furthermore, an easing of requirements is afforded by the wide sound track in reducing the requisite amplifier gain and scanning beam intensity for a given sound output.

There are several possible forms that a small sound film might assume, but of these only three were given serious consideration as representing a close approach to the desired specifications.

In the first method considered, it was proposed to produce, by whatever means might be found suitable, a small edition of the 35 mm. sound film. The relative size and location of the resulting picture and sound track would, by this method, remain the same as on the larger film. However, due to the location of the sound track, the area of the picture would be considerably less than that of the 16 mm. silent film, and the extent of this reduction would depend on the sound track dimensions. This produces a condition incompatible with the requirements that we have already outlined.

In order to avoid some of the disadvantages of the type of film just described it was proposed to adopt a film having a width of 20 millimeters. The dimensions of this film were to be based on the 16 mm. standards, the additional 4 millimeters of width being obtained by increasing the distance between one row of perforations and the edge of the film. Thus it would be possible to have both a standard size picture and a sound track of adequate width to meet our requirements. But, we have gained these advantages at the expense of a larger film and the establishment of a new standard width. New processing equipment or extensive modifications of the old equipment would be required and, in order to project standard silent film, it would be necessary to provide the projector with an adjustable picture gate.

The third type of film proposed differs from the 16 mm. standard in only one respect: namely, that the perforations along one edge of the film are eliminated, thus providing space for the sound track. The size and shape of the picture and the spacing of perforations remain exactly as in the standard silent film. In the space made available it is possible to place a sound track 0.060 inch wide, a width adequate to meet the requirements of low ground noise level. Since the center lines of film and picture coincide, it is evident that a projector designed to utilize this film can also be used for the showing of standard silent film.

The means available for producing the 16 mm. positive print must be considered in choosing a suitable type of film. If an original 16 mm. negative is available, the actual size and location of the sound track are of but slight importance from the standpoint of producing the final print, since contact printing from a duplicate negative would be satisfactory. However, it is safe to say that practically all 16 mm. sound picture prints will be made by reduction from 35 mm. film. Here the question arises as to which form of 16 mm. film lends itself most readily to the economical production of projection prints of high quality.

The final print can be produced by any one of the following methods:

(1) By continuous optical reduction printing of both picture and sound direct from a 35 mm. duplicate negative to the 16 mm. positive print.

(2) By printing from a 16 mm. duplicate negative obtained by optical reduction of both picture and sound from a 35 mm. master positive.

(3) By contact printing from a 16 mm. duplicate negative made by reduction of the picture and re-recording of the sound from a 35 mm. master positive.

It was claimed for the first process that the number of steps involved would be less than for any other, since both picture and sound could be printed at the same time and with one light source. It was soon realized that this could not be a universal practice for two reasons. First, in order not to limit the design of the projector, the lead of the sound ahead of the picture had to be increased from twenty frames, the standard number, to twenty-five frames for the smaller film. This at once made necessary either two passages of the film through the printer or the use of separate optical systems for printing sound and picture.

Second, for a certain type of recording, the exposure timing in printing must be held constant. The picture, on the other hand, requires various degrees of exposure for the different scenes, so that printing of both picture and sound with a single optical system is not practicable unless a special and additional duplicate negative is prepared.

The number of separate steps or transfers involved is a factor in both cost and quality of the projection print. We must remember that with each transfer of the sound record a certain loss of quality is inevitable, unless the method of transfer includes some means of compensating for the losses of the higher frequencies. This compen-

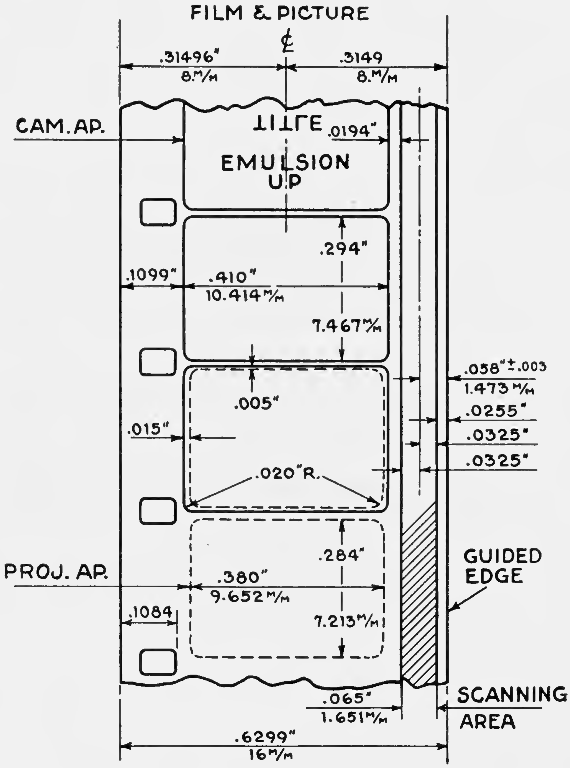

FIG. 1. Picture and sound track dimensions. Undeveloped 16 mm. positive film.

sation can best be made in a process involving re-recording, such as the second method outlined above. This method also permits compensation for the slit losses incident to the lower linear speed of 16 mm. film, and should therefore be considered as the preferred method.

Since the re-recording process can be applied with equal facility to all the proposed film layouts, and the other two processes involve difficulties that would be encountered regardless of the particular form of film selected, no special advantage can be claimed, from the standpoint of processing, for any one of the three proposed films.

Based on the foregoing analysis, the third type of film was selected as fulfilling all the special requirements of a small sound film. The dimensions and relative location of the picture and sound are shown in Fig. 1.

It was necessary, of course, to make extensive tests to determine the effect on the film life of eliminating the sprocket holes along one edge. With the film working under the normal tension required for satis-

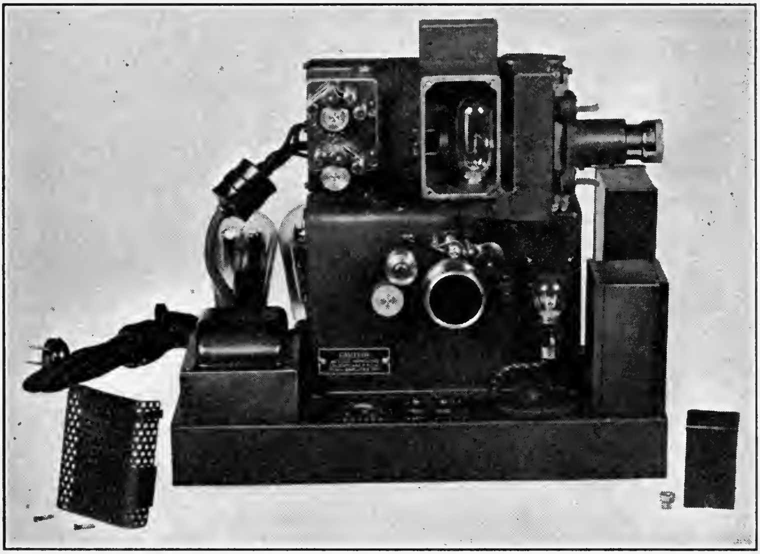

Fig. 2. Projector-amplifier unit removed from case.

factory operation of the sound reproducer, it was found that a film life of from 300 to 500 showings could be expected.

In the design of the equipment now available, extreme compactness has been achieved. As can be seen in Fig. 2, the amplifier forms a base for the projector, and, in turn, the lower part of the projector serves as a mechanical and electrical shield for the photoelectric cell and first amplifier stage. By this arrangement the photoelectric cell coupling circuit is placed close to the amplifier, resulting in a reduction in the attenuation of the higher frequencies at this point.

The construction of the projector, sound head, and amplifier is shown in Fig. 3. A rectangularly shaped casting supports the sound reproducer mechanism and encloses the photoelectric cell, as previously mentioned. The mechanical filter system consists of a film-pulled flywheel and a rotating drum, the latter serving to carry the film past the sound take-off point and to maintain sufficient tension in the film to insure traction between the film and the flywheel roller. The film is held in contact with the drum by means of a pressure roller provided with a lateral adjustment for alignment of the sound track with the scanning beam. The sound track overhangs the edge of the drum, and a mirror mounted inside the drum reflects the modulated light through an opening in the sound head into the photoelectric cell.

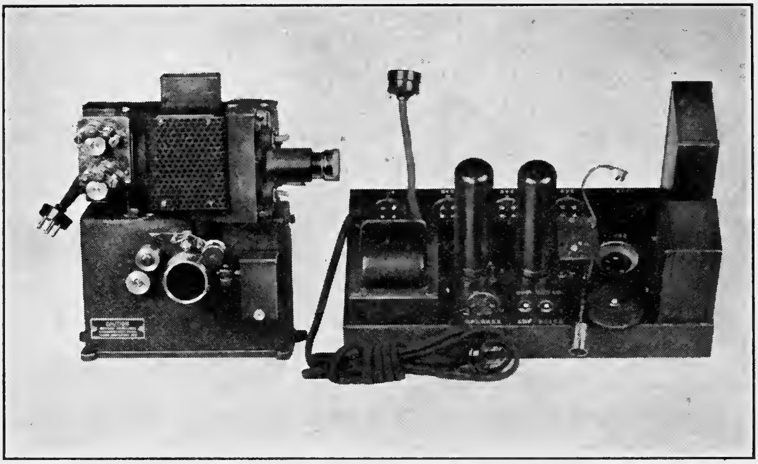

FIG. 3. Projector and amplifier before assembly.

The sound optical system is of the slitless type, in which an image of a helical filament is focused on the sound track. This is accomplished by three small cylindrical lenses, which are mounted in a moulded bakelite barrel approximately $1^3/_{32}$ inches long by $^5/_8$ inch in diameter. The extremely small size of this system has contributed largely to the compactness of the general design.

The projector mechanism is supported by the sound head, and consists of a capacitor type of induction motor equipped with special end bells that serve as housings for the sprocket drive gears and the intermittent mechanism.

Two sprockets are mounted one above the other at the rear end of the motor and are driven by gears meshing with a worm on the end of the motor shaft. The upper sprocket feeds the film into a loop, which passes over the top of the lamp house and into the top of the picture gate. The lower sprocket serves to pull the film through the sound mechanism below and to feed it into the take-up reel mounted on the outside of the case.

The film pull-down is of the claw type, actuated by two cams mounted integrally with the shutter. The mechanism is enclosed in the housing at the front end of the motor. The pull-down ratio is 1 to 6, which gives a shutter efficiency of 60 per cent.

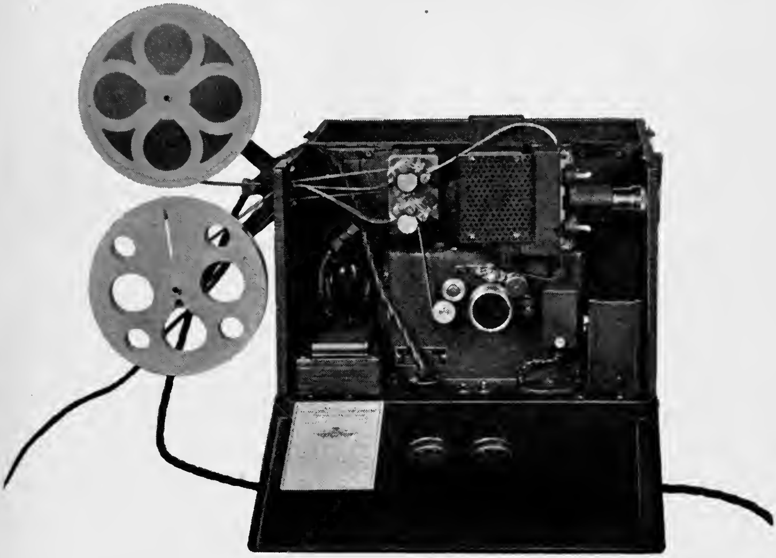

Fig. 4. Projector-amplifier unit ready for operation.

The amplifier consists of two stages of voltage amplification and a push-pull output stage capable of supplying three watts of undistorted power. Six tubes in addition to the photoelectric cell are required. These are, two UX-245's in the output stage, one each UY-224A and UX-227 voltage amplifiers, one UX-280 rectifier, and one UX-245 oscillator.

The projector-amplifier unit is mounted permanently inside a carrying case that serves to enclose the apparatus during operation. Fig. 4 shows the case opened, with the reel bracket in place and the film threaded in the projector. The reel bracket can be removed and stored in the case for transportation.

In setting up the equipment for operation it is necessary to make only two connections, one for the power supply and the other for the connection between the amplifier and the loud speaker. A view of the equipment connected for operation is shown in Fig. 5.

Two different loud speaker models are available. In one of these an eight inch cone is mounted permanently inside a small carrying case, in which space is also provided for carrying several reels of film.

FIG. 5. Complete 16 mm. sound-on-film equipment ready for operation.

The other model is equipped with a directional baffle which can be dismantled, the sections nesting together for transportation.

The projection equipment described has been designed with special reference to those applications for which extreme portability is requisite, and for use in the home or in small classrooms where a picture of moderate size is satisfactory, for which reasons a small projection lamp was incorporated. With this lamp, however, it has been found possible, in conjunction with a highly efficient optical system, to obtain screen illumination comparing favorably with results previously obtained with lamps of considerably greater power.

MOTION PICTURES WITH SOUND ON STANDARD 16 MM. FILM*

H. G. TASKER AND A. W. CARPENTER**

Summary.—*The development of sound on 16 mm. film presents technical problems that have resulted in the proposal of many unconventional arrangements of sound track and picture as possible solutions. Each has for its object a simplification of this development problem in one or more respects, and each makes some sacrifice of cost either in the film itself, the machinery for projection, or in the machinery and methods of preparing the prints.*

The solution here described avoids these cost penalties by employing standard 16 mm. film with a sound track and picture arrangement entirely comparable with the conventional 35 mm. release prints except for photographic reduction of both picture and sound track in the proper proportion. These reduction prints are made directly from 35 mm. negatives that have not been modified in any particular.

Three groups of sound-on-film projectors for use with this film have been developed. These include a complete home model, combining radio, phonograph, sound-on-disk, sound-on-film, and silent projection; a schoolroom model arranged for sound and silent film only, and an industrial model intended only for sound-film projection, which is arranged in a portable carrying case. All these machines are self-threading.

The admittedly attractive features of motion pictures with sound on 16 mm. film have heretofore been obscured by some rather difficult technical problems. Obviously, the greatest advantage of 16 mm. film lies in its low cost per reel. This holds true in each of the contemplated fields of application, whether industrial, educational, or home entertainment. On the other hand, the factors that permit this low cost, namely, narrow gauge and low film speed, are the very features that present the most severe technical difficulties in the problem of producing sound from such film.

Were it not for these difficulties there would be very little occasion to discuss standards for 16 mm. film. Since the 16 mm. field must always depend in a large measure upon 35 mm. sources, it is obvious that the most attractive standard would be a simple reduction from standard 35 mm. sound film in the appropriate ratio 1 to 0.4. A dis-

* Presented at the Spring, 1932, Meeting at Washington, D. C.

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cussion of the penalties involved in any departure from this standard is, therefore, pertinent.

It is evident that the difficulty of resolving the higher frequencies from any film varies inversely as the film speed. For example, a frequency of 6000 cycles on a 16 mm. film, moving at a speed of 24 frames per second (36 feet per minute), is equivalent to a frequency of 15,000 cycles on a standard 35 mm. sound track. It must be admitted that if such a 16 mm. film were to provide only 40 per cent as good quality as was available in the theaters at the time 16 mm. development began, the results would be highly unsatisfactory. It is not surprising, therefore, that many of the early workers in this field devoted much thought to the possibility of relatively higher film speeds for 16 mm. Among the many suggestions that resulted were several that contemplated film speeds of 72 feet per minute, obtained by projecting alternate frames; and others in which the picture is turned through a right angle and the perforations spaced further apart to obtain speeds ranging from 45 to 90 feet per minute.

Although each is technically feasible, none of these suggestions are economically practical, most of them being limited by lack of flexibility in production or by excessive film cost. As time passed and as these limitations were more acutely realized, there remained no doubt of the desirability of a simple reduction from existing 35 mm. standards, provided only that the technical difficulties could be overcome and satisfactory results obtained.

Upon further reflection there appears to be some hope that satisfactory resolution of high frequencies can be realized from a film traveling at 36 feet per minute. While it is true that $^4/_{10}$ of the quality even now commercially available in theaters would still be unsatisfactory, it happens that the film itself is by no means the only important factor in present day 35 mm. quality. Recent work has demonstrated that the film is a very much better transfer medium for sound than much of the apparatus necessarily associated with it. On the other hand, the difference in quality between 35 mm. and 16 mm. film rests entirely with the capabilities of the film itself and of the optical elements associated with it, for the reason that microphones, amplifiers, light modulators, light-sensitive cells, and loud speakers all have characteristics entirely independent of the speed with which the film may move whether in recording, printing, or in reproducing sound.

In view of these facts, the developmental work here described was begun with the idea of adopting a film standard that would offer the simplest production methods at the lowest possible film cost, quite regardless of the technical difficulties to be overcome. Should it later prove that these difficulties were insurmountable or their solution not commercially feasible, some more favorable form of film layout could then be chosen more intelligently with a more accurate knowledge of the relative merits and penalties involved. This determination led naturally to the adoption of straight optical reduction of the present S. M. P. E. standard 35 mm. sound prints. The results of this developmental work have been very gratifying in that this simple optical reduction of 35 mm. sound prints to 16 mm. sound prints has been justified as an entirely practical and very economical means of producing such film.

In making such a film, standard 16 mm. film stock with 2 rows of sprocket perforations is employed, and the sound track occupies a place alongside the picture just as in 35 mm. sound films. The relative dimensions of picture and sound track are practically identical, except that the slightly greater relative width of 16 mm. film as measured between sprocket holes makes it possible to allow proportionately larger unused margins on either side of the sound track, if desired.

On the other hand, the Society has already had occasion to consider a film layout[1] in which it is attempted to obtain a wider sound track without widening the film, at the sacrifice of one row of sprocket holes. Of all the suggestions that have been made for 16 mm. sound film layouts, only this and the simple reduced standard have been seriously considered for standardization by the Society; and it seems appropriate, therefore, to make direct comparison of the essential features of each.

Fig. 1 shows direct optical reduction of sound and picture on a standard 16 mm. film having the usual two rows of perforations and in all dimensions identical with the film stock being used for silent 16 mm. projection. The sound track occupies the position that corresponds to 35 mm. film, but is reduced in the appropriate proportions. Since 35 mm. sound film operates at 24 frames per second, the 16 mm. film derived from it must also be projected at this speed, with a resulting film velocity of 36 feet per minute. Consequently, the total length of any 16 mm. sound track must be exactly $^4/_{10}$ the length of the original 35 mm. track from which it was taken. Since the space available between the sprocket holes on 16 mm. film is very nearly $^4/_{10}$ that of 35 mm. film, it is appropriate to reduce all dimensions of sound track and picture areas in this proportion.

Having chosen this reduction ratio, it then becomes possible to construct a running reduction printer that will reduce the sound track from the original 35 mm. sound negatives, and will likewise reduce the picture from the original 35 mm. picture negatives. The availability

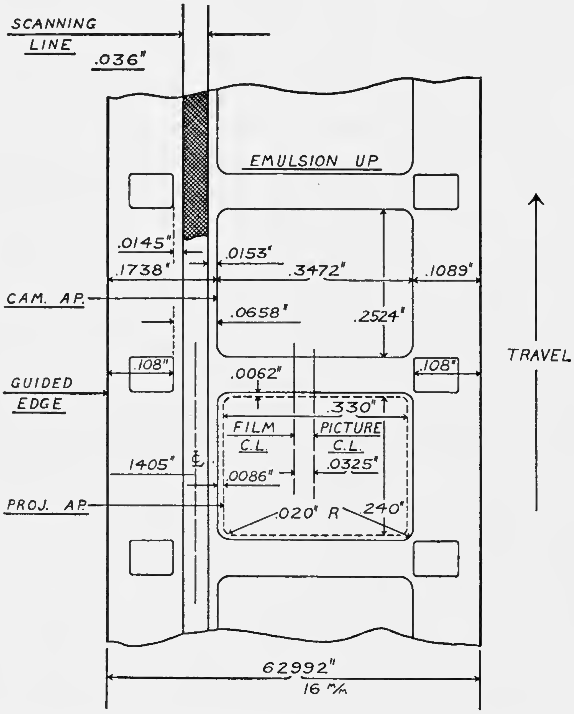

FIG. 1. Optical reduction of sound and picture on standard 16 mm. film.

of such a printer to 16 mm. production is a matter of considerable importance, because running printers of this sort do not involve the surface rubbing common to contact running printers, nor the mechanical wear of step printers that so seriously limits the life of the negatives in ordinary 35 mm. printers. This advantage of the running optical printer results from the fact that the two films must necessarily be spaced apart, with an optical system between, and it is a simple matter to design the printer so that no part of the picture area or sound track area ever comes in contact with any part of the machine. In an experimental printer of this kind, a loop of negative film was run through the machine more than 3000 times without showing any scratching or other deterioration of the useful areas.

The arrangement shown in Fig. 2* abandons one row of sprocket holes in favor of a somewhat wider sound track and larger picture

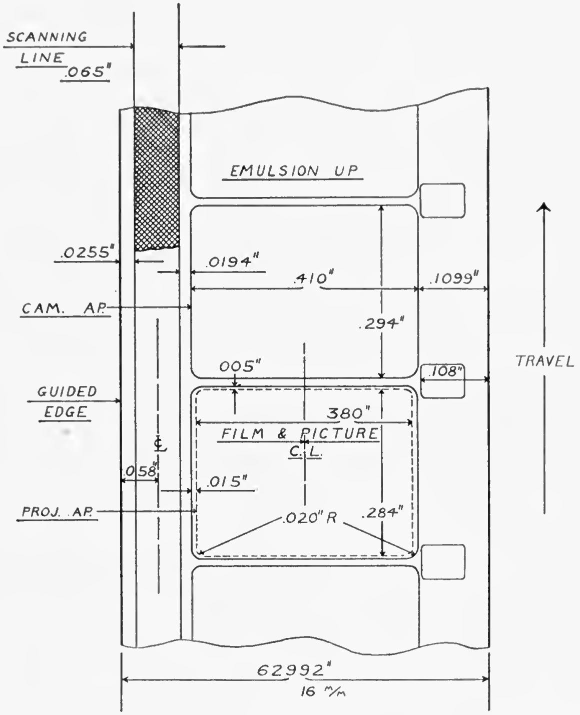

FIG. 2. Arrangement abandoning one row of perforations in favor of a somewhat wider sound track and larger picture area.

area, but the advantages that it appears to offer are by no means unmixed with difficulties. The sound track is now proportionately wider than in the original 35 mm. negative, and hence reduction printing of such a sound track could be accomplished only by means of an optical system that would distort the image sufficiently to give a reduction ratio of only 1 to 0.77 in the horizontal direction, while

* Dimensions shown are modifications of the original proposal, and correspond more exactly to those being considered for standardization.

reducing the image 1 to 0.40 in the direction of travel. This difficulty is by no means insurmountable but may well be avoided, and it should further be remembered that such a printer could not possibly be employed to print the picture.

The only alternate methods possible are to re-record the original sound track either on 35 mm. or on 16 mm. film in such a way as to obtain the relatively greater width required. The 16 mm. print is then obtained from either of these negatives by normal reduction printing or by contact printing, respectively. In the case of contact printing from one 16 mm. film to another, the effect of grain becomes important and may more than cancel any gain in noise level that might otherwise result from the wider sound track.

The proposed dimensions of the film shown in Fig. 2 are such as to allow a 65 mil scanning line as compared with 84 mils used in 35 mm. work; and the resulting tolerances on either side of the sound track, while photographically adequate, leave very little space for mechanical support of the film, especially as compared with Fig. 1, in which more than 100 mils is available for support on either side of the film. Whether or not the additional scanning line length that can be gained in this manner is worth the risks that must be taken, is a question that must be measured in terms of signal output and volume range. Signal output is of little consequence except as it relates to the problem of amplifier noise, and this is largely a function of the sound optical system, the light-sensitive cell and the amplifier design, which matters will be discussed later.

With any given sample of film and any given technic, the available volume range will be diminished as the length of the scanning line decreases. For variable-density recording, a 50 per cent reduction in the scanning line length will diminish the volume range by 3 decibels, while for variable width recording, the reduction will be somewhat more than 3 decibels, unless the tolerances between scanning line length and peak modulation are reduced in proportion. Such items as film quality, recording methods, and processing technic may, however, introduce vastly greater changes in the volume range, so that the length of the scanning line, within reasonable limits, is a matter of doubtful importance.

The difficulties of printing a suitable sound track for the layout of Fig. 2 are paralleled by the problem of obtaining a satisfactory picture of the dimensions proposed. It will normally happen that the original 35 mm. negative from which it is desired to obtain a 16 mm. print will be a sound picture negative, because of a desire to use the same subject for 35 mm. applications. In such a negative, the picture is displaced to one side of the film to accommodate the sound track, and there are substantial spaces between successive frames. Consequently, it is impossible to use such a negative in a running reduction printer to produce the film layout shown in Fig. 2; since it would, in fact, produce precisely the arrangement shown in Fig. 1. This is due to the requirement of all such printers that the mechanical motion of the films and optical motion of the images must exactly correspond. If, on the other hand, the original negative is placed in a step reduction printer and the optical ratio is changed to "blow-up" the picture to the size shown in Fig. 2, the negative will be subjected to the dangerous wear and tear imposed by such printers. It is necessary, therefore, to make a duplicate negative of the picture whenever any considerable number of prints are required; and when step printers are used, a number of such negatives will be necessary to accommodate production on any considerable scale.

In contrast to these difficulties, the layout of Fig. 1 affords the greatest of ease and flexibility in production. A single printer may be used for either sound or picture; and, in the case of combination negatives, for both. It is ready at a moment's notice to produce a sound, picture, or combination print from the original negatives without the delays attendant upon duping and re-recording. The method may be applied with equal facility to any number of prints, whether one, a dozen, or several hundred, with quite negligible depreciation of the negatives. In practice it has been found possible to operate such a printer at speeds as high as 60 feet per minute of 35 mm. film, and speeds of 90 feet or more may be expected. In consequence, the number of such machines required to equip a film laboratory for quantity production will be very small and capital investment may be held at a minimum.

The projection problems surrounding the two types of film under discussion present similar comparisons. Most users of 16 mm. film are familiar with the tearing of the sprocket holes that often occurs when operating ordinary silent 16 mm. projectors, and considerable doubt exists as to whether a single row of sprocket holes could be expected to endure under the even higher projection speeds required for sound film operation on 16 mm. In 35 mm. film, 8 sprocket holes per frame are employed, and the film is handled by skilled operators. Under such conditions satisfactory film life may be expected; but there is a vast difference between these conditions and those that the 16 mm. film will encounter in home, school, and office, where the equipment must be operated by persons not necessarily mechanically inclined, and the provision of only one sprocket hole per frame seems very dangerous.

The difficulty of mechanically supporting film of the type shown in Fig. 2 without scratching the sound track area has already been mentioned. In contrast, the layout of Fig. 1 provides ample support on either side of the film. It is often desirable to arrange a machine for alternate use with translucent and reflection screens, and with the film of Fig. 1 the required picture inversion may be accomplished by reversing the film in the gate. With the film of Fig. 2 this is obviously impossible, as the sprocket teeth would then engage the portion occupied by the sound track, with disastrous effect on the latter. For such a film, the needful inversion must be effected by a relatively expensive optical device.

As in the case of sound track width, the somewhat smaller picture area available in Fig. 1 is of considerably less importance than appears from first observation. With a given subject and identical film stock, the pictures resulting from these two diagrams may present discoverable but by no means serious differences. Current developments in finer grained emulsions by this organization and others may soon be expected to yield picture quality which is beyond reproach in either diagram, 1 or 2.

Projectors designed to accommodate either of these sound films are also capable of projecting any existing silent films that the owner may have in his library. In the case of Fig. 1 a lever is provided to change the aperture size from sound to silent dimensions, as desired.

The design of suitable machines to project 16 mm. sound films is perhaps as interesting a development as that of producing the film itself. When 35 mm. sound-on-film was first introduced in the theater, no attempt was made to replace the original picture projector, but instead, the sound reproducing means was provided as an attachment to the picture projector. The considerable dimensions of the 35 mm. film, and the fact that one or two makes of 35 mm. projector comprised the bulk of the field, made this arrangement feasible. In the 16 mm. field, however, the problem was quite different, for the dimensions of the film are small, the number of different makes of projectors quite large, and the cost of adding sound to an existing projector, if possible at all, would be a relatively large portion of the cost of manufacturing a complete new machine.

Furthermore, most of the 16 mm. projectors now in use were designed without special thought as to quietness of operation. In the 35 mm. field, quietness is not an important item, since the projection apparatus is all enclosed in a fire-proof booth which may also be

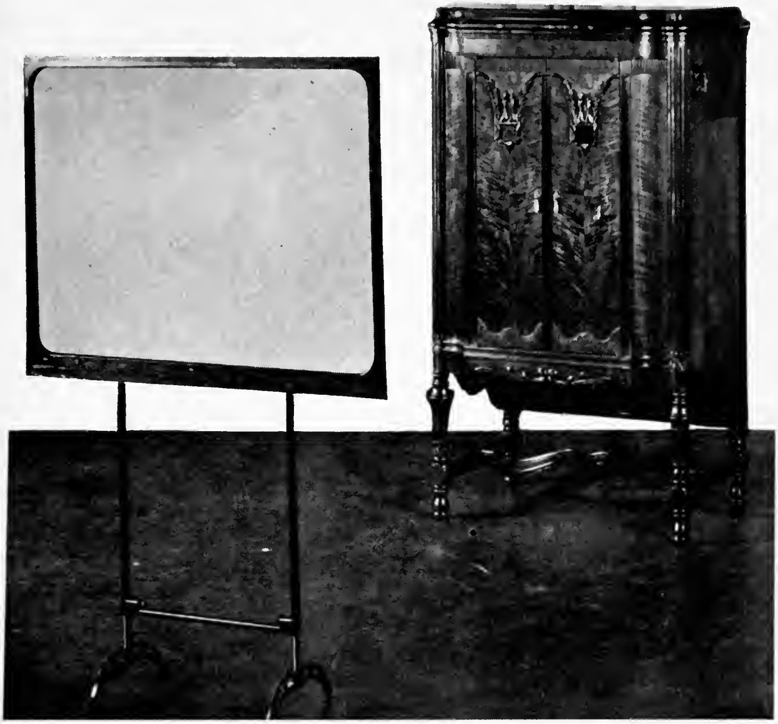

FIG. 3. Home model combination projector, radio, and phonograph.

reasonably sound-proof. On the other hand, 16 mm. projectors are normally operated in the same room with the audience, and if noisy, they must be enclosed in suitable sound-proof cases, which may be quite expensive. For this, and other reasons, it becomes highly desirable to design a 16 mm. sound film projector as a complete unit, and to take such steps as will insure quietness of operation, not only initially, but throughout its life. The projection machines developed by United Research Corporation have been carefully designed to provide long life and quiet operation, avoiding high-speed shafts and reciprocating parts that might tend to cause noisy operation as the machine gets older.

The home model shown in Fig. 3 is a very complete home entertainment device, providing radio, phonograph for both standard and long playing records, silent 16 mm. projection, 16 mm. sound pictures with synchronous disk, and 16 mm. pictures with the sound-

FIG. 4. The classroom model, same as Fig. 3 except that cabinet is designed as a piece of schoolroom furniture.

on-film. The mechanism is conveniently arranged across the front of the cabinet for accessibility in threading, and the threading process is reduced to one of extreme simplicity by means of a self-threading arrangement. In operation, the doors may be closed if desired, as all the needful controls, such as volume control, focusing, and framing, are conveniently located in a protective recess on the side of the cabinet. Either reflection or translucent screens may be used, and in the latter case the screen shown in Fig. 3 folds up and drops into a pocket in the back of the machine when not in use.

The classroom model shown in Fig. 4 is similar in external appearance to the home model, except that its cabinet is designed as a piece of schoolroom furniture. The loud speaker is located in the cover, which opens forward to an upright position when in use. This machine also may be used with a translucent screen for projection from the front of the schoolroom, or the machine may be located in the back of the room and used with a reflection screen on the wall. It is equipped for silent and sound-on-film projection only, but like the

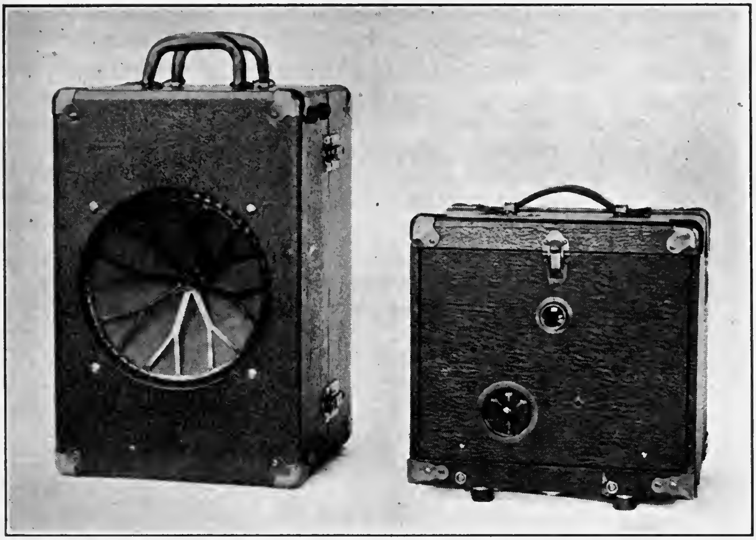

FIG. 5. The portable model; the case on the right contains the projector mechanism, the case on the left contains the loud speaker, amplifier, and space for film reels.

home model, has the self-threading feature that makes it a very convenient accessory to classroom instruction.

The portable model shown in Fig. 5 is arranged in two carrying cases; the one containing the projector mechanism and the other an amplifier, loud speaker, and space for film reels. This model is especially adapted to industrial and educational applications, and is of very rugged construction. Self-threading is again a feature of this machine.

Three-stage amplifiers, employing ordinary triode vacuum tubes, are used in the portable and schoolroom models, the amplifier circuits being of unusual design. The light-sensitive cells used in these machines are a special type of selenium cell developed by United Research engineers. Their very high sensitivity and very small residual noise make them admirably suited for 16 mm. work. They have an exceptionally high signal strength at very low frequencies, amounting to as much as one volt at 60 cycles. This fact is extremely useful in suppressing amplifier hum, since the full low frequency output of the cell may be applied to the grid of the first tube, thus obtaining a very high signal-to-hum ratio at the lowest point in the system. Needful suppression of low frequencies is then effected later in the circuit, thereby substantially reducing the hum voltages. These properties of the selenium cell make the length of the scanning line a negligible matter so far as signal strength is concerned.

REFERENCE

[1] May, R. P.: "16 Mm. Sound Film Dimensions," *J. Soc. Mot. Pict. Eng.*, **18** (Apr., 1932), No. 4, p. 488.

A PORTABLE 16 MM. SOUND PICTURE SYSTEM*

R. A. MILLER AND H. PFANNENSTIEHL**

Summary.—*This paper describes a portable sound-on-disk reproducing system developed for the Western Electric Company by Bell Telephone Laboratories. This system has been developed to permit the introduction of the sound picture into fields not readily reached by theater reproducing systems, e. g., the classroom and the lecture hall. Pictures are projected from 16 millimeter film at the rate of 24 frames per second in synchronism with the reproduction of sound from a 33$^1/_3$ rpm. disk record.*

Two main units make up the system, a portable projector-turntable unit and a portable amplifier-loud speaker unit. The projector head, turntable, electrical reproducer, and driving mechanism are comprised in the portable projector-turntable unit. The electrical energy delivered by the reproducer is delivered to the portable amplifier-loud speaker unit, which serves to amplify and convert it into sufficient acoustical energy for instructing or entertaining audiences of several hundred persons. The system derives its power from the usual house-lighting circuits.

The Western Electric portable sound picture system described in this paper projects pictures from a 16 millimeter film, at the rate of 24 frames per second in synchronism with the reproduction of sound from a 33$^1/_3$ rpm. disk record. This system is intended primarily for non-theatrical purposes and can be made ready for operation in a very few minutes. Exclusive of the screen, all necessary apparatus is contained in two carrying cases, one of which contains a complete projector-turntable unit, the other an amplifier-loud speaker unit.

The two units and their carrying cases are shown in Fig. 1. The projector-turntable unit may be operated when mounted on a table or other suitable support. The amplifier-loud speaker unit is operated as shown, with both covers removed. Cords of suitable length are provided for the system so that the amplifier may be placed behind or adjacent to the screen (at some distance from the projector) to create the illusion that the screen image is the source of the sound.

Fig. 2 shows the carrying cases, with the covers in place, and ready for transportation. The projector-turntable unit is clamped in place when the covers of its carrying case are closed, thereby holding it

* Presented at the Spring, 1932, Meeting at Washington, D. C.

** Bell Telephone Laboratories, New York, N. Y.

firmly in the case during transportation. Covers on the front and rear of the amplifier-loud speaker carrying case protect it during transportation.

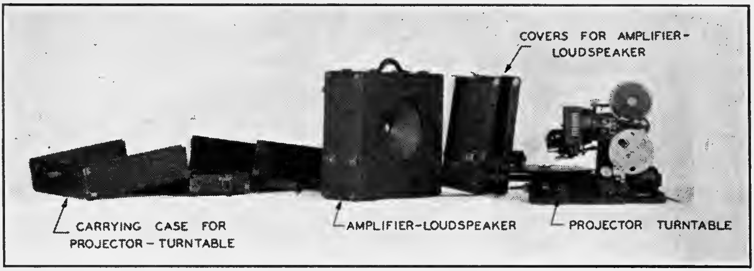

FIG. 1. Units of 16 mm. portable sound picture reproducing system.

Portable folding screens with suitable carrying cases are available, or the picture may be projected on any stationary screen of suitable size.

Projector-Turntable Unit.—Fig. 3 shows the projector-turntable unit

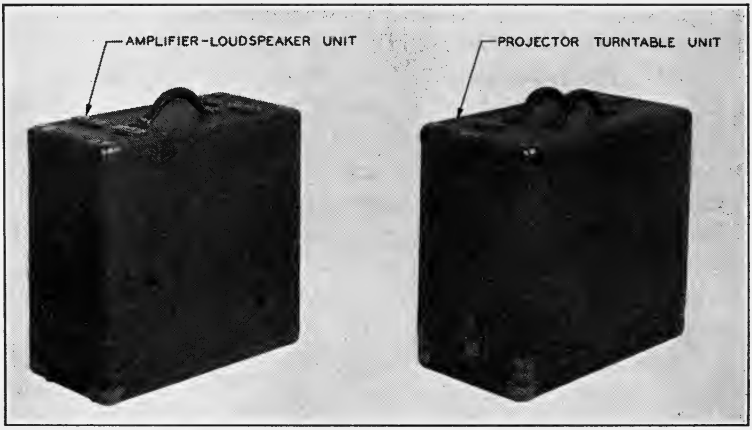

FIG. 2. Carrying cases for amplifier-loud speaker and projector-turntable units.

set up ready for operation. All apparatus on this unit is mounted on a common base, the projector at about the center, and the driving motor and turntable on either end and slightly under the projector.

This arrangement provides for compactness and ease of operation. Lightness of weight is achieved by making all the parts of aluminum so far as possible.

The projector head is mounted on a pivot upon a pedestal, and a screw adjustment is provided for tilting the head and so adjusting it for the projection angle from about 15 degrees above to 5 degrees below the horizontal.

The projector, when equipped with a 2 inch projection lens, and on

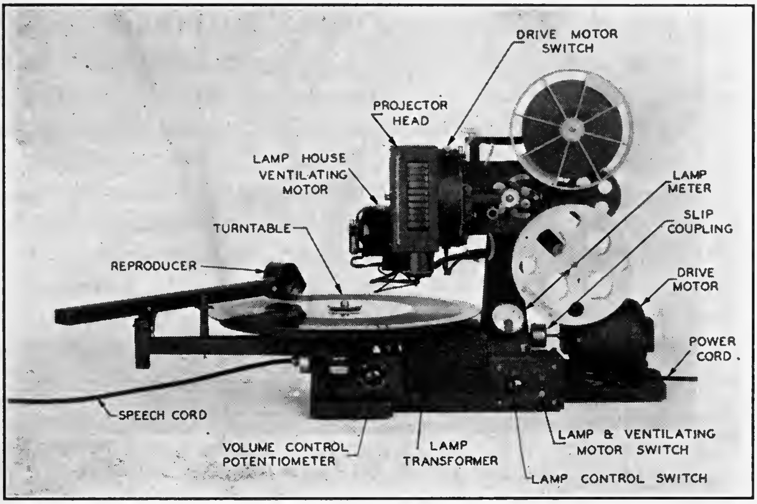

FIG. 3. The 16 mm. projector-turntable unit.

a throw of 40 ft., is capable of projecting a well-illuminated picture 5 by 6 feet in size.

Light for projecting the picture is furnished by one of the standard projection lamps selected to suit the type of service and nature of the commercial power supply available. Since the amount of light and the life of the lamp are greatly affected by the voltage impressed upon the lamp, a voltmeter has been provided, the normal operating voltage being indicated on the scale in red. Variation of the power delivered to the projection lamp and compensation for line voltage changes are effected by means of four taps on the primary of an autotransformer by which the line voltage (115) is stepped down to the voltage required by the lamp. Selection of the proper lamp voltage is made by means of a four-position reciprocating switch. In general, the best results are obtained by operating the lamp at its rated voltage. If the throw is very short, an increased life from the projection lamp may be obtained by running the lamp below the rated voltage. Where the projection distance is very great, the voltage of the lamp may be increased to obtain greater illumination. Such service, however, will shorten the life of the lamp. Referring to Fig. 3, the main lamp switch and the transformer tap selecting switch are mounted in the base of the machine in front of the pedestal supporting the projector head.

Because of the large amount of heat generated by the projection lamp and the restricted area of the lamp house, forced ventilation is necessary if excessive lamp house temperatures are to be avoided. A forced draft through the lamp house for the purpose of maintaining normal temperatures is maintained by a small fan mounted as a part of the projector head assembly. This fan is driven by a small shaded-pole motor. Features of this motor are noiseless operation, absence of a starting mechanism subject to wear, and freedom from electrical disturbances that might have an effect upon the audio frequency circuits of the system. Beyond an occasional oiling of the motor, no further attention is necessary for its maintenance. The switch that provides power to the lamp also provides power for this motor so as to guard against using the lamp without adequate ventilation.

The power supplied to the motor used to drive the projector head and turntable is controlled by means of a switch mounted on the projector head as a part of the light douser mechanism. This mechanism is so arranged that in the case of losing either the upper or lower film loop between the sprocket and intermittent, the douser drops in front of the light beam, and power to the motor is cut off, thereby preventing injury to the film. Synchronization of picture and sound are effected by connecting the projector and turntable through gears to a main shaft driven by the motor.

The motor normally used to drive this machine is of the induction type, rated at $^1/_{20}$ hp., and operates at a speed varying from 3540 to 3560 rpm. over a voltage range varying from 100 to 125 volts. A slip coupling has been introduced between the motor and the main driving shaft, arranged to slip during the acceleration of the motor and to pick up the machine load gradually. As soon as the machine attains its normal operating speed, it is driven without further slipping of this coupling. If, however, an excessive load is placed on this drive while the machine is in operation, the coupling will slip and prevent forcing or damaging any part of the mechanisms.

As the apparatus will usually be operated in the same room in which the audience is seated, it is necessary that machine noises be reduced to a point at which they will not disturb the audience. The motor is dynamically balanced and operates very quietly. Also, the projector head, turntable drive, and other mechanisms have been made to run smoothly and quietly. Completed machines are tested for the total

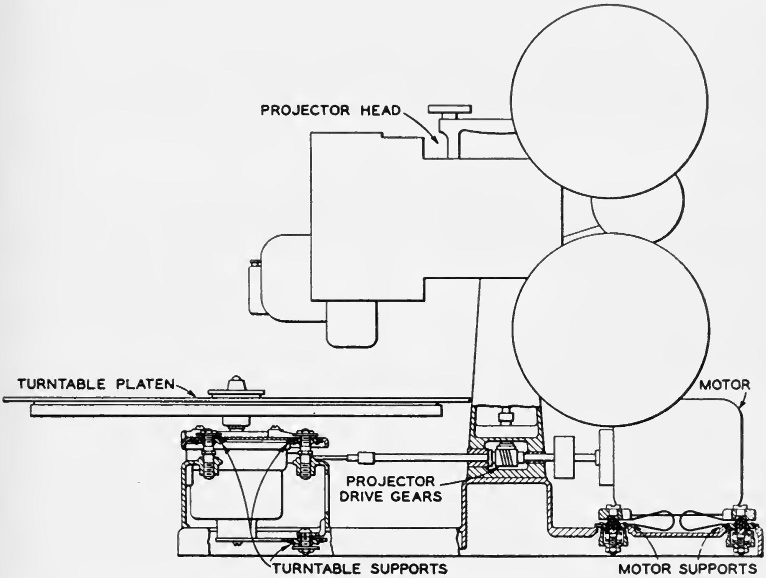

FIG. 4. Diagrammatic drawing of projector-turntable unit showing method of mounting the motor and turntable.

acoustical noise emitted, by means of an acoustical noise measuring set. The noise thus measured must be less than a value that has been established as not seriously affecting the intelligibility.

In sound reproducing apparatus of this type, it is extremely important to prevent any vibrations in the sound pick-up or reproducer unit except those produced by the sound groove in the record. Machine vibrations caused by the motor, gears, projector mechanism, *etc.*, if allowed to vibrate the pick-up unit may distort the reproduced sound in an objectionable degree.

As previously mentioned, the motor, projector head, and turntable-reproducer assembly are mounted on a common base. Therefore, cushions have been provided to absorb vibrations from these sources so as to minimize their effect on sound quality.

The method employed to do this is illustrated in Fig. 4. It will be noted that the motor is mounted on four supports consisting of adjustable springs, which locate the motor in the vertical position, and rubber disks, which locate it in the horizontal position. By making the resiliency of these cushions of the proper value, practically no motor vibrations are transmitted to the base. The armature shaft of the motor is connected to the slip coupling on the main driving shaft by a short length of flexible shaft, which also tends to prevent the

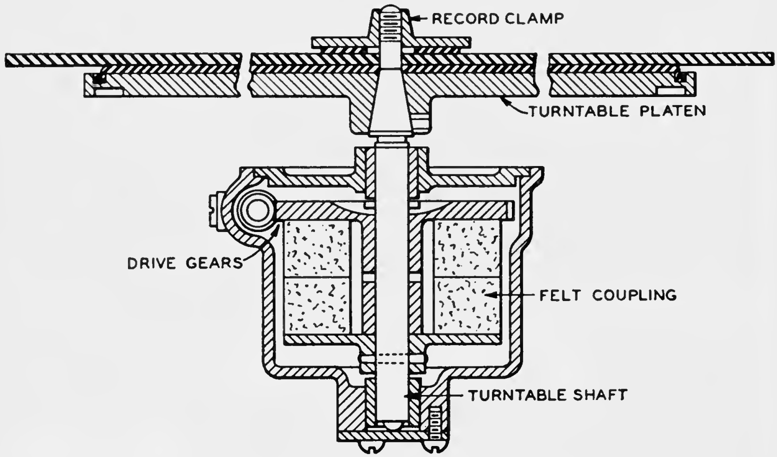

FIG. 5. Cross-section through turntable drive system.

transmission of motor vibrations to the base and allows for slight misalignment of these two shafts.

The complete turntable-reproducer assembly is mounted on rubber cushions as shown on the left of Fig. 4. The turntable-reproducer assembly consists of a turntable worm drive attached to a platform that also supports a swinging bracket, on the free end of which the reproducer and its arm are pivoted. This platform is mounted on the main base through rubber cushions, which absorb and dampen machine base vibrations, thus preventing the turntable-reproducer assembly from being vibrated sufficiently to distort the reproduced sound noticeably. To meet this condition the turntable-reproducer assembly is designed and adjusted so that the noise introduced into the output of the system when used with an average commercial disk record is at least 30 decibels below the output of the reproducer.

Fig. 5 is a cross-section of the turntable drive system. The turntable is driven from the main shaft through a flexible joint by means of a worm gear reduction. The low-speed worm wheel is mounted so that it is free to turn on the vertical shaft that carries the turntable. This turntable shaft is connected to the worm wheel by means of a loose coupling consisting of a cylinder of especially selected felt. The resiliency of this felt cylinder and the mass of the turntable platen are so proportioned as to form a mechanical filter which absorbs rotational speed changes in the worm wheel caused by variation in gear teeth spacing, *etc.* The turntable platen is thereby rotated with a freedom from "flutter" that compares very favorably with present sound-on-film theater equipment.

Any tendency to oscillate is reduced by the inherent damping within the felt. Relative movement between the turntable shaft and the worm wheel is limited by a suitable stop.

The outside dimensions of the carrying case for the projector-turntable unit are 22 inches long, 20 inches high, and 11 inches deep, and the complete outfit weighs about 75 pounds.

Amplifier-Loud Speaker Unit.—This unit consists of an a-c. operated amplifier and a loud speaker of the dynamic type, assembled into a convenient carrying case. Aside from the necessary power and speech cords, the projector, and the screen, this is the only apparatus required to make up the complete portable sound-on-disk reproducing system.

The amplifier and dynamic loud speaker are mounted within a substantial leather-grained, fabric-covered, ply-wood carrying case, having front and rear covers that are removed during operation to expose the opening of the dynamic loud speaker and to ventilate the amplifier. The carrying case is approximately 20 inches square and 10 inches deep with the covers in place, and the unit weighs approximately 60 pounds assembled for transportation. Fig. 6 shows a rear view of the unit with the cover removed. Facilities are provided in the trunk both for carrying the two cords required and for spare vacuum tubes.

The amplifier used with this system gives an energy output level that will enable the loud speaker to deliver sufficient acoustical power for instructing or entertaining an audience of several hundred persons. As previously mentioned, this amplifier is entirely operated by alternating current, and the power for its operation may be obtained from any house-lighting system, the voltage and frequency of which lie between 100 and 125 volts and 50 and 65 cycles, respectively. The power consumed is approximately 90 watts. In order that maximum life may be obtained from the vacuum tubes, a line voltage selector switch has been provided, permitting operation of the vacuum tube filaments at the lowest brilliancy consistent with satisfactory amplifier operation. Under the average operating conditions, a life in excess

FIG. 6. Interior view of amplifier-loud speaker unit.

of 2500 hours of continuous service may be expected of the vacuum tubes. This may be considered equivalent to several years' service from the average system. Connection from the amplifier to the a-c. outlet is normally made by means of the 50 foot cord furnished as a part of this reproducing system.

The vacuum tubes used in the amplifier are of newly developed types, designed particularly to act most effectively for audio frequency amplification. In addition, the vacuum tubes used in the two input stages have been especially constructed to be free from any microphonic response that might arise from either mechanical vibration of the tubes or acoustical shock resulting from their proximity to the loud speaker, which at times may be called upon to deliver relatively high acoustical pressures. Referring to the circuit diagram, Fig. 7, it will be noted that three stages of amplification are employed, using the Western Electric 262A equipotential vacuum tubes of the

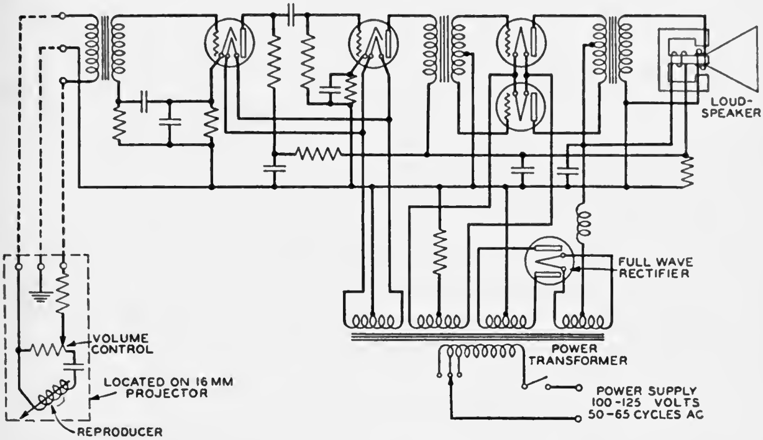

FIG. 7. Schematic diagram of amplifier-loud speaker unit.

heater type, resistance coupled, in the two preliminary or voltage stages, and two Western Electric 275A vacuum tubes in push-pull arrangement in the power stage. A Western Electric 274A full-wave rectifier vacuum tube serves to rectify the stepped-up line voltage, which when properly filtered, is used for both operating the plate

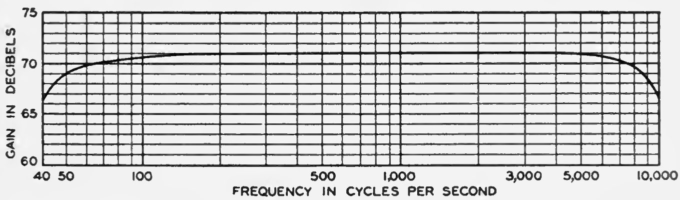

FIG. 8. Gain-frequency characteristic of amplifier.

circuits of the amplifier tubes and for energizing the field of the loud speaker. The heaters of the equipotential cathode vacuum tubes (262A) used in the two preliminary stages, and also the filaments of all the other vacuum tubes, are operated on "raw" alternating current.

The gain of the amplifier is approximately 71 decibels, and is practically uniform over the greater part of the range of audio frequencies requisite to the highest quality of reproduction, the variation in transmission between 70 and 7000 cycles being only about one decibel. Fig. 8 shows the transmission characteristic of the amplifier between frequencies of 40 and 10,000 cycles per second. The output level of the amplifier in decibels is +27, referred to a zero level of six milliwatts at a frequency of 1000 cycles per second; that is, it is capable of delivering an undistorted output of 3 watts with but one per cent of third harmonic. Odd harmonics of order higher than the third are negligible, and substantially all the even harmonics are lacking, owing to the push-pull arrangement of the power tubes. This relatively high output level has been achieved at the comparatively low plate voltage of 200 volts through the development of the Western Electric 275A vacuum tube.

When designing this amplifier, high quality of reproduction and long life were regarded as paramount. To this end, all apparatus entering into the construction of the amplifier has been held to the rigid requirements of a service where long life and reliability are essential. Except for the vacuum tubes, no elements have been used that are expected to deteriorate with either age or prolonged usage, nor are the various component parts being called upon to perform duties other than normal in the interest of economy or compactness. The amplifier is capable of operating indefinitely at all temperatures, up to and including ambient temperatures of 100°F., thereby making possible thoroughly reliable operation under an unusually wide range of climatic conditions.

All parts of the system have been carefully shielded, and hence in so far as is reasonable, are free from the effects of stray electrical interference. The system has been so designed that successful operation is possible without externally grounding the system. The noise introduced into the output by operation on alternating current is relatively negligible. While this noise may be audible at a distance as great as three feet from the loud speaker under static conditions in a quiet room, the level of this noise is some 45 or 50 decibels lower than the output level of the amplifier. That is, the volume range of the system with respect to the a-c. noise is 45 or 50 decibels, or is adequate to impose no limitation upon the playing of commercial disk records. It is to be noted further that this amount of a-c. noise is the maximum that will be found in the system under the worst possible conditions of commercial operation, and has been obtained without noise balancing and compensating devices that might, when adjusted by unskilled persons, detract from the quality of reproduction. Only the control of the a-c. voltage is requisite to the successful operation of the system, other than the regulation of the volume from the loud speaker.

No gain control is provided in the amplifier-loud speaker unit, as, aside from the control of the a-c. line voltage at the time of putting the system into operation, all further control operations are centered at the projector. For the control of the power delivered to the input of the loud speaking telephone outfit and hence its output, a potentiometer having a useful range of about 45 decibels, continuously variable and having an "off" position, is mounted on the front of the projector base.

The loud speaker is of the dynamic or direct radiator type having a 10-inch diaphragm or radiator and an externally excited field. As mounted in the carrying case, the response characteristic is consistent with the over-all response of the complete equipment, as shown in Fig. 9.

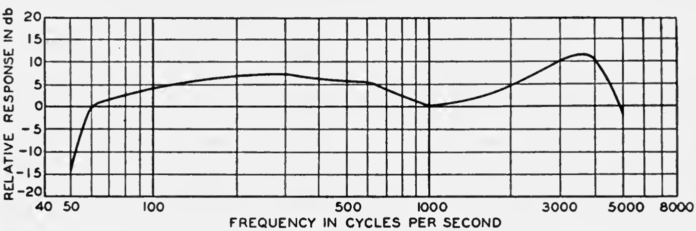

FIG. 9. Over-all response-frequency characteristic of entire system, exclusive of the record.

As previously mentioned, excitation current from the field is obtained from the rectifier and filter included as part of the amplifier assembly.

Fig. 9 shows the overall frequency response characteristic of the complete system, exclusive of the record. In this characteristic have been included the response of the reproducer, the transmission of the amplifier and the volume control network, and the response of the speaker. This characteristic does not show the minor response irregularities of the reproducer and loud speaker, but does show the irregularities that might be noticeable to the ear. In designing the system every effort has been made to preserve the naturalness of speech so often lacking in the reproduction afforded by loud speakers of the dynamic type. This has been achieved by eliminating the "boominess" that results from a preponderance of low frequencies, and by adequately supplying the higher frequencies that add so much to the brilliance of speech.

MODERN TOOLS AND METHODS USED IN SERVICING SOUND EQUIPMENT*

J. MAURAN**

Summary.—*The quality of reproduction of sound in a theater must be good at all times, and sound outages must be kept to a minimum. This can be accomplished only by having the equipment checked carefully and periodically by engineers specially qualified and equipped for such work. Certain parts of sound equipment are subject to wear. The parts most likely to fail are carefully inspected for danger signs by the engineer on each of his visits. Other parts, critical in adjustment, are readjusted on each visit to maintain the quality of sound at the high standard set by the manufacturer and demanded by the public.*

RCA Photophone, Inc., has devised special appliances and tools to facilitate the adjustment of sound reproducing equipment. This paper describes the special test reel and methods used to maintain the sound quality at the required high standards.

It has been the policy of leading sound equipment manufacturers to sell routine service with their reproducing equipment. While there are a number of good reasons for the adoption of such a policy, its justification has not always been made clear to the exhibitors. As a result, routine service has been a subject of considerable discussion among exhibitors since the introduction of sound into motion pictures. It is not the purpose of this paper to outline the reasons for such a policy. However, before entering into a detailed discussion of the service tools and methods employed, it will be well worth while to review the reasons for the extreme care exercised by the sound equipment manufacturers in the selection and equipment of their service personnel.

The entertainment field today, as in the case of other industries, is in a highly competitive state. This applies not only to the relations between equipment manufacturers, but also to those existing between theaters, producers, and various fields of entertainment. Under these circumstances, the public reaction to a picture affects more than the financial returns to the exhibitor. Each picture adds or detracts from the score, which in its cumulative effect spells the success or

* Presented at the Spring, 1932, Meeting at Washington, D. C.

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

failure of producers, distributors, and equipment manufacturers. Therefore, nothing can be overlooked that may in any way detract from a full enjoyment of a screen presentation. Aside from its artistry and technic, the picture must be well photographed and the sound accompaniment must be of high quality, both in rendition and recording. With all the necessary qualifications, however, a film production may still give poor results when used in reproducing equipment that either is not up to modern standards of quality or is in a poor state of maintenance. Recognizing the effect of individual performances on the sound motion picture industry as a whole, it is therefore not surprising to find that equipment manufacturers are making every effort to organize a well-equipped service force to maintain the equipment in the best possible operating condition.

The problem of maintenance when referred to sound equipment consists of two main features: (1) the prevention of sound outages, (2) the maintenance of the quality of reproduction that is normal for the equipment. Given a sound equipment in which the component parts are of good manufacture and have an adequate factor of safety, the problem of prevention of sound outage resolves itself into a periodic check of the parts that wear or deteriorate with use and must be replaced before they cause trouble. The maintenance of the normal quality of reproduction, on the other hand, requires a careful check and possible readjustment of various components of the equipment that influence the quality of the output. For the past three years, manufacturers of sound equipment have been making efforts to simplify their equipment and to reduce such adjustments to a minimum. While there has been continued progress in this direction, there are still a number of adjustments that require special tools and specially trained men. It is the purpose of this paper first to outline briefly the parts of the equipment that are the most likely to cause trouble, and then to study in detail the servicing methods employed in checking, correcting, and adjusting them.

In discussing the problem of maintaining sound installations, it is convenient to divide the equipment into three main subdivisions: (1) The sound head, (2) The amplifier and control panels, (3) the speaker. Of the three groups, the sound head requires the most attention, and is the most exacting in its adjustments. The condition and adjustment of every mechanical unit used in the constant motion of the field in front of the light beam affects the quality of the sound, and every part of the optical system that may affect the size, position, and intensity of the light beam influences the volume and the quality of the reproduction. Of the various components, the condition of the constant-speed sprocket and the adjustment of the sound gate assembly are the most critical. Unless the film moves at an absolutely uniform speed through the gate, the resultant sound will have what is termed a sprocket or gate "flutter," the exact designation depending upon the cause of the flutter. The presence of such a flutter is usually evidenced by a characteristic rasping noise, which is particularly noticeable at the higher frequencies. Where this condition exists, the trouble may be due to excessively worn sprocket teeth, the use of a

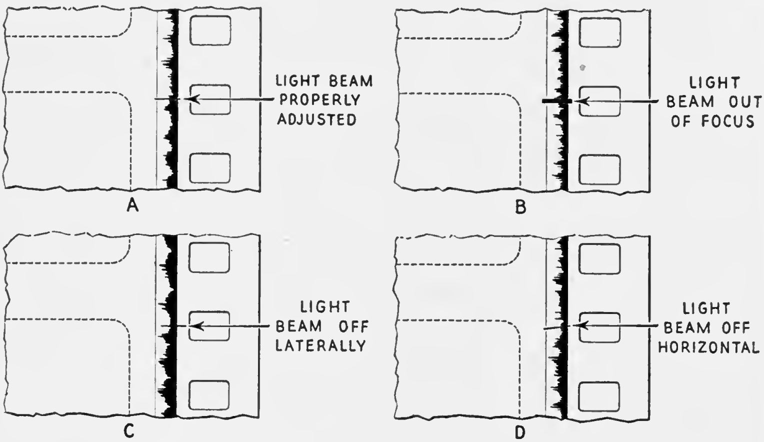

FIG. 1. Diagrammatic representation of the various positions of the light beam with reference to the sound track.

constant-speed sprocket of incorrect diameter, or to the lack of the necessary tension in the springs of the pressure gate. The adjustment of these springs is quite critical. If the tension of the spring is inadequate, there will not be a sufficient "drag" or "holdback" on the film, with consequent gate flutter. On the other hand, if the tension is excessive, there will be abnormal wearing of the teeth of the constant-speed sprocket, with a decided tendency to "hook."

The adjustment of the light beam passing from the exciter lamp to the sound track has a material bearing on the quality of reproduction. Fig. 1 represents diagrammatically the various positions of the light beam with reference to the sound track. Fig. 1(*A*) shows the position of the light beam when properly adjusted in reference to the sound track. Fig. 1(*B*) illustrates the case where the light beam has the proper lateral adjustment but has not been properly focused. In the case of Fig. 1(*C*) the light beam does not have the proper lateral adjustment, so that it does not scan the entire width of the sound track. In Fig. 1(*D*) the light beam is properly focused and has the proper lateral adjustment, but the light slit is not horizontal. In all the last three cases, distortion in one form or another will be introduced, with a consequent loss in the quality of reproduction. To maintain the normal high standard of reproduction, it is essential that the service engineer carefully check the adjustment of the light beam on his periodic visits to the theater, and to make the necessary readjustments in accordance with the methods to be described.

Other maintenance items on the sound head are exciter lamps and photoelectric cells. Exciter lamps, in particular, deteriorate with use, and have to be replaced frequently. As their replacement and adjustment in the socket is a comparatively simple process, however, they are rarely the cause of annoyance. In addition, there is the possibility of obtaining poor sound quality or of sound outage due to excessive wearing of gears and drive chains and loosening of belts.

Compared with the sound head, amplifiers present an easy problem to the maintenance man. Tubes, and rectifier stacks or batteries, where used, are the only items that deteriorate materially with use, and should be inspected periodically to avoid possible sound outage or deterioration in quality. Recent improvements in rectifier stacks have rendered these units quite reliable and have prolonged their life, so that no trouble should be expected from them until the equipment has been in service for several years. As they approach the end of their useful life, however, there is a gradual increase in the reverse current and in the internal resistance, with a consequent loss in efficiency of rectification. At this stage, the stack should either be replaced or kept under close surveillance to avoid sound outage.

Batteries have always been considered a reliable source of direct current. It is rather difficult to give an accurate estimate of the life of a storage battery since the life is so materially affected by the number of hours it is used daily, the rates of charge and discharge, and the general care given by the projectionist. Regardless of this fact, however, a battery should not be a source of anxiety in view of the fact that it invariably gives adequate advance indication of approaching failure. These danger signals consist of its inability to hold a charge and the necessity of frequent charging to maintain the proper voltage.

Various component parts of the amplifier are, of course, subject to failure. Such failures are, however, infrequent, and cannot be predicted to forestall a possible sound outage. The maintenance man's only recourse is to see that the various amplifier units are kept reasonably free from dirt and dust, particularly in the section between exposed wires or terminals, and periodically to ascertain that none of the power transformers or condensers are heating excessively.

We now come to the question of speaker maintenance, which presents an even simpler problem than the amplifier. Assuming that the stage speaker has been properly installed behind the sound screen, there is very little likelihood of difficulty from this source unless someone tampers with the unit. The service engineer, however, generally makes it a point to listen carefully to the reproduction from the stage speaker to discover rattles or distortion that may have developed since his last visit to the theater. Where such trouble is definitely traced to the loud speaker, it is usually found to be due to a loose wire or to a lateral displacement of the speaker cone, allowing the voice coils to rub against the sides of the field air gap.

The sound screen, behind which the speaker is located, frequently presents a maintenance problem, particularly if it is of the porous variety. The pores of such a screen accumulate dust, and, unless the screen be cleaned periodically, there will be a gradual loss in sound and deterioration in quality. Where such difficulty is experienced, the question as to whether the screen is at fault can be definitely decided by comparing the volume and the quality of the speaker output with the screen in place, and with the screen "flown" or removed.

The foregoing outline briefly covers some of the main problems encountered in the maintenance of theater sound equipment. It indicates the parts of the equipment that must be kept under surveillance or checked periodically to prevent sound outage and to obtain the best possible sound quality and service from the equipment. On their periodic visits to the theater to make such inspections, the service engineers encounter some difficulty due to limitations of working time and of space in which they must perform their tests. As there can be no interruption of the performance, practically all the checking operations have to be performed either before or after it. This of course, means additional expense for the exhibitor. Therefore, to keep overtime to a minimum, the work must be performed as rapidly as possible, and, because of the limited space in the average projection booth, it must be done with as few instruments as possible. These two factors, as well as the obvious one of reasonable accuracy, must naturally be taken into account in designing test equipment to be used in maintaining sound equipment.

The RCA Photophone service engineer's test equipment consists essentially of a tool kit, a multitester or set analyzer, and a test reel.

There is very little of special interest in the service engineer's tool kit (Fig. 2). It contains a complete set of tools for installing and servicing sound heads and amplifiers. In addition to items such as

FIG. 2. Service engineer's kit of tools.

hammers, screw drivers, files, wrenches, pliers, *etc.*, the kit is furnished with a relay adjusting tool, a relay contact cleaner, special size socket wrenches, a taper-pin pusher, a gear remover, a circuit tester, and a special optical adjusting tool. The use of the last item will be described in connection with the use of the test film.

The KR-13 multitester (Fig. 3), specially designed for RCA Photophone, embodies in a compact form all the meters and special testing devices needed in sound equipment work. The various meters, with the necessary shunts and multipliers, will measure direct currents from 1 microampere to 75 amperes, d-c. voltages from 0.1 to 750 and a-c. voltages from 1 to 250. By means of a plug that may be inserted in the various amplifier sockets, tube and amplifier measurements may be made under conditions simulating those of normal operation. A microammeter, with a range of 15 microamperes, is used for checking photoelectric cells and for making measurements of high resistance.

In addition to the above, the KR-13 multitester is provided with special binding posts for making "continuity" tests and for phasing speakers. A thermal output meter, in conjunction with the RCA Photophone test film, is used for making frequency response measurements and optical system adjustments.

The standard RCA Photophone test film is used as a source of signal output for making practically all the necessary measurements and adjustments of sound equipment. The film is approximately 1000

FIG. 3. Service engineer's multitester.

feet long and has a sound track on each edge. It is so recorded that it is unnecessary to rewind the film to play the track on the opposite edge of the film. The recording on one edge of the film includes 140 feet of "buzz" track, 200 feet of 9000-cycle parallel line track, 100 feet of 1000 cycles followed by a constant voltage frequency test track varying, in equal steps, from 50 cycles to 6000 cycles.

Fig. 4 represents an enlarged facsimile of the so-called "buzz" track. Essentially, it consists of two chopper tracks, each 10 mils wide, spaced 90 mils apart. The chopper track nearest the sprocket hole is a 300-cycle record, and the other chopper track is a 700-cycle record.

The track is designed to make the lateral optical system adjustment and to determine the extent of film "weave" in the sound gate by a listening test, without the aid of eyepieces or reflecting mirrors. When the film is properly adjusted in the sound gate, the light beam from the exciter lamp will fall between the two chopper tracks, and there will be no signal output from the stage speakers. When, on the other hand, the light beam is off to one side or the other, as illustrated in Fig. 4(*B*), a constant note will be reproduced in the speakers, the frequency and volume of which will depend on the extent and the direction in which the film is off. If the note heard is of 300-cycle frequency, the film guides should be adjusted to move the film outward; if the 700-cycle note is heard, the film guides must be adjusted to move the film further in. Occasionally, due to a warped film or a maladjustment of the gate tension springs, difficulty will be experienced through film "weave." Such a condition will be indicated by

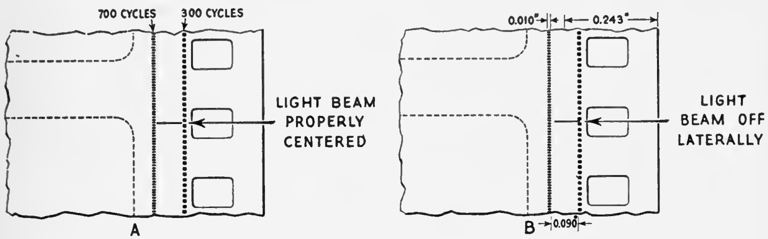

FIG. 4. Enlarged facsimile of the "buzz" track.

the reproduction in the speakers of a 300- and a 700-cycle note alternately, the extent and frequency of the weave corresponding to the volume of the signal and the frequency of the alterations, respectively.

Having centered the light beam on the sound track by means of the "buzz" track, as described above, the 9000-cycle parallel line track is used for making the rotational and focal adjustments of the optical system. This track consists of a series of parallel lines, each 70 mils long and 1 mil wide, spaced 1 mil apart. Fig. 5 shows enlarged diagrams of the 9000-cycle parallel line track: (*A*) shows the case where the light beam has not been properly focused on the sound track; (*B*) shows the case where the rotational adjustment is incorrect; that is, the light beam is not horizontal; (*C*) shows the case where both the focal and the rotational adjustments have been properly made to obtain maximum response. It is obvious from these diagrams, and the theory of reproduction from film, that the maximum signal will be obtained from the sound track when the light beam is sharply focused to a width of 1 mil or less, and is absolutely parallel to the lines on the sound track.

In making the adjustment, the thermal output meter on the multitester is connected across the speaker terminals of the power amplifier, with a resistor load substituted for the speaker voice coil. With the 9000-cycle parallel line track running through the sound gate, the focal adjustment of the optical system is gradually varied, and the reading of the output meter is observed. As the light beam becomes more and more concentrated, the output of the amplifier is gradually increased until perfect focus is attained. If the adjusting screw is

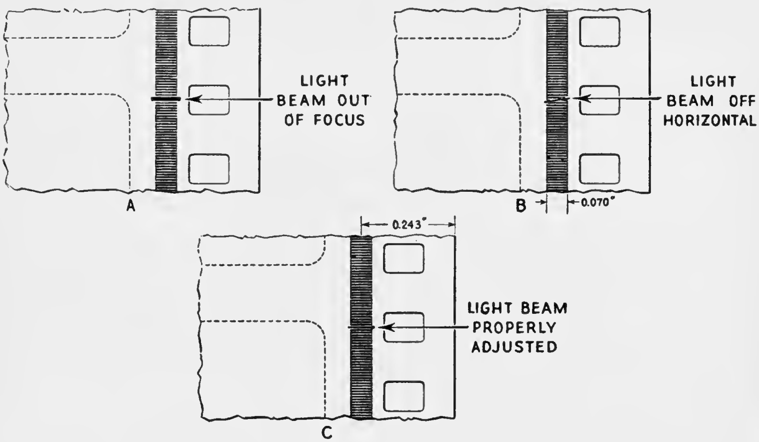

FIG. 5. Enlarged diagrams of the 9000-cycle parallel line track.

turned beyond this point, the readings of the output meter will pass through a maximum and start to decrease. The adjusting screw should then be turned back until the peak is reached, at which point the set screw must be tightened.

In the later type of optical systems, the light slit is fixed with reference to the machined base of the optical unit, so that no adjustment is necessary. On the older units, however, the light slit is movable, so that a rotational adjustment is necessary to obtain maximum output from a given sound track and to avoid distortion. This adjustment is effected by using the same tools and methods employed in making the focal adjustment. With a 9000-cycle parallel line track running through the gate, the aperture plate is rocked back and forth by means of a vernier extension rod (Fig. 6) until maximum reading is obtained on the output meter, at which point the plate is then fixed by tightening the set screw. By the use of this method, the light beam may be adjusted to within one-half a degree of the horizontal lines on the sound track.

The frequency test track, which follows the 9000-cycle parallel line track, is used to obtain overall output characteristic curves for the sound head and amplifier. The output response obtained in this way could be calibrated so that the curve may be plotted in volts, in decibels, or as a percentage of output at a given frequency. In

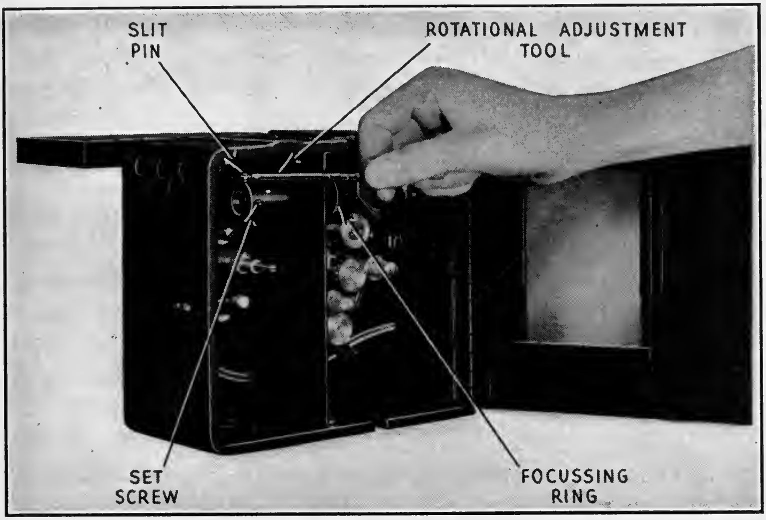

FIG. 6. Showing method of making rotational adjustment of optical system.

the case of the multitester, it is found convenient to plot output curves as a percentage of the output voltage at 1000 cycles. Fig. 7 shows a characteristic output curve corrected for slit losses.

The frequency test track is also useful for locating the causes of rattling or buzzing of speakers. Among the various frequencies included in the frequency track, there will be one that will correspond to the natural frequency of the loose wire or part, so that it will start to vibrate. The faulty element, having thus been located, may then be tightened or adjusted.

The foregoing covers the description and uses of the recording on one edge of the standard test film. On the other edge of the film is a series of recordings of various musical instruments, and masculine and feminine voices, each section of the track being a special test for some particular characteristic of the equipment. The first in line is a piano solo track expressly intended for checking and determining by ear, the extent of "wows" in the reproduced sound. The composition of this piano solo includes sustained notes that exaggerate the "wows" in reproducing equipment. All the necessary adjustments for the elimination of "wows" and "flutters" is performed during the playing of this selection.

A flute solo follows the piano solo. This recording may be used in a listening test as a check to determine the adjustment of the optical system, and the possible presence of sprocket "flutter." It may also

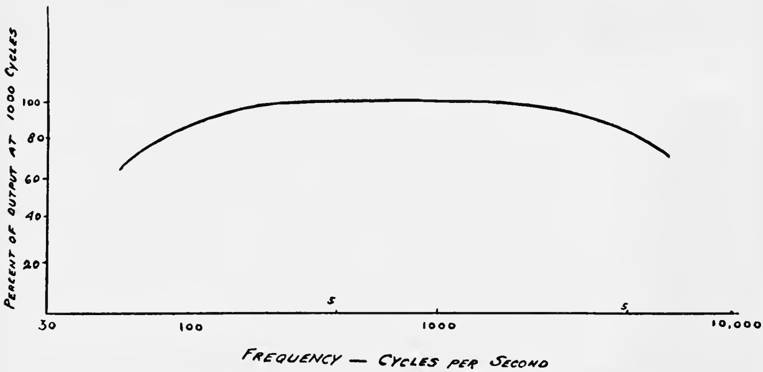

FIG. 7. Characteristic output curve corrected for slit losses.

be used to locate loose metal or wooden parts in the vicinity of the stage loud speaker that may vibrate in sympathy with reproduced sound.

The flute solo has an abundance of slurred notes in the high frequency range. In the listening test, a lack of brilliance, crispness, or definition, particularly in the higher frequency range, will indicate that the optical system is out of adjustment. Sprocket "flutter" or improper gate and optical system adjustments are indicated by a "fuzziness" of the high frequency notes.

Two violin selections and one cello selection are next. One violin selection is a standard RCA Photophone variable width recording; the other is recorded with RCA Photophone anti-ground noise track. These selections are used to determine, by ear, the frequency balance; using the cello to check the response at the low frequencies, the standard variable area muted violin record to check the middle range, and the anti-ground noise violin record, as well as the flute record, to check the upper range.

Vocal solos and dialog are next; these are used to check for intelligibility, clarity, and naturalness of reproduction. They provide a good test for the middle range of frequencies, which have the greatest influence on the intelligibility of speech.

The above outline briefly covers the standard methods employed today in testing and maintaining sound equipment. In the present state of the art, it is difficult to predict the outcome of the present trends in the design of sound equipment. Manufacturers recognize the desirability and are striving for further simplification of the equipment. At the same time, there will have to be a decided improvement in the standards of sound quality to meet the demands of a public that is becoming more and more discriminating; and instead of eliminating adjustments, it may be necessary to add to them or to refine the present test methods to meet the new standards. For the present, at least, it goes without saying that any sound system, the servicing of which does not include meticulous care and complete periodic checks with adequate instruments will not, week in and week out, give the high quality of reproduction increasingly demanded by the theater-going public.

PROBLEMS OF A THEATER MANAGER*

NAT GLASSER**

Summary.—*The contrasting nature of the points of view held by motion picture engineers and managers of theaters, as regards the ultimate presentation of entertainment, is discussed. The fact that the ultimate objective of both engineers and theater managers is identical, in providing a contribution to what is commonly called showmanship, is emphasized; and the especially urgent need of appreciation of this conception in times like these is pointed out. The engineer regards motion picture technology as an end, whereas the manager regards it as the means to that end. Where the end is a common one, it is clear that the two contrasting points of view can not be compatible; and it is the appreciation of this fact that will lead ultimately to a form of coöperation that will be greatly productive of results in the future.*

That an evident disparity exists between the points of view of engineers and theater managers has been quite evident for some time, although both engineers and managers may undoubtedly be classified as showmen. The engineer looks upon the motion picture business as a field of invention, whereas the manager regards it as a means of providing entertainment. Thus, the engineer believes that his objective is accomplished when he achieves perfection of sound and picture mechanism, as far as perfection may be expected to be achieved; the manager, on the other hand, regards his sound and projection equipment as merely a means to an end, his objective being to create an appreciative public consciousness for entertainment.

Thus, we have two contrasting points of view: from one of which motion picture technology is considered as an end; from the other of which it is regarded as a means. Let us study the details of the question, and endeavor to ascertain whether the engineer and the manager really are at loggerheads, or whether their interests are in reality rooted in common ground.

A manager who is worthy of his hire looks upon his theater as his business. Whether he works for a company operating a chain of theaters, for the owner of an individual theater, or whether he operates his own theater, his prime objective is to provide entertainment that

* Presented at the Spring, 1932, Meeting at Washington, D. C.

** Warner Bros., Washington, D. C.

will satisfy the majority of his patrons, and thus to earn, above the expenses of operating the theater, a profit proportionate to the investment. The ideal manager is one who is capable of attracting a clientele from which is constantly derived at least a reasonable profit each week; he is one who, by economic discrimination, keeps expenses at a minimum; and who, through his personality and good judgment, builds an appreciable good-will for his theater.

Such a manager looks upon his mechanical equipment as a means to an end. He contends for perfect projection, and demands the highest quality of reproduction of sound obtainable in his theater. The realization of these requirements, so essential to a good theater, is not however, the ultimate aim of the manager; although it is of profound importance in booking, advertising, exploitation, the creation of good-will, and the like, all of which contribute materially to the attainment of perfection in entertainment. The manager, therefore, looks upon perfection of entertainment as the ultimate end of his endeavors, and as the only satisfactory target toward which he should aim. After all, the business of managing a theater is decidedly different from that of managing a mercantile establishment: the manager of a theater sells entertainment, but, unlike the merchant, he does not give his patrons a bundle to take home to show to their friends, but rather brings them into his theater for no other purpose than to entertain them, in the best possible way at his command.

With no common thought in mind, there is bound to be friction between the two groups, the engineers and the managers. If the engineer does not know the problems of the theater, its inception and its development, he will assume that his work lies only in the field of mechanical advancement and research. The manager, on the other hand, unacquainted with the problems of engineering, believes that his mechanism is only a medium for presenting entertainment.

A common ground exists, in my opinion, on which both engineers and managers should meet in order to study their problems, which, after all, are mutual problems. I contend that the objectives of the engineer and of the manager are identical, and that the endeavors of both these groups of men are but phases of the aggregation of endeavor known as *showmanship*.

Regardless of how one might wish to define *showmanship*, there can be no doubt that it is a synthesis of a great variety of ideas, experience, constructive endeavor, and forethought. Having the objective in common, of contributing jointly to this showmanship, engineers and managers will be striving for the same end. The engineer will be tolerant of his manager-associate; and where it happens that the manager has only a slight knowledge of his technical difficulties, the engineer will enlighten him accordingly.

The problems of the engineer are the problems of the manager also, and *vice versa*. When the engineer and the manager work in unison, achievements of far greater magnitude than those that have been accomplished in the past may be realized. The time is ripe for new technologic developments, and it is only the engineer who can contribute this phase to showmanship.

The manager displays his showmanship when he devises a campaign that creates good-will and interest of the general sort; the producer brings into evidence his showmanship when he deviates from the usual paths and produces a picture that blazes the way for a host of imitations; the engineer displays his showmanship when he devises technologic improvements of the apparatus that the producer and manager must use in production and exhibition.

To the American engineers and to the Warner Brothers, the pioneers of the sound movies, must go the credit for Vitaphone and the other sound mediums now in use. The time is ripe for new developments in mechanical showmanship, and it is to the engineers that we look for these developments.

The engineer, as well as others, is never satisfied with accomplished performance: he must improve the performance, develop new technic, solve existing problems, and indicate new directions in which showmanship may develop. The engineer must develop a cool source of light for projectors, and thus reduce the hazard of fire; he must eventually produce a device that will automatically control the intensity of reproduction of sound in the theater, in accordance with the varying number of persons in the audience; and I am sure that it will not be long before the engineer will provide us with a device that will automatically make the requisite adjustment of the projector or film whenever a tendency toward inaccurate framing may occur. Such improvements are looked for by managers; the theater men everywhere are looking to the engineer for developments and accomplishments so visionary, of such importance, and of such great scope, that the stimuli for which we are all seeking will be realized. And with all this there must grow a better, a new, a more comprehensive understanding of the collective *showmanship* that results from the concerted efforts of the engineer, the producer, and the theater manager.

HOW THE S. M. P. E. CAN BE OF GREATER SERVICE TO THEATER MANAGERS*

CHARLES E. LEWIS**

Summary.—*The many problems pertaining to the equipment of a motion picture theater are discussed, and the author offers the suggestion that the S. M. P. E. organize and maintain a service bureau to which theater owners and managers may address the many problems encountered in operating their theaters, with a view of receiving clear and intelligent answers unbiased or prejudiced by manufacturer's influence. Among the problems referred to are those connected with sound reproducing apparatus, screens, ventilation, booth equipment, film mutilation, size of picture, acoustics, care of film, savings of electrical power, seating, etc.*

The exhibitor or theater manager may be likened to the driver of an automobile, of which there are two types: first, the man who may be an excellent driver, but who knows little or nothing about the mechanism that causes that automobile to run; and second, the man who has a keen understanding and knowledge of the intricate mechanism of the automobile, who has a fair understanding of the machinery under his control and who, therefore, derives better service and satisfaction from it.

So there are two separate and distinct types of theater operators. First, we have the manager who operates his theater efficiently and perhaps profitably, but who has little or no understanding of the many important phases of its equipment. This class of manager is by far in the majority. Those operators who possess an excellent knowledge of the theater's equipment are so few that they hardly rate the distinction of being even termed the minority. They perhaps represent one in a thousand.

The difference, however, between the man who operates an automobile about which he knows nothing, and the man who operates a theater about which he knows nothing, is that the latter is anxious to acquire a knowledge and understanding but is at a loss to know where to obtain it; assuming, of course, that such information is available.

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* Presented at the Spring, 1932, Meeting at Washington, D. C.

** Motion Picture Herald, New York, N. Y.

Not enough emphasis has been placed upon the equipment and furnishings of the theater. The manager has been, in many cases, oversold on show-merchandising and undersold on maintaining his theater in perfect condition.

To arouse his interest in the many intricate parts of his theater is a step in the right direction. But the great task is to create in these showmen the urge to lay their troubles and problems before the Society of Motion Picture Engineers, and to look to that body for intelligent advice, guidance, and instruction, free from bias, prejudice, or undue influence.

It would be absurd to say that advice about equipment is not available from other sources. Unfortunately, it is available from too many sources, and from too selfish sources. So much so, that the average exhibitor naturally distrusts many of these sources of advice and information about his theater and its multifarious equipment. This is not said in criticism of our supply houses or equipment contractors: it is only fair to assume that they are in business for the purpose of selling their merchandise. One can hardly expect them to take up the problems of the theater owner with a view of selling him a competitor's product. So, naturally, they endeavor to make their products fit the problem regardless of other existing conditions. This is not always the best way to help an exhibitor out of his difficulties.

By means of convincing publicity, the theater owner, house manager, and all others vitally involved in theater operation, should be encouraged to communicate their troubles and problems to a bureau of this Society. Such publicity should convince the manager that his problem will not be referred to some equipment manufacturer or others primarily interested in selling him something. He must feel assured that if there is something that he does not understand, concerning the wearing or replacing of expensive parts, the solving of screen problems, the correction of difficulties of projection, sound reproduction, ventilation, and so on, he could address a letter to the bureau conveying as accurately as possible the nature of his trouble, and then receive an immediate, easily understood reply, so far as it is possible to reply. Intelligently handled, such a bureau would quickly gain the confidence of theater managers and owners.

How little a theater owner had to know in the past in order to be rated as successful is well known. He had his theater, with its booth and a couple of projectors, and he had a screen; but beyond having paid for these items, he took little or no interest in how they functioned or whether they were receiving the attention and care they required. To "run the show" was his only interest, an attitude that could not be changed.

Modern group or circuit control has materially changed this point of view; the circuits were quick to recognize the economic importance of the equipment and of caring for it, and we find that departments devoted to these phases of exhibition are a most important part of all large circuits.

But the number of large national circuits is small, so that it is only proper that the attention of this Society be directed particularly toward the problems of the many independent theater owners and managers.

About a year ago, the owner of a small theater, dissatisfied with his projection, called upon the representative of a supply company to determine the reason for the poor projection.

The man sent by the supply company was the regular representative in that territory, and after a lengthy conversation with the theater owner and projectionists he recommended new lamp houses as the solution of the difficulty.

The theater owner, acting upon this advice, purchased two new lamp houses, which cost him quite a sum. The new lamp houses failed to improve the projection materially. After paying several large fees to various so-called experts, he finally succeeded in obtaining the services of a reputable engineer, who inspected the entire equipment, from the meter room to the arcs in the lamp houses, and found that, due to trouble in the generator and a few faulty connections, the full amperage was not being delivered to the arc and that consequently the screen was being insufficiently illuminated.

If this exhibitor could have consulted in the beginning, a bureau of the Society, and have explained to it his troubles, without relying upon a supply house salesman, he would have arrived at the solution of his problem much more quickly and certainly less expensively.

I shall now mention some of the problems encountered in the operation of theaters. The first problem of course, occurs in connection with the reproduction of sound. Others not so important, but very important nevertheless, are related to air-conditioning and other forms of ventilating and cooling apparatus, condition of prints while in the theater's possession, *etc.*

In the sound equipment we have an intricate and costly network of wires, panel boards, exciter lamps, amplifiers, horns, *etc.*, all necessary for properly reproducing sound from film or disk. Most of the houses, according to surveys made by various trade bodies, are equipped with apparatus made by either the Western Electric Co., or RCA Photophone, Inc. These companies maintain service men who make regular inspections and tests in the field, in addition to recommendations of necessary changes, replacements, and repairs.

What, if anything, does the theater owner know of the technicalities of his equipment? Little or nothing at all. Certainly he knows that the exciter lamps and photoelectric cells require replacement, because he has to pay the bills for them at frequent intervals. Certainly he knows that the fader must be set according to the sound and changing conditions in the auditorium. Of course, he knows that the batteries (if he has them) must be recharged and kept in good condition.

But what does he know about "bellows-assemblies," or "condensers," or the thousand and one other technically named parts which, he is told, must be replaced from time to time and for which he must pay as frequently.

There is apparently no standard by which expensive sound equipment may be judged. It is a case of paying a small fortune for something that never becomes one's property, and then spending another small fortune to keep it in first-class condition. And when the Society stops to consider what these repairs and replacements amount to in the average small theater, then, and only then, can it begin to appreciate the need of educating the present-day theater owner in matters of cost and of explaining to him the reasons why the various parts constantly break down and need to be replaced.

Through ignorance alone and no other cause, many fine theaters are today operating with projection booth equipment urgently in need of attention. Dependence is placed almost entirely upon the projectionists, many of whom are conscientious and capable; but unfortunately there are also many who are hardly better than ordinary "operators." The latter do not realize the importance of calling their employers' attention to little defects while they are yet little, thus avoiding costly repairs and breakdowns later.

The care and overhauling of the mechanism is another matter with which the theater operator should be familiar, so that he would not have to depend entirely upon the projectionist. Many projectionists suffer from the delusion that if they keep their machines running without burdening the theater owner with minor maintenance charges, they are regarded as more efficient than the projectionists who insist upon keeping their equipment in first-class condition at all times.

It is the theater owner's or manager's duty to check his equipment with the projectionists, and to make certain that the mechanism is kept in good order and is overhauled at frequent intervals. There is no question but that they would be quite willing to do this, were they convinced that such routine expenditures would turn out to be savings in the end.

On the subject of ventilation: it is startling to realize how little is known about this important part of the theater's equipment. To the great majority of theater owners, referring to the exhibitor in the average small community, ventilating equipment consists of merely a couple of exhaust fans and nothing more. When the weather is warm, the usher, operator, or doorman is told to "turn on the fans," and there ends the exhibitor's knowledge of his ventilating units. Larger houses have their air-conditioning and refrigerating plants, which, fortunately, require for their operation expert engineers who fully understand the equipment and how to get the most out of it. But these are the exception rather than the rule. For the most part, ordinary exhaust or blower fans are the only equipment used for ventilating theaters throughout the country. Adequate education in this matter would probably prompt many exhibitors to install more up-to-date equipment.

Then again, there are many theaters already equipped with up-to-date apparatus, the full advantages of which are not realized due to the lack of knowledge of how to operate it.

Again we have the parallel, of the man who drives the automobile. When he experiences a little trouble, not knowing what it is all about, he drives to the nearest service station, where, instead of being educated, he is charged a fee for making a minor adjustment or repair, and is sent on his way.

The theater operator is in the same predicament. When his ventilating equipment does not function properly, he notifies the company that installed it, or some supposedly recognized agency for the maintenance and repair of such equipment. A service man sent to the theater makes some slight adjustment, leaves a bill and goes his way. And so the exhibitor remains as ignorant of his equipment as he was before the service man arrived.

Suppose that the exhibitor knew that the Society of Motion Picture Engineers maintained a bureau to which he could apply for information about his ventilation troubles. Does it not sound reasonable that he would grasp the opportunity of addressing a letter to this bureau, explaining his difficulties and asking for advice and guidance? How much good can be accomplished by providing such technical education for the theater operators, I leave to your own imagination.

Now the question of caring for film: thousands of feet of film entering the theater each week must stand the grind until the engagement is over, and then must be shipped back to the exchanges whence it will again be shipped to other exhibitors.

What, if any, thought is given by the exhibitor to the care given the film while in his possession? Very little. In the dim and distant past the exhibitor bought a pair of rewinders, a few film magazines, and a bottle of cement, thus completely discharging himself of his duties. As he rarely hears further about it, he never quite realizes that the reason why he is receiving prints that are in bad condition is that other exhibitors like himself are indifferent to the care of film, and so abuse it that it becomes hardly fit for further use and a cause of aggravation and worry to the next exhibitor.

If the mutilation of film caused by faulty projectors and dilapidated rewinders were stopped, the print thereby being given a fair chance of accomplishing its natural life, ordinary wear and tear excepted, a saving amounting to thousands of dollars would result. Savings would be achieved by the distributor and exhibitor alike, in avoiding terrific losses due to fires, not to mention the panic hazards, *etc.*, all entirely due to such negligence; and the reproduction of sound, too, would immediately improve, due to the better care given to the sound track.

There is no doubt that many theaters today lack proper acoustical treatment. Chief among the reasons for this is the fact that many theater owners fear that the cost of good material and of installing it is entirely too great. They do not seem to be aware that there are various types of material, or that a proper survey of the particular situation might indicate the need of making only a small expenditure.

But visualizing a high cost, the exhibitors hesitate from month to month, permitting the performance of their expensive sound equipment to be ruined by the unsatisfactory acoustical conditions of their theaters.

As to sound screens, thousands of theater owners would like to know just where they stand in this matter. Many of the sound screens installed during the mad rush for sound equipment proved entirely unsatisfactory as to length of service, especially as compared with the screens used for silent projection.

As another point in this connection, many exhibitors purchased sound screens under the impression that, like the silent screens, they could be recoated, refinished, or cleaned by some process that would add to their years of service. Most of the exhibitors now find that when the sound screens begin to fade or become discolored they must be replaced with new ones. So here again we find an important item of theatrical equipment about which so many exhibitors know little and on which they can get still less satisfactory information, other than from salesmen.

It will surprise you to know how many screens are too small for the theaters in which they are installed. No doubt, a great deal of complaint must come from the patrons of such theaters, especially where the smallness of the projected image makes it extremely difficult for patrons sitting at a distance from the screen to obtain a clear definition of the characters. The Society might suggest to many of these exhibitors that they determine the possibility of enlarging their picture by merely changing the masking and the lenses.

I recall visiting, a short time ago, a theater in which the projected picture was small. I asked the owner why he did not increase its size by at least fifty per cent, and was informed that he could not afford to spend the money for a new screen and new lenses; a reply that emphasized the unfortunate ignorance of many theater operators, whose screens might be large enough, but who masked them to conform to the size of the image projected by their present lenses.

Reverting to the question of projection room equipment, there must be considered, in addition to the projectors themselves, the various forms of transformer, generator, rectifier and rheostat; also, the type of lamp house and arc employed, because when all is said and done, the power of the arcs determines the definition, clearness, and brightness of the picture projected upon the screen.

A bureau, the functions of which would be to educate the exhibitor and theater manager in these matters so that they may derive the utmost satisfaction from their equipment, would help them to make great strides in improving the quality of projection, and thereby improve their business.

The question of heating a theater is another important factor that, like the old-fashioned exhaust fans, means no more to the exhibitor than starting a fire and putting coal into the furnace. The exhibitor could no doubt realize a saving and improve the comfort of his patrons by installing modern equipment, either automatic oil burners or automatic coal stokers.

The quantity of electrical power utilized in theaters has already attracted no end of attention from various groups and organizations specializing in the so-called reduction of electrical rates and electrical consumption; but, unfortunately, their methods are purely mercenary and their first thoughts are of personal profits for themselves rather than of ultimate savings for the theater.

It would be a simple matter for the educational bureau of the Society, if I can call it such, to point out to the owners and managers of theaters, the various means by which they could reduce their electrical expenses without reducing the efficiency of the equipment or affecting the audience's appreciation of the show. The proper choice of wattage of the various electrical fixtures, and the size of the generator; the use of low-intensity lamps for the theater of moderate size, and the installation of mercury flashers represent but a few of the direct means of reducing the electrical costs involved in operating a modern theater.

Those whose work confines them to cities like New York, Chicago, and other key cities, are rather prone to underestimate the isolation of theaters in the small towns, so far as obtaining the needed and expert advice on the many matters that we can probably obtain merely by picking up our telephones.

To appreciate fully how difficult it is for the theater of the small town—and sight must not be lost of the fact that the great majority of theaters throughout the country are located in small towns—to receive accurate and reliable advice on their problems, it is necessary to operate a theater oneself in order to appreciate the hundred and one problems that confront the small town theater owner, and the inadequacy of the advice upon which he must rely.

Consider the question of seats. The chairs cause probably more annoyance than any other feature of theater maintenance, particularly in theaters located outside of key cities.

The matter of resulphuring seat standards, tightening the various parts, and keeping the arm rests securely fastened to the standards, is a job that the average theater porter or usher could hardly be expected to understand, despite the fact that the manager depends upon them to keep the seats in serviceable condition. Yet, it is by no means difficult to instruct the theater owner in the manner of doing these things in a quick, efficient, and inexpensive manner.

In any number of theaters seat standards are still made tight to the concrete floors by using cement which, as you probably know, is of no use whatever, as the shaking of the seats by the patrons grinds it into powder. Still other theater owners permit their porters or maintenance men to use lead for this purpose, as unsuccessfully as to use cement.

Circuits have overcome the seat difficulty almost entirely, but education was required to awaken them to the importance of the matters, just as will be the case with the thousands of independent theater owners. This likewise applies to the recovering of seats, the covers of which have become worn or torn. From theaters in small towns these seats must be shipped to distant points to be recovered. It would be a simple matter for managers to purchase the leather and recover these seats themselves, since we here are probably well aware of the fact that this is far from being a difficult task. Merely that the covering of seats may be profitable to some of the seating companies, is no justification for our permitting the small theater owner to continue to spend money so foolishly. He can buy his leather in large quantities and do all of the necessary recovering himself. It might be difficult for the members of the Society to apprehend the tremendous number of theaters in which are found up-to-date sound and projection equipment, but yet seats that properly belong in a museum rather than in a theater.

In recent years, those theater owners have heard a great deal about the *de luxe* theaters built during the theater boom, and have read all sorts of stories about the beautiful plush, upholstered, Marshall-spring seats with heavily upholstered backs; and they have also heard, no doubt, of the cost of such chairs. They could be given to understand that their present chairs could be replaced by up-to-date chairs with spring seats, or could be reseated at a reasonable price. By so doing not only the comfort of the patrons would be improved, but an increase of business ought to result.

I have been asked whether the comments received from patrons on the mechanical quality of the shows are of any value to the theater manager; and I can answer emphatically, "Yes." The public today is "show-minded." Good roads have made it possible for them to visit nearby large cities where are found the newer and more up-to-date theaters, and as a consequence they have no hesitation about speaking to the manager or owner of their local theater and comparing it with the better theaters in the large cities.

Such comments more than anything else have undoubtedly forced many a reluctant theater owner to improve the mechanical presentation of his shows. The enterprising theater owner not only wants the comments and criticisms of his patrons, but invites them; and when a complaint is registered by a few patrons on the poor quality of the projection, the owner will in many cases be glad to improve it, provided he knows how to do so at the least possible cost.

Another question that has been addressed to me on many occasions is whether, since the advent of sound, theaters rehearse their shows before admitting the public to see them. When sound was first introduced, it was *via* disks and synchronism of the film and disk was necessary. Therefore, it was vitally important that every theater screen its show some time before admitting the public, so as to allow sufficient time in which to synchronize the show, obtain new disks or prints, and make other necessary changes. This, however, has been eliminated from practically all but the *de luxe*, grade *A* theaters, because the recording of sound on the film has completely eradicated the danger of asynchronization; and as this was the chief reason for rehearsals, exhibitors are now content to revert to the pre-sound methods and see the show for the first time themselves at the first performance.

Quite often, complaints are registered that the projection in a theater is poor: the picture is much too dark. This I have found, in most cases, to be due not so much to the equipment as to the darkness of the particular print shipped by the distributor. If the distributing companies would refrain from circulating dark prints, this trouble would be eliminated.

I have made it a point to inquire of theatrical men throughout the country what they thought of the possibilities of wide film, and in view of the physical layout of the majority of theaters outside the key cities, the introduction of wide screens would be not only impracticable, but in many cases impossible. The present size of picture, in the opinion of most theater managers, should remain; no change should be made at this time.

Another question that has been asked from time to time referred to the reproduction of radio broadcast programs in motion picture theaters. In answering a question of this kind, it must be kept in mind that the large sound companies such as Electrical Research Products, Inc., and RCA Photophone Inc., do not permit the connection of radio receivers to the amplifiers of the sound equipment of the theater. Nevertheless, where certain programs are very popular locally, enterprising theater managers have made such connections without the consent of these companies, and presented them in their theaters *via* their loud speakers behind the screen.

Such other matters as seat indicators, rear projection, electrical organs, patron-counting systems, and other such new equipment, are of little importance or of value to the great majority of theaters throughout the country, and the discussion of such matters would be out of place in this paper.

It must be kept in mind that while a few subjects of common interest to engineers and exhibitors have been selected for this paper, it would be impossible to discuss all the phases of theater operation. To do so would entail a discussion that would last for days; but I feel that if the comments made in this paper have proved interesting and will serve as an incentive for the creation of the bureau referred to, a great deal will have been accomplished.

The many problems that would confront a bureau of this kind, and the thousand and one questions that it would be in a position to answer, would be tremendous.

Such a bureau would have to maintain files and information pertaining to all the phases of present-day theater operation. It would soon win the confidence of theater managers and owners, so that they would write to the bureau for opinions, advice, guidance, and education in whatever subject they may be interested.

THE FILM PROBLEMS OF THEATER OPERATION*

STANLEY SUMNER**

Summary.—*The paper treats of the condition of film after it has been used thirty or more days, and the effect produced by poor reels and bent and damaged film cases upon the photographic and other qualities of the film that have required so many years of endeavor to perfect. The paper concludes with suggestions to the home offices as regards their method of handling replacement requisitions from exchanges in the territory.*

In November, 1926, a theater in which I am interested was opened in Harvard Square, directly opposite Harvard College Yard, some three miles from the center of Boston. The theater accommodated about 2000 persons, and presented both motion pictures and stage shows. The clientele, of which perhaps 25 per cent was composed of college men and women, and the remainder of the better class of residents of Cambridge and surrounding towns, was not interested in the stage presentation; but rather preferred a straight motion picture program of the best pictures obtainable. Local conditions necessitated the showing of pictures some thirty days after the completion of the first-run Boston showing, and we followed the old New England custom of presenting double features with short subjects, giving a full three-hour show operating continuously from 2 P.M. until 11 P.M., seven days a week.

Prior to the opening of the University Theater, the theaters that I had managed had been built by groups of men who, knowing nothing about the show business, had had the buildings constructed according to the plans of the architect; in some cases embellishing them in accordance with their own generally impracticable ideas, but in most cases altering the architect's original specifications in order to economize here and there. As a consequence of this experience, I harbored the idea that were I ever to have anything to do with building a theater, I would correct the hundreds of defects that I felt I had discovered in theaters built by other men.

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* Presented at the Spring, 1932, Meeting at Washington, D. C.

** University Theater, Cambridge, Mass.

The University Theater presented such an opportunity; with few exceptions, everything was built into the theater originally that seemed requisite to efficient operation, and that appeared to be the last word in respect to the comfort of the patron without making him awe-struck by the gaudiness and over-pretentiousness of the modern movie palace.

The projection room stands as originally built. It measures twenty-six feet by ten feet, with an adjoining generator room thirty feet by ten feet, so that the sound installation for three projectors was made without having to make any structural changes. The lack of air conditioning or refrigerating systems has troubled us considerably, but at the time the theater was built we felt that the requisite expenditure of $50,000 was most unwise for a suburban theater. We are now convinced that conditioned air is necessary in all theaters, and we are making plans for installing such equipment.

In connection with the operation of theaters, I feel that there are some problems which, though in themselves trivial, might be studied by the Society, particularly as regards the technical instruction of those in charge of the handling of film. I am referring particularly to the care of the film when it is in the theaters of the country, actually earning the money that keeps the wheels of Hollywood in motion.

Largely through the untiring research work of members of the Society, the industry has made great strides in improving film stock, photographic processes, sound reproduction, in fact, everything that contributes to the motion picture; but the seemingly trivial things must not be neglected. These things should be called to the attention of those who handle film and, among others, the following topics should be considered: film in use, reels on which the film is wound, cases in which the reels are shipped to the theaters, inspection departments maintained by the film exchanges, and replacement requisitions as received in the home office originating from the film exchanges out in the territory.

(1) *Reels.*—The winding of film on a bent reel will, even in a single winding, spoil the most perfect sound and photographic effects, obtained only after long years of endeavor.

(2) *Cases.*—The packing of new and perfect reels into a film case that has been dented and jammed will, in one shipment, spoil the reel and in turn the film, *etc.* A film case is rarely opened without disclosing a collection of dirt, dust, sweepings, and film clippings. The accumulation of a year or more rests on the bottom of the case. In

shipping, these cases are inverted many times, the dirt is scattered over the reels and gradually works into the windings, causing the scratches with which you are only too well acquainted.

(3) *Inspection Departments.*—The young women employed in the film exchange inspection rooms pass film as satisfactory when most of the sprockets on one side of the film remain intact; a patch is approved if it is cemented at least halfway across; the alignment of the rewinder seems to be of no importance; and whether the band will fit over the film after it is wound, whether it is tightly or loosely wound or unevenly wound, is given little or no consideration. I recommend that every exchange center employ an efficient and competent film expert, as is done by the Boston office of Metro-Goldwyn-Mayer and Paramount, who should have complete jurisdiction over the inspection, receiving, and shipping departments. His duties should be: (1) to delegate competent persons to inspect every film case; (2) to see that the film case is free from dirt and that it is not bent; (3) that the required number of reels will fit into the film case easily and without jamming; (4) to ascertain whether the reels are in perfect condition; (5) to make sure that the film is wound on the reels so that the sides of the winding will be smooth from the hub to the periphery; (6) to inspect personally and at frequent intervals the film approved by the various inspectors, *etc.;* (7) to require inspectors to report film damage of any kind immediately after the film is returned by theaters; (8) and to require that theaters pay for such damage. If this inspection is done honestly and efficiently and the film is sent in perfect condition to the theater, a confidence would be built up in the minds of theater managers and they would be satisfied to pay for damaged film.

It is not unusual for my projectionists to work two or three hours on a single feature in order to put it into the condition they think it should be in to assure its safe travel through the projectors; and I want at this time to give you a brief account of an occurrence that I feel will convince you of the need of properly and adequately instructing the film exchanges, theater managers, and projectionists in matters like these.

About three or four months ago my chief projectionist reported that he had been working more than two hours on a Fox feature and had made so many cuts that he felt that he had ruined the continuity of the picture, cutting in some instances, where the sprockets were completely broken out, as much as twenty feet. He had gone hurriedly through the last four reels without attempting to make repairs, and was sure that if it were to be put in usable condition, there would be nothing left of the story. I got in touch with the local Fox Exchange and found that although no extra print was available, there was one ready for shipment to another local theater that could be exchanged for this one if we could arrange to return the print immediately.

The exchange was made; and upon inquiry, prompted by curiosity, I found that the bad print was being sent to a theater seating about 2000 persons in a city adjoining Cambridge. The exchange manager told me that he never received complaints about the condition of his film. I told him that I was not surprised, and wagered that he would receive no complaint from the theater that was to receive the print that I had reported as fit for the junk heap. We found that this theater ran a full twelve shows and made no complaint either during or at the end of the run. I might say in passing that in this particular theater, two reels of a feature had been burned up the week before this particular incident occurred.

Replacement.—I recommend that one print of each subject, both shorts and features, be maintained solely as replacement prints so that never, except in the case of emergency, shall a print be sent from an exchange in imperfect condition, normal wear and tear excused. I further recommend that the home offices have on hand a sufficient number of prints to maintain upon requisition the quota of replacement prints in the exchanges.

I recommend that a system of educating the projectionist be evolved and that every operator's union be encouraged to detail a man to inspect the conditions of booths within a given territory; and that the union be encouraged to take drastic action, if necessary, against men whose work does not measure up to the given standard.

I recommend that a standard code of inspection be worked out and that it be used by all distributors; such a code has been suggested to me by Mr. J. L. Caddigan of the Boston Paramount Exchange.

In closing, I shall read a brief paper that Mr. Caddigan sent some time ago through the territory served by his exchange:

"Dependence is a poor trade to follow, and projectionists who rely solely upon the film exchanges to furnish them good prints may find their confidence misplaced. Projectionists are neglecting a great responsibility. Every poor print received in the projection room should be reported immediately to the theater manager who, in turn, should forward the report to the film exchange in question.

"The film exchange inspection department is in a sense like a dam, holding back from the theaters a flood of bad prints. As the inspection department is a combination of mechanical and human elements, its perfection can not be guaranteed; and occasionally a weak spot develops in its structure.

"Hydroelectric power companies throughout the world keep a constant watch on their source of power (the dam), and an immediate report is made of any sign of weakness. A poor print is a warning of weakness in the structure of the inspection department of the exchange; and unless the exchange receives immediate notice of this condition, a serious leak might develop, flooding the theaters with poor prints and bringing disaster to the box-office and projectionists.

"An idea prevalent among projectionists and managers is that the reporting of poor prints is void of results. This is an error. If the report is addressed to the proper person in the exchange, the sender may be sure that it will receive immediate attention. A leak is of no value to anyone, and the projectionist should never hesitate to report a poor print, as he may find his neglect to do so will be a boomerang.

"Bad reels and damaged film cases, in fact, any agency that tends to cause film mutilation and damage, should be noted in these reports.

"The film exchange is desirous of serving the theaters with good prints. Theaters and audiences are entitled to them; and with cooperation between the exchanges and the theaters, poor prints will become a memory."

THEATER OPERATING PROBLEMS*

M. A. LIGHTMAN**

Summary.—*Owing to the advent of sound at a highly prosperous time and the tremendous demand for pictures that was placed upon Hollywood, more emphasis was placed upon quantity than upon quality. The capacity of the country for exhibiting motion pictures was increased beyond reason, and as a result, some drastic measures must be taken to rectify the situation. The exhibitor's prime interest lies in the picture, not in the means of producing it. It remains for the engineer to develop new principles of projection, such as color and stereoscopy, to provide the business of exhibiting with new attractions.*

Unfortunately, sound came into the picture at a time when the prosperity of the country was greatest, and when thoughts of valuation were submerged by the great urge to produce. Many ridiculous things were done; too many theaters were built and too many seats were placed in them, with no thought of a possible excess of theaters and seats in the future. Perhaps, if we had kept this possibility in mind, we should not have the headaches that we have today.

A tremendous demand was placed upon Hollywood; and pictures were produced to satisfy this demand, the emphasis being placed upon quantity rather than upon quality. To grind out the six or seven hundred pictures that were produced was preposterous.

The motion picture industry is in a very serious condition, and I can not refrain from expressing the thought that unless we begin to appreciate the fact, and unless the engineers devise ways and means of correcting this situation, we are doomed. We have too many large theaters today, and must take a loss. I know of a city having theaters the total seating capacity of which is 22,000, as compared with a total population of 150,000 persons. Of the total population, twenty or thirty thousand are infants or are infirm, so that in the theaters of that city one seat is provided daily for every five persons, or about one seat for each person every five days. To fill all the seats, every person in the city would have to attend the

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* Presented at the Spring, 1932, Meeting at Washington, D. C.

** Motion Picture Theater Owners of America, New York, N. Y.

theaters nearly sixty times a year. This emphasizes the folly of the situation; it is impossible to guess how an exhibitor can "get by" under such circumstances.

Some drastic measures must be taken to rectify this situation. Next year will be the last in which the present method of distribution will be used. I said some time ago, in Canada, that companies would not continue to produce sixty or seventy one hundred per cent dialog pictures each year; but rather fifty per cent dialog, with proper sound effects. The art today is different from what it was; the change is slow in coming, but it is our business to recognize that it is coming.

When on a recent visit to Hollywood, I saw all the phases of making motion pictures, and was greatly impressed by the completeness of the technical and engineering developments. What an amazing thing it is to realize that on each lot is a complete city, self-sufficient in all its appointments, from hotels to machine shops and laboratories.

As for the exhibitor, there are three things of prime importance to him: (1) the projection of the picture to the screen; (2) the comfort, happiness, and freedom from eye-strain of his patrons; and (3) the entertainment value of the picture itself.

The projection of the picture is what interests the engineer. Although the motion picture is today far superior to what it was in the beginning, yet one who thinks of it in terms of mechanical perfection can easily become annoyed. There is much room for improvement, especially as regards the reproduction of sound. Some means must be taken to prevent the emission of noise from the projection room into the auditorium, and, in fact, to make the projection room quieter, so that the projectionist will be better able to determine the quality of the reproduction. The projectionist would be more attentive to his duties in a quiet room; noise tends to make him careless.

The elimination of noise would do wonders in enhancing our appreciation of silent sequences. The important feature of a picture is the contact that is established between the audience and the actors, and with disturbing noises it is impossible to enjoy a complete appreciation of the picture.

The placing of an image on the screen is the last phase of the business, yet, in fact, it is the only thing that counts. I do not care what technical theories are involved, the only thing that interests the exhibitor is what he shows to his patrons. The exhibitor is the agency of contact between the public and the industry, and his independence should be raised to the highest degree. He should feel his responsibility and realize how important his mission is. Regardless of what one's point of view may be, he must be able to look at the picture on the screen and see the product as a finished job.

I should like to make a few simple suggestions. If it were possible to change the height of the aperture so that more action could be photographed on a given length of film, a saving of 15 or 20 per cent would be effected in raw stock. The saving would be considerable also to the exhibitor, in costs and expressage. No one can say that if 200 feet could be the standard, it would not be more effective than 500; with half the number of reels and 1700 feet of film equivalent to 2000, the film expenses could be cut in half.

Grandeur film is too wide; the large size of the image interferes with the creation of the intimacy desired between the picture and the audience. The same is true of the large screen. Why can we not agree upon a size of picture somewhat larger than the one we have at present—say, in the ratio of $1^1/_3$ for the width to 1 for the height? Concerning color, one of the greatest problems in dealing with colored pictures is that of obtaining good results on a flat surface; a three-dimensional process would assist materially in solving this problem. If these things were given to us singly, today, I am afraid they would be of no use to us. If it is the intent of the engineer to release such developments, I would like him to delay doing so, and to realize color and stereoscopy in a process that is economical and to which our existing equipment can be adapted. When all these improvements can be given us at one time and with little cost, then they will be most welcome and beneficial.

THE FUTURE OF MOTION PICTURES*

COURTLAND SMITH**

***Summary.**—The motion picture screen is compared to a printing press in its possibilities for the dissemination of knowledge. Rear projection is discussed; also the necessity for encouraging independent producers, and of producing films dealing with educational and scientific subjects in addition to the dramatic features.*

With the birth of the motion picture, the world found a new medium of expression, destined to be the most potent it had ever known, and perhaps more permanent in its influence than the printed word. Those first to use this medium used it for providing amusement only, without realizing its immense potential applications.

The pioneers of the motion picture industry were men of great courage and vision. They have now passed away: they are either dead, out of business, or exhausted: Zukor, Marcus Loew, Fox, these three men, with the Schenks, were the pioneers of the business. The men who are now directing the motion picture business, with one or two exceptions are, I believe, a second "crop," having no great vision or courage. Their responsibilities are too heavy, considering the 72 millions of dollars that the industry represents. We can not hope for much from these men.

Strange as it may seem, I feel that it is quite fitting that the future of the motion picture be discussed here rather than in Hollywood. It is to the engineers and scientists that we look to pull this industry out of the existing depression and to make apparent the fact that the motion picture is the most far-reaching, powerful, and potent of all mediums of expression.

The motion picture screen is like a printing press. It should be capable, it must be capable, of depicting anything that the printing press can print. It must not be limited to novels, but must cover a wide range of subjects: education, literature, amusement, travel, personalities, science, invention, and everything that has to do with

* Presented at the Spring, 1932, Meeting at Washington, D. C.

** Pathé News, New York, N. Y.

human life. That can be done only when all the mechanisms connected with motion picture production are assembled. Pictures ought to be as easily produced in Cleveland and Jacksonville as in Hollywood. Hollywood is one of the greatest centers of production, but when a man goes to Hollywood, his mind usually becomes closed to anything new. Engineers must make it possible to photograph everywhere. They must make it possible to produce a full-length picture in Chicago, or in Klamath Falls, or in Tallahassee. The engineer must make possible for the motion picture the same wide and rapid production and distribution that the printing press makes for the newspaper.

There is nothing more interesting than the animated cartoon. Cartoons, to become available for home exhibition, must not be costly either to produce or to rent. Some cameras have already been designed with this thought in mind. But the engineer has the job of simplifying the apparatus; of making the apparatus more reliable and the requisite specialized labor less necessary, so that the motion picture may become as generally used as is the printed word.

That is one reason I am interested in the development of the newsreel theater, and finally, the small theater. The small theater has such tremendous advantages over the larger theater that it will ultimately lead in providing amusement and education.

I should like to explain one thing about rear projection. It has no particular advantage except that it permits retaining the ceiling height found in any store. No store lacks head clearance. The advantage of choosing a "store" for theatrical purposes is that there are thousands of locations from which to choose. Also, it should be remembered that the "store theater," if a failure, as some theaters have been in the past, can easily be closed, the equipment can be removed, and the store be used for purposes other than theatrical.

Ten years from now, we will regard as silly the time when "all the eggs were in one basket." One might as well expect to achieve excellence in literature by bringing one hundred authors into this room and saying to them: "I want you to turn out one thousand articles a year." The authors immediately would become fifty per cent less efficient. We will never again have great successes produced by the large companies, operated as they have been in the past. Motion picture production must be broken up. D. W. Griffith was the greatest producer we ever had, but he produced only one really great picture. Independent production must be encouraged, for we must have a certain number of successful pictures each year, and these will not come from the large companies.

The small theater is successful; and when there are short programs it is quite successful. I have followed 700 programs of shorts, ranging from good to excellent and not one has been a failure. Unlike features, well chosen short programs cover all subjects. The great, heavy productions and the over-advertised, over-rated features have lost the American audience. I see in the future an increase in the use of the screen for other than feature productions.

As for the engineers, I believe that they have done their work only fairly well. They made a mistake when they allowed the recording of sound to be taken from New York and rushed to Hollywood, where it was not understood. If the engineer ever has the right to control what he makes and creates, he ought to have something to say about how it is to be used.

I want to repeat just once; the screen may be likened to a printing press, which will reproduce exactly what is put on it. We have high-speed newspaper presses, little job presses. It is now possible to "print" on the theater screens in New York, in Portland, and in Tulsa, Oklahoma. But in addition the motion picture must enter the homes, schools, and theaters, and especially the industrial field. Accurate, mobile, cheap apparatus is required. All that lies in the future.

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SOCIETY ANNOUNCEMENTS

ANNOUNCEMENT OF FALL MEETING

NEW YORK, N. Y.

OCTOBER, 5, 1932

The 1932 Fall meeting of the Society of Motion Picture Engineers will be held at New York, N. Y., on October 5, 1932. Owing to the prevailing conditions, the Fall meeting this year will be limited to one day, and will be coincident with a meeting of the New York Section. The tentative arrangements provide for holding the meeting in the auditorium of the Electrical Institute of New York, in the Grand Central Palace, Madison Avenue and 48th Street, New York, N. Y.

An attractive technical program is being planned by the Board of Managers of the New York Section, and it is expected that preceding the meeting an informal dinner will be held at a hotel convenient to the place of meeting. The election and installation of the new officers for the year 1933, of both the general Society and of the New York Section will take place at the meeting. Nominations have been completed and voting ballots are being mailed to the active membership of the general Society and the New York Section, respectively.

Complete details concerning the meeting will be mailed to the membership of the Society in the near future.

STANDARDS COMMITTEE

At a meeting held on July 14 in New York, N. Y., additional consideration was given to the report dealing with the standardization of 16 millimeter sound film, presented at the Washington meeting of the Society and returned to the Committee for further consideration. After considerable discussion, and after a film demonstration presented for the purpose of illustrating several technical questions as regards methods of recording sound, the Committee finally agreed to resubmit its original report to the Board of Governors for validation action, with the recommendation that when publication has been made and comments obtained from the industry, an opportunity be afforded for an oral hearing to the proponents of the two dimensional plans contained in the Committee's report.

In addition, the Committee continued in its work of revising and bringing up to date the dimensional standards now contained in the booklet known as "Dimensional Standards for Motion Picture Apparatus and Recommended Practice, ASA-Z22-1930."

SUB-COMMITTEE ON EXCHANGE PRACTICES

A meeting of this sub-committee of the Committee on the Care and Development of Film was held at the General Office of the Society on July 20, at which time the data collected by the members of the sub-committee dealing with the various problems of exchanges were discussed, preparatory to incorporating them in a preliminary report. This data related to both technical and administrative activities of exchanges.

SUB-COMMITTEE ON LABORATORY PRACTICES

A meeting of this sub-committee of the Committee on the Care and Development of Film was held at the General Office of the Society on August 18. Provisions were made for allotting the various phases of the sub-committee's work to the several members, so as to gather data that later may form the basis of the fall report. The scope of the sub-committee's work includes the development and preparation of negative film, printing and duplicating, developing and fixing of positive film, drying of film, handling of film during processing, and matters relating to the sensitometric control of processing and printing. The possibility of standardizing various phases of the processing technic is being given close attention, with a view of indicating the means to be taken toward realizing a close control of gamma in accordance with picture and sound requirements.

EMPLOYMENT ADVERTISEMENTS

In order to assist members of the Society who are desirous of obtaining positions, the Board of Governors decided to establish in the JOURNAL an "Employment Page." Advertisements on that page will be available to members of the S. M. P. E. who desire positions and to manufacturing concerns seeking trained men for positions. Material for publication is subject to editing, and must be sent to the General Office of the Society by the 10th of the month prior to publication. Replies to advertisements should be addressed to the box number indicated. All replies will be forwarded directly to the advertiser.

Each employment advertisement shall not exceed one-sixth page in length; a charge of $2.00 will be made for a single insertion, or $5.00 for three consecutive insertions.

SUSTAINING MEMBERS

Agfa Ansco Corp.
Bausch & Lomb Optical Co.
Bell & Howell Co.
Bell Telephone Laboratories, Inc.
Case Research Laboratory
Du Pont Film Manufacturing Co.
Eastman Kodak Co.
Electrical Research Products, Inc.
Mole-Richardson, Inc.
National Carbon Co.
RCA Photophone, Inc.
Technicolor Motion Picture Corp.

The Society regrets to announce the death of an honorary member

Jean Acme Le Roy

whose name is hereby added to the

HONOR ROLL

of the Society of Motion Picture Engineers

The Society regrets to announce the deaths of

William R. Brewster

July 15, 1932

Vane R. Cralley

July 4, 1932

Henry Dain

July 24, 1932

HONOR ROLL

OF THE

SOCIETY OF MOTION PICTURE ENGINEERS

By action of the Board of Governors, October 4, 1931, this Honor Roll was established for the purpose of perpetuating the names of distinguished pioneers who are now deceased:

LOUIS AIMÉ AUGUSTIN LE PRINCE
WILLIAM FRIESE-GREENE
THOMAS ALVA EDISON
GEORGE EASTMAN
JEAN ACME LE ROY

PAMPHLETS, BOOKLETS, AND CATALOGUES RECEIVED

Copies of the publications listed here may be obtained free of charge by addressing a request to the manufacturer named. Manufacturers are requested to send new publications to the General Office of the Society immediately upon issue.

Akeley Camera, Inc.: A leaflet describing new audio cameras for single and dual systems; various features of the cameras are listed, and detailed photographs are shown. The leaflet also describes the Akeley recording machine, a roller gate recording unit, cable reels, and a collapsible film spool. Address: 175 Varick St., New York, N. Y.

Da Lite Screen Co.: A leaflet describing a new screen for use in schools, churches, *etc.* The screen, mounted on a metal spring roller, is raised into place by means of a crank that actuates folding side-arms, which stretch the screen at the end of the raising operation. Built into a steel-bound trunk fiber case; three types of silent screen: white, beaded, and silver; two types of sound screen: white and beaded. Address: 2723 N. Crawford Ave., Chicago, Ill.

Hall & Connolly, Inc.: A booklet describing the type *HC*-10 automatic super-intensity projection lamp, in which the projection of an image of the arc upon a thermostat at the rear end of the lamp controls the speed of the feed motor, and hence the rate of feed of the carbons. The type *EF* super-intensity spot, flood, and effect light is also described. Address: 24 Van Dam St., New York, N. Y.

Jenkins & Adair, Inc.: Bulletins *24*, *25*, and *28* describe, respectively, a recording amplifier for sound-on-film recording (portable or for rack mounting), a series of plugs and receptacles for newsreel and portable sound equipment, and the new type *B* 35 mm. recorder. Bulletin *23* describes in detail the construction and operation of the type *B* 35 mm. recorder. Address: 3333 Belmont Ave., Chicago, Ill.

Miles Reproducer Co., Inc.: Catalogue *P*, a leaflet, describes the Miles power amplifiers and portable public address systems. Catalogue *E* describes microphones, exponential horns and baffles, and accessories. Address: 244 W. 23rd St., New York, N. Y.

Motion Picture Lighting Co., Inc.: A booklet entitled "Lighting and Sound Equipment for Motion Pictures," referring to the sales and rental of motion picture producing and stage lighting equipment. Address: 34–12 Graham Ave., Long Island City, N. Y.

Operadio Mfg. Co.: Leaflet describing a new dual amplifier for use in theaters; model *64* furnished complete with two independent amplifiers, monitor speaker, and control panel for operation from two sound heads; model *52* the same as model *64* except that one amplifier unit is omitted. Address: St. Charles, Ill.

JOURNAL

OF THE SOCIETY OF

MOTION PICTURE ENGINEERS

Volume XIX **OCTOBER, 1932** **Number 4**

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JOURNAL
OF THE SOCIETY OF
MOTION PICTURE ENGINEERS

SYLVAN HARRIS, EDITOR

Published monthly at Easton, Pa., by the Society of Motion Picture Engineers.

Publication Office, 20th & Northampton Sts., Easton, Pa.
General and Editorial Office, 33 West 42nd St., New York, N. Y.

Subscription to non-members, $12.00 per annum; to members, $9.00 per annum, included in their annual membership dues; single copies, $1.50. A discount on subscriptions 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 33 W. 42nd St., New York, N. Y.

Entered as second class matter January 15, 1930, at the Post Office at Easton, Pa., under the Act of March 3, 1879.

THE BELL & HOWELL FULLY AUTOMATIC SOUND PICTURE PRODUCTION PRINTER*

A. S. HOWELL, B. E. STECHBART, AND R. F. MITCHELL**

Summary.—*A new printer, in which the fundamental design is established on basic sensitometric specifications, is described. An analysis is presented of the requirements of the laboratory ideal of a printing machine, including such specifications as fully automatic fool-proof interlocking, elimination of operator's mistakes and film wastage, and many other features desirable in a machine of this type. The paper describes the new printer fully and shows how the printer can be set in practice to conform to absolute sensitometric standards.*

The first commercially successful sound pictures came into prominence with the use of a synchronized disk, and the system presented no printing problems. However, since 1928, when sound-on-film gradually became accepted for the making and showing of sound pictures, printing problems of the laboratories were multiplied many times.

Sound records on film lend themselves ideally to the continuous principle of printing, and it was fortunate for the industry that continuous printers were already available. The sound tracks of the first sound-on-film pictures were printed by masking the aperture. Quite often, two printers were run in tandem. It was not long before printers were equipped with adjustable masks so that both the picture and the sound track could be printed on the same machine. In any case, two printing operations were involved, one for the sound track and one for the picture.

Numerous attempts had been made to avoid the double printing operation; one of the first involved the construction of a double dial, double back shutter continuous printer. With this machine, the sound track and picture areas had individual light adjustments, and were accordingly both printed together at the aperture. Another arrangement was to mount two complete printer heads on one pedestal. This was the equivalent of running two printers in tandem. Apart from the mechanical complications involved in the last two

* Presented at the Spring, 1932, Meeting at Washington, D. C.

** Bell & Howell Co., Chicago, Ill.

methods, the operator had to be particularly alert to operate the two dials efficiently.

Another scheme adopted by a few laboratories was to use a supplementary "drum" containing a small rheostat-controlled light behind a sound printing aperture. This was probably found satisfactory in cases where the sound track was of the same intensity throughout the roll. This ideal is not always encountered in practice, and the method is limited accordingly.

It soon became obvious that the continuous principle of design would have to undergo an entire change and that a new kind of machine was demanded. This new machine must be of the continuous type, specifically designed for composite picture and sound printing. The problem was, just what were the requirements of sound printing?

Three years ago, when this problem was presented to the industry, neither the width of the sound track nor its location on the film had been standardized. Laboratories had different standards, studios and sound departments all had varying specifications and requirements. Then again, sound was first recorded on film by the single system, in which the sound was recorded on and printed from the same picture negative. Inasmuch as the double system was rapidly coming to be used almost exclusively for production work, it would have been unfortunate had such a printer been designed only to fulfill the requirements of the first single system. Therefore, in the preliminary investigation of the problem, it was decided that the new machine should primarily be designed for printing a composite positive from separate sound and picture negatives; and yet be capable of single system operation and adaptable to printing straight silent full aperture pictures.

Careful thought was given to the possibility of future requirements of the industry. It was apparent that radical changes of design and methods were needed, and that it was desirable and necessary that the new printer be designed to satisfy the demands of modern scientific densitometric control of prints.

Following is a detailed analysis of the requirements of such a machine, and the way in which those requirements have been fulfilled in the new fully automatic picture and sound production printer.

(1) Must be fully automatic.
(*a*) Fool-proof interlocking.

(b) Automatic oiling.
(c) Positive drive throughout; no belts.
(d) Automatic trips for film breakage, current failure, lamp failure, *etc.*
(e) Safety features to prevent accidents.

(2) Must fulfill requirements for densitometric control.
(a) Light steps must vary by equal amounts.
(b) Range of light steps must be ample for any condition likely to be encountered in practice.
(c) Definite relation between light steps and H & D curve of film.
(d) Master light control to match each lamp and each head.

(3) Constant and uniform velocity of film movement at printing aperture.
(a) Mechanical filter on each head, independently adjustable.
(b) Precision sprocket at aperture.
(c) Curved path at aperture to compensate for average normal shrinkage.

(4) Precise contact of positive and negative films at printing aperture.
(a) Use of compressed air on both sides (used also for cleaning, and helps to prevent scratches and abrasions).
(b) Means for balancing air pressure at aperture and gates of each head.
(c) Automatic air-pressure gauge to keep air pressure constant.

(5) Provision for cleaning film without removing it from machine.
(a) Compressed air (used also for maintaining film contact at aperture).
(b) Use of vacuum in conjunction with compressed air.

(6) Printing light.
(a) Must be ample for all requirements.
(b) Distribution of light over printing aperture must be particularly even.

(7) Elimination of notches on the negative film and elimination of resistances in light circuit.
(a) Use of traveling film matte.
(b) Economy of matte film by running matte at $^1/_4$ speed.

(8) Elimination of unnecessary labor.
(a) No rethreading.
(b) No rewinding. } Machine to print from either end of negative.
(c) One operator to be able to handle several machines; this involves a preset automatic light change, and two printing heads, one for picture and one for sound.

(9) Elimination of mistakes and film wastage.
(a) One man responsible for setting up machine.
(b) Operator not able to change adjustments, but only to thread positive and to start machine.

(10) Provision for printing key number simultaneously with picture and sound.

(11) Provision for inserting filters between light and positive films for duplicating, *etc.*, to modify spectral characteristics of printing light.

(12) Temperature control.
(*a*) Cooling of lamps.
(*b*) Cooling of motor.

(13) Ability to speed up machine, if desired.

(14) Provision for separate aperture for printing black line between sound and picture, if needed.

(15) Provision for duplex printing, if required.

(16) Voltmeters, footage indicators, ruby lights, and other standard accessories.

As soon as the specifications of such a printer were formulated, work was started on a model. This paper describes the printer designed to meet these exigencies.

DESCRIPTION OF THE MACHINE

Fig. 1 is a front view of the new sound and picture production printer. The positive film runs horizontally from one take-up to the other (*3*). The left-hand head is the sound head and the right-hand head prints the picture. This arrangement is mainly for convenience and for standardizing leaders, *etc.* The picture negative runs from one lower spool to the other (*22*) through the cleaners (*17* and *20*) and trips up to the printing aperture with its associated sprockets and tension rollers. The matte film, controlling the amount of light reaching the negative and positive films, runs to and from the spools (*21*). The matte also runs through trips and cleaners to the lower side of the sprocket housing. In this position, it runs between the reflector unit (*18*) and the printing aperture. The arrangement is the same for both the sound and picture heads. The trip rollers are located just below the cleaners (*17*, *20*, *27*, *29*) and are shown in Figs. 2 and 7. A pivoted roller is held up by the film passing between it and the fixed roller. Should any of the negative or matte films break, for any reason, one of these rollers will drop and operate a trip bar. The trip bar operates a mercury switch that shuts off the machine. The arrangement described is necessary in order that the machine may be tripped by a comparatively light roller at any one of eight different points. After passing the trip roller, the film enters the cleaner. A *U*-shaped tube with fine holes drilled on the inner sides directs a jet of compressed air against both sides of the film. At the rear of the cleaner is an opening to the exhaust pump. The pressures of the compressed air and vacuum are balanced so that no air enters or escapes from the cleaner. The danger of col-

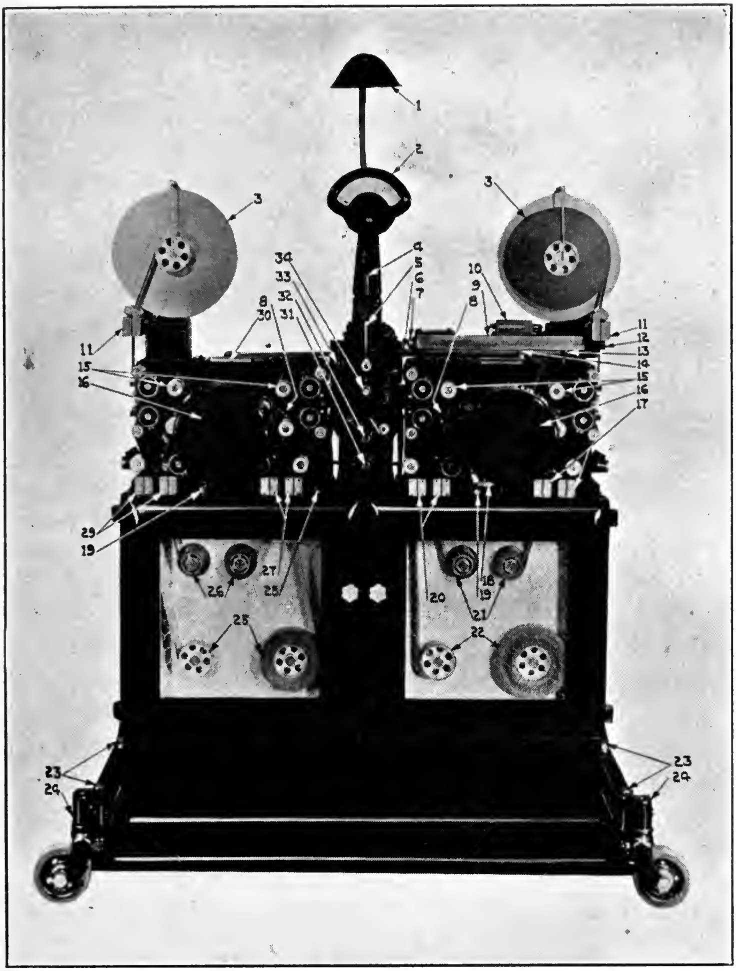


FIG. 1. Front view of printer: (*1*) ruby lamp; (*2*) voltmeter; (*3*) feed and take-up; (*4*) safety trip; (*5*) interlocking starting handle; (*6*) interlocking footage dial trip bar; (*7*) frame indicator; (*8*) adjustable weight tension rollers, calibrated in ounces of tension; (*9*) run footage setting dial; (*10*) total footage counter; (*11*) film cleaners for positive film; (*12*) socket for setting trips for length of run; (*13*) run footage pointer (trips bar *6* at zero and when it reaches pointer *14*); (*14*) run limit tripping pointer; (*15*) adjustable weight tension rollers, note threading marks; (*16*) mechanical filters, operating directly on main printing sprockets; (*17*) film cleaners; (*18*) reflector holder; (*19*) interlocking matte gate opening handle; (*20*) film cleaners; (*21*) picture negative matte feed and take-up; (*22*) picture negative feed and take-up; (*23*) bolts for raising printer off ground; (*24*) trucking attachment for conveniently moving printer; (*25*) sound negative feed and take-up; (*26*) sound negative matte feed and take-up; (*27*) film cleaners; (*28*) switch for ruby lights; (*29*) film cleaners; (*30*) face plate for setting gate blocks accurately; (*31*) brake release socket; (*32*) socket for turning machine by hand for setting up; (*33*) solenoid trip release; (*34*) idler roller (fitted

lecting dirt from the air in the room is thus avoided. Note that each film is cleaned both before and after it passes the aperture.

In practice, the cleaners are found to function very satisfactorily, so that it is not necessary to remove the negative for cleaning except occasionally when a great number of prints are being made. After passing the cleaner, the films go to the feed and take-up sprockets, whence the negative goes to the tension rollers. These tension rollers are fitted with adjustable weights so that the tension can be

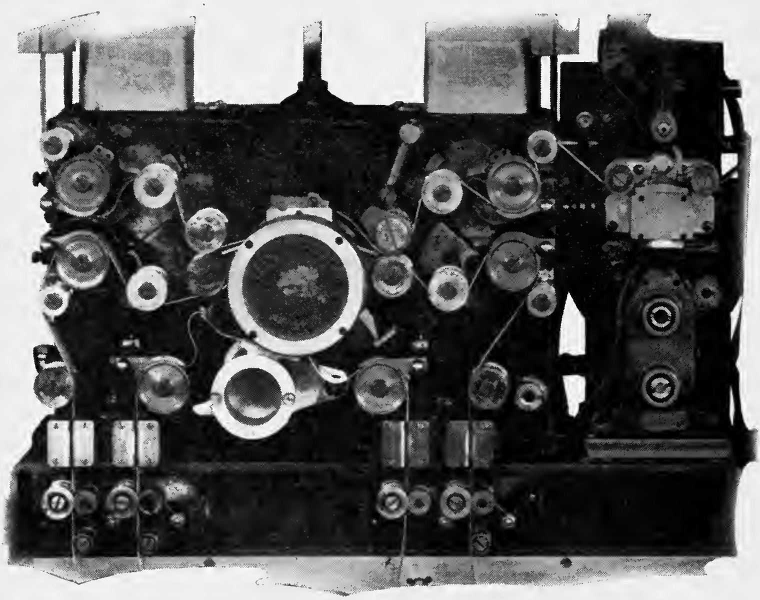


FIG. 2. Close-up of part of printing mechanism (taken early during construction) showing arrangement of tension rollers, matte, and printing apertures. Also shows device for printing line on either side of sound track and part of extra head for duplex printing.

adjusted to suit the humidity and the preferences of individual laboratories.

The matte film does not pass over any tension rollers. Instead, it is threaded with a loop on either side of the lower aperture. The matte is run at one-quarter of the speed of the negative in order to conserve matte film as much as possible. This necessitates operating the matte at the aperture by an intermittent, to effect a quick transition of splices past the aperture. If this were not done, the splice would change the density of at least one full frame of the picture, an effect that would be noticeable and objectionable. A standard form of Geneva cam mechanism is used for this purpose.

Fig. 2, taken early during the construction of the printer, before the mechanical filter and other features were added, shows the general arrangement of the trips, tension weights, *etc.* (Incidentally, Fig. 2 shows the extra take-up installed for duplex printing and the alterna-

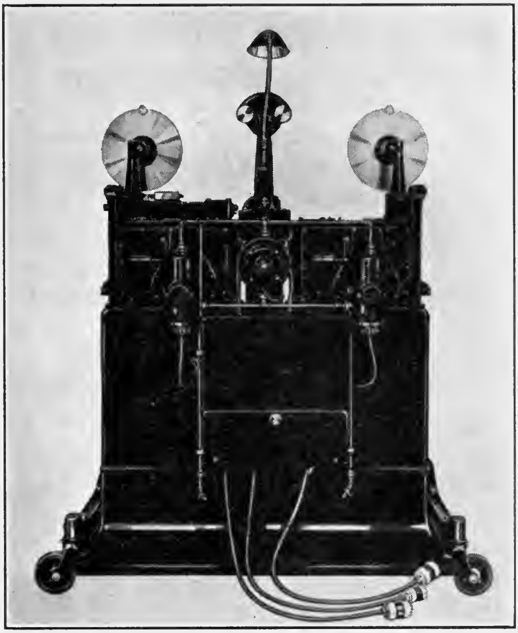


FIG. 3. Rear of printer, showing arrangement of water pipes, lamp houses, water, air, vacuum, and electrical connections.

tive aperture fitted on the central head. The latter unit was developed for printing a black line on either side of the sound track, and is added only when so specified.)

Fig. 3 is a rear view of the machine illustrating the arrangement of the lamp houses, the motor, the water cooling pipes, and the electrical connections. The lamp houses are of ample capacity, and are provided with adjustable reflectors. The lamps are mounted in special preset focusing bases so that the filaments will always line up correctly. The lamp fits into a special base fitted with a bayonet lock so that the whole unit can be removed from the bottom of the lamp house very readily. Fig. 3 also shows the dashpots in each head connected with the tripping mechanism for the purpose of damping the movement of loop tension rollers.

The switch box is covered by a large plate held in place by screws, which can be removed for examination and adjustment of electrical relays and other units. The lower part is in the form of a door, and provides immediate access to the safety fuses only. Three sets of fuses are provided: one on the d-c. supply for the lamps, one on the three-phase supply for the motors, and one on the single-phase supply for the general lighting circuits. The 110-volt, single phase supply is used for general lighting only. The transformer for marginal printing lights is in the 220-volt, three-phase circuit using one of the phases. The trips are also in the three-phase circuit. The edge printing lamps are the regular 6-volt automobile type of lamp, and provision is made so that the voltage of these lamps can be adjusted within limits ordinarily needed in practice to vary the printing exposure. The transformer that supplies these lamps is of the compensating type, *i. e.*, it provides constant secondary voltage regardless of the line voltage fluctuations.

The lower door allows access to three small switches so that it is possible to throw out of circuit any or all of the three-edge printing lights. In disconnecting these lamps, a ballast resistance is thrown into the circuit so that the effective printing light of the remaining lamp or lamps will be unchanged.

One of the most fundamental requirements of the new printer was that of providing a printing light for each head. First of all, ample illumination had to be provided, especially if the machine were to be speeded up or if very dense negatives were to be handled. It was also felt desirable that the lamps operate on a voltage slightly lower than rated. This insures against premature burnouts and, what is more important, assures a satisfactory constancy of the emitted light. For these reasons, while 250-watt lamps are suggested, the machine will accommodate 500-watt lamps quite readily.

Another factor demanding consideration at this point was that of cooling. It was felt that provision for water cooling was essential, especially if the larger lamps were used and if several machines were together in one room. The lamp houses are mounted at the rear of the machine. This arrangement keeps the water pipes clear of the mechanism, allows convenient access to the lamps and condensers, and yet keeps them out of the way of the operator.

Fig. 4 shows diagrammatically the arrangement of the illuminating system. In order to diffuse the light evenly, a ground glass is inserted in the condenser. Immediately before reaching the reflector, the light passes through a lens that focuses the image of the condenser ground glass at a point about an inch or so above the printing aperture. This lighting system provides a diffused printing light that many feel is the most desirable for the requirements of contact printing.

An interesting point has been brought out by one of the laboratories

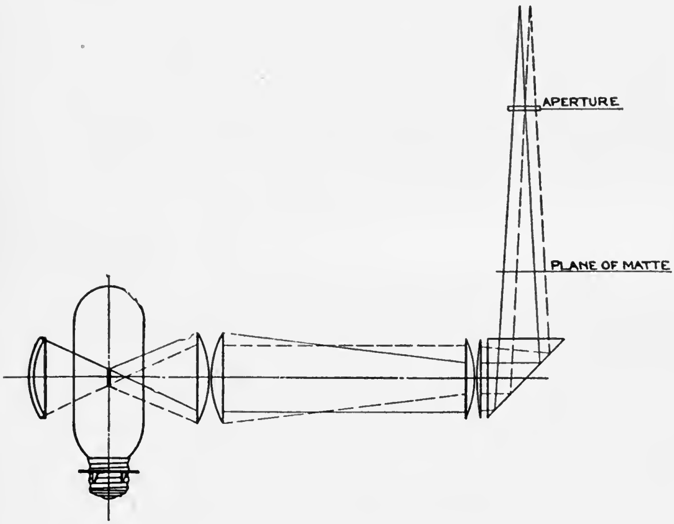


FIG. 4. Diagram of lighting system.

that tested this machine; this laboratory prefers a specular printing light of high intensity, in order that the width of the printing aperture may be reduced as far as possible. The machine is readily adapted to a change of the entire lighting system so as to give a specular light of high intensity. Experiments are under way at this time to determine the most satisfactory arrangement for this purpose. It speaks well for the flexibility of the instrument that it can be adapted to use two such radically different forms of illumination.

It should be pointed out at this juncture that in order for a specular light to print satisfactorily, the film must move past the printing aperture at an extremely uniform speed. The very nature of specular printing demands accuracy of collimation of the light; otherwise the crossing of the rays from the extreme ends of the fairly large light source that is necessarily used, will form a cone having an angle sufficiently large to offset the theoretical advantages of specular light printing. Then again, the slightest departure from perfect contact between the films would exaggerate the condition. It is desirable that the aperture be made as narrow as is practically possible so as to print the higher sound frequencies. It is obvious that the narrower the printing aperture, the higher must be the intensity of the printing light, and the more critical becomes the question of speed variation.

The experiments now being conducted are to determine a satisfactory compromise between the diffusion and the collimation of the light through an aperture of reasonably small width, without using a lamp of excessively high wattage. We anticipate that the

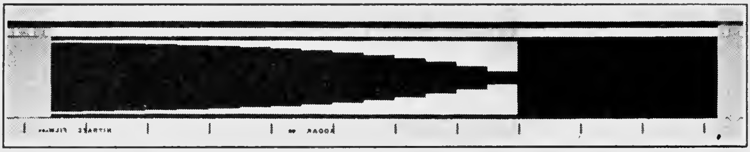


FIG 5. Sensitometric matte for test purposes.

investigation into the respective merits of the two forms of printing, as adapted to our printer, will lead to some interesting conclusions. It is quite possible that a compromise between the two systems may be effected.

The matte film that controls the intensity of the light reaching the printing aperture is positioned so that it acts as an external iris. The matte is a film with the central portion opaque and with the clear portion on either side of varying widths depending on the amount of light the matte is intended to pass. Fig. 5 shows a special matte for testing purposes that will be discussed later on. After numerous experiments with different kinds of matte films and various combinations of lenses and prisms, the present arrangement was finally selected.

It is not only possible, but quite probable, that the mattes may be altered for specular light printing. The entire system of controlling the light is extremely flexible, and seems adaptable to almost any requirements that may be imposed. An important advantage of the matte method of light control is found in connection with short scenes. In one reel printed on this machine, there were 147 light changes, some only ten or eleven frames long. The ability to handle such a negative properly and with no danger of miss-lights is something that any laboratory man can appreciate fully.

The next fundamental requisite for the ideal printer was that of providing for scientific densitometric control. Sound-on-film has been responsible for the conforming of laboratory procedure to definite tolerances of gamma in both the picture and the sound portions of the film. It is a fact, established by Hurter and Driffield, that, with a certain exposure, variations in developing will alter only the over-all contrast, within the range of the emulsion, of course. Considering this from a different angle, the over-all contrast or gamma and the density of the silver deposit necessary to obtain the proper quality of sound or picture are fixed within close limits by the characteristics of the projector and amplifying equipment. Therefore, with a given positive emulsion and its associated development conditions, the controlling factor is the exposure—in this case, the printing light. It is possible to vary the development to obtain a certain density in the film and thereby compensate for errors in exposure. However, this changes the contrast ratio between the highlights and shadows, and is not desirable. For these reasons, it has been felt necessary that the control of the printer light and the variations in printer light steps conform to definite sensitometric specifications.

Assuming that ample light is available for any printing condition likely to be encountered, the number of light steps (mattes) and the differences between steps had to be established. The approach to this problem was to determine what portions of the H & D curve of the positive film were used in practice. Theoretically, the film should be exposed and developed so that only the straight-line portion would be considered. It is customary, however, to use the shoulder (the overexposure) portion of the curve and, in many cases, the toe part also. Different laboratories have different standards as to how black a dress suit should appear in the print, or how light a face; the contrast of these extremes in relation to the general contrast of the middle tones. For this reason, it is suggested that all sensitometric tests be made to check the middle part of the printer range, corresponding to the straight-line portion of the H & D curve.

It was finally decided that a range of thirty steps, having exposure increments of 10 per cent each, would solve the problem. This provides a range of 15.8 to 1 in a geometric series. For all practical purposes, this can be taken as 16 to 1.

Another very interesting problem has come up in connection with the practical operation of the printer, and that is, the matching of this new machine to the model *D* printers now in general use. It so happens that when model *D* printers were adapted for sound printing, they had to be equipped with a back shutter for controlling the light at a point approximately half-way between the light source and the printing aperture. The back shutter was developed after the printer was originally designed, and it changed the original logarithmic progression of exposure of the model *D* printer to an arithmetical progression. As a matter of fact, it is not an exact arithmetical progression, but close enough to be considered such.

The result of this is that laboratory practice is now established, and that the Cinex and other timing machines are set to the approximately arithmetical progression. Furthermore, the operators are all accustomed to the fact that the light steps in the lower part of the scale cause changes of density different from those in the upper part of the scale. In a laboratory where the men are accustomed to operate on the toe of the H & D curve, the arithmetical progression of exposure has considerable advantages, in that it gives a reasonably constant change of density between printer steps. For this reason, and because of the desirability of matching the new printer to existing printers when used side by side, we have had a request to develop a set of mattes giving an exposure that varies arithmetically, matching the existing model *D* printers.

This is a recent development and one not quite expected, as it was felt that the geometrical progression represented the most satisfactory arrangement for all laboratory conditions. In the present model *D* printer, the range is approximately 6 to 1. We feel that the greatly extended range of the new printer (16 to 1) is sufficient to permit all laboratory printing to be done on the straight-line portion of the H & D curve, and thereby to avoid the complications of toe and shoulder printing. At least, the toe and shoulder would only be used when the normal density ratio has to be changed to obtain some particular effect. This again speaks for the flexibility of the machine, in that the mattes can be adapted to the specific requirements of any laboratory if necessary.

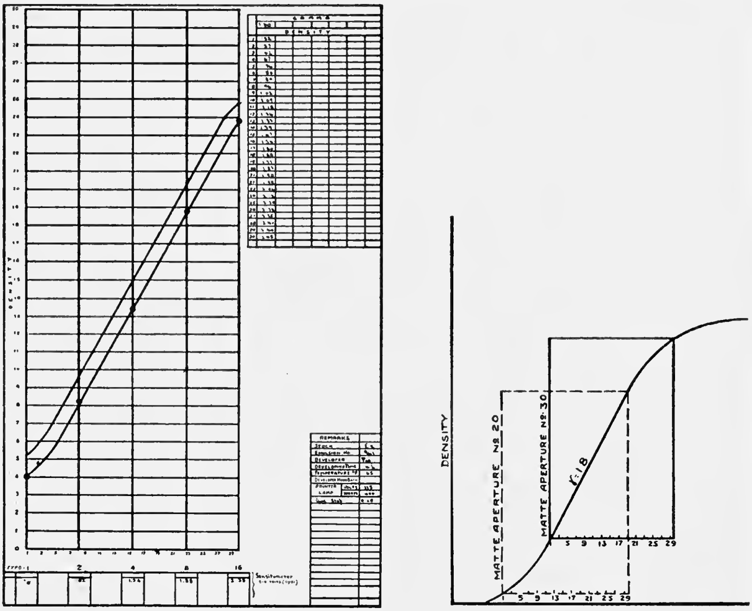
If it were possible for a laboratory to standardize its processing so that the film would be developed always to a given gamma, say, for example, 1.8, now fairly well accepted in practice, it would be possible to develop a series of mattes that would give *exact* changes in density between each exposure step throughout the entire range of the printer. In other words, the first four or five mattes would be made in arithmetical progression; mattes, say, from No. 5 to No. 20, would be in geometrical progression, and the remaining mattes would be calculated in reverse arithmetical progression. These mattes would expose for a portion of the toe, the straight line, and a portion of the shoulder of the H & D curve for that gamma. This would, of course, require that the printer be set so that the effective intensity of the printing light would expose the film so that the correct portion of the H & D curve would be utilized. If either the gamma or the light intensity were varied, this method would exaggerate the condition it is designed to avoid.

As will be shown later, the printer can be set very readily by adjusting the master matte control shutter (Fig. 7). It is a little too early to say whether it will be possible so to design the mattes as to realize this ideal; that depends upon whether laboratory practice can be made to conform to the limits called for by the method. As another complication there is the question as to whether the individual laboratories will need individual changes of density at the extreme toe and shoulder portions of the curve. Theoretically, the idea seems to have a lot to recommend it, and it will be interesting to see whether or not it will be possible to realize, in practice, the fine considerations of theoretical sensitometry.

TESTING AND SETTING THE TRANSMISSION FACTORS OF MATTES

Fig. 6 is a typical chart used in all the preliminary tests of the printer. Not only does this chart show how the printer conforms to definite sensitometric mandates, but it has several other interesting features. To insure accuracy, a special sensitometer was built, having exposure steps of 1, 2, 4, 8, and 16, respectively. A piece of film was run through the sensitometer, printing five strips along the length of the film. A length of film of the same emulsion number was printed in the printer, using clear film as a negative and a matte as shown in Fig. 5. The matte is made of short lengths of alternate matte numbers 1, 3, 5, ..., 29. The two films were developed together in a standard positive developer for a specified time at 65° F.

The densities of the five sensitometric strips and of the fifteen printer steps were then measured and charted as shown in Fig. 6. From a series of such charts, the best voltages for printer and sensitometer lamps were determined. A very interesting point was brought out, that the printer could instantly be matched to the sensitometer by merely changing the master matte control shutter on the printer heads. This shutter, shown in Fig. 7, is located at



(*a*) (*b*)

FIG. 6. Charts showing (*a*) printer and standard sensitometric tests plotted together to show how auxiliary matte control shutter can be adjusted two points to match them; (*b*) how adjustment of auxiliary matte control shutter sets the printer with respect to the H & D curve of the positive emulsion.

the matte aperture. It is adjusted by means of a dial set alongside; the dial is calibrated from 1 to 30, corresponding to the matte steps.

Referring again to Fig. 6, it will be seen that the curve representing the printer tests has the same slope (gamma) as the sensitometric curve, but is displaced laterally on the abscissa by an amount represented by two printer steps. Now, by turning down the matte dial *two* points and duplicating the test, the two curves will be found identical. The ability to set the printer from a chart to give a predetermined result is highly important. Each laboratory has only to establish the curve to which it plans to work, and each head of each printer can be checked against that standard at any time.

A convenient method of testing the printer and of maintaining a constant check on all prints is to insert a sensitometer matte, (Fig. 5) at the beginning of the roll. A piece of clear film of equiva-

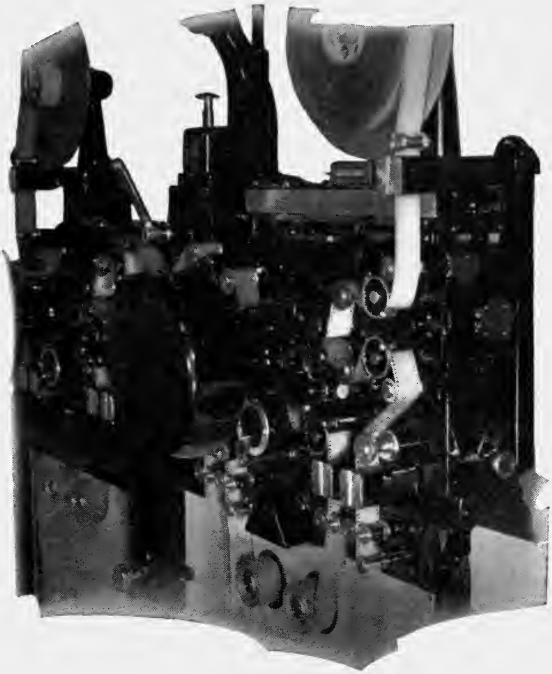


FIG. 7. Close-up of mechanism showing arrangement of mechanical filter, reflector, matte gate handle, matte film loop, and auxiliary matte shutter control dial.

lent length is likewise spliced in with the negative. If preferred, as, for instance, on the sound head, a piece of film of the density of unmodulated sound track can be used instead. This provides a sensitometric strip with each print so that a positive check can be made at any time. It is particularly useful for checking the sound head, as it is independent of any form of sound track.

A series of carefully conducted tests has furnished assurance that the printer actually permits quick and accurate checking and scientific control under production conditions. This, of course, is exclusive of special modifications that individual laboratories may prefer in the use of the toe or shoulder portions of the H & D curve. However, the printer control is as positive as can be made; and in the individual laboratory, the control is absolute and final, once a definite standard is established.

PRELIMINARIES TO SETTING UP THE PRINTER

(1) Making the mattes.
(2) Timing the negative.
(3) Splicing the mattes to match the negative.

Fig. 8 shows several views of the camera for making mattes and the master mattes used. The film is run past an aperture that is masked by the steel mattes inserted through the slot in the camera door. The pointer at the rear of the camera is then set at the number corresponding to the number of the steel matte being used. This uncovers a corresponding part of the sprocket. Thirty small holes are drilled in the sprocket and a numbered strip of film aligned behind these holes. Inside the sprocket is a small lamp, which prints the number of the matte periodically along the edge of the film, so the latter can always be identified. We will not dwell on the actual timing of the negative, as the procedure in each laboratory is so well established. As soon as the matte to be used for each scene is determined, the films are ready for assembly.

At this point, we will digress for a moment to consider the question of leaders. It is obvious that, owing to the distance between the two heads, the sound negative and the corresponding matte must be set in exact relation to the picture negative and matte. They must be so arranged that when the first frame of the picture reaches the sound aperture, the sound negative will be printed twenty frames in advance, in accordance with standard practice. To be sure that this can be done correctly and with the greatest ease, the leaders are so arranged that all that the set-up man has to do is to thread the machine with the starting marks of each leader at the various apertures. Fig. 9 illustrates the method clearly. Negatives are furnished with the printer so that the laboratory can print extra leaders whenever needed.

A special attachment is fitted to the standard splicer for matching negatives and mattes. Fig. 10 shows a close-up of the mechanism. A double sprocket is fitted to the splicer in addition to suitable take-up

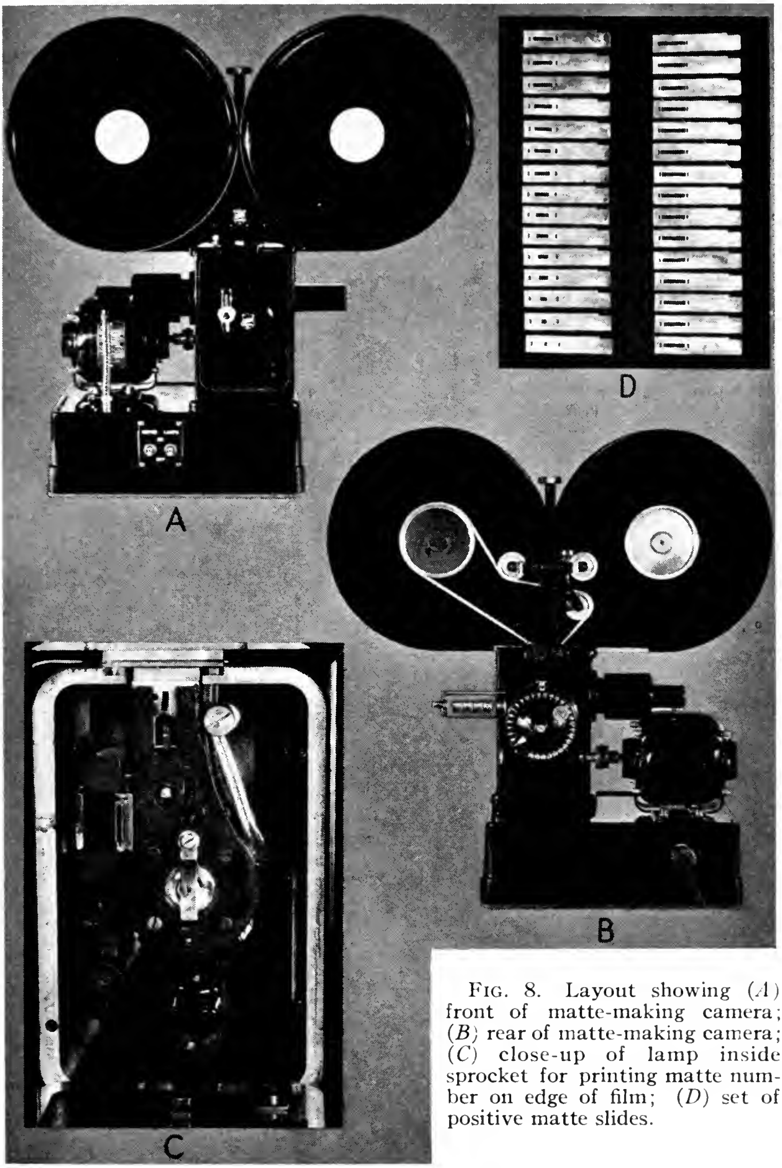


FIG. 8. Layout showing (*A*) front of matte-making camera; (*B*) rear of matte-making camera; (*C*) close-up of lamp inside sprocket for printing matte number on edge of film; (*D*) set of positive matte slides.

pulleys, flanges, *etc.* Inasmuch as the matte runs at one-quarter of the speed of the negative, the smaller sprocket is one-quarter the diameter of the large one.

A small light inside the large sprockets shines through the aperture (above the number *8* in Fig. 10) and facilitates setting the starting mark in place, and also enables the operator to set the splice between two scenes in that position. The leaders are spliced to a piece of clear negative and to the sensitometer matte, respectively, and threaded with the starting marks in alignment on the two sprockets. The little gate is then lowered on the matte sprocket. The footage counter is then set at zero and the handle is turned until the end of the sensitometer matte is reached.

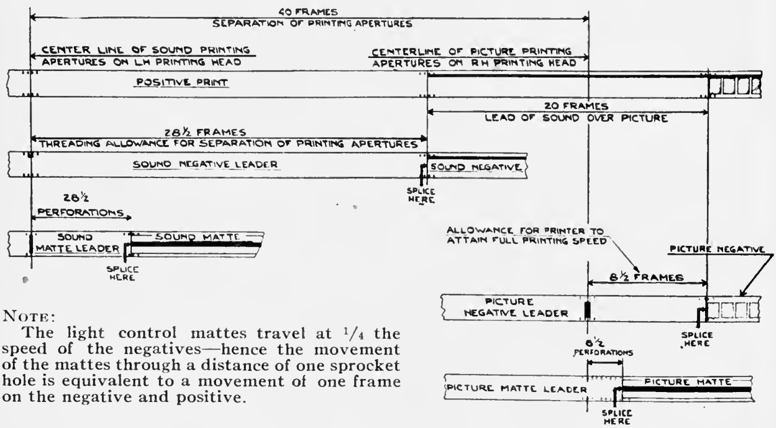


FIG. 9. Relative threading positions for automatic sound and picture printer; leaders spliced to negatives and mattes to insure exact synchronism of finished print.

A few inches of the clear negative are allowed for subsequent cutting and splicing of the positive. The first scene of the negative is spliced on and the crank turned to bring the splice back to the illuminated aperture on the large sprocket. The lever on the matte gate is pulled, making a slight notch in the edge of the matte film. The notching plunger is clearly visible in the picture. The handle is then reversed for a few turns and the next matte spliced to the first. The little notch shows the exact point for splicing. The remainder of the negative is then treated in the same manner. While this procedure may seem somewhat complicated, it is really very simple and takes only a short time to do. When finished, the matte is matched perfectly with the negative and, furthermore, a double check is obtained on the over-all footage. The printer is now ready to be set up for running a large number of prints automatically.

It might not be out of place to mention, briefly, an alternative method of setting the mattes, which is quite feasible in practice and which will probably be preferred by laboratories after they become accustomed to the new system. In the mean time, the special splicer adaptation was felt more convenient. The alternative

FIG. 10. B & H standard splicing machine with attachment to facilitate splicing matte films in exact synchronism with negatives.

method consists simply in measuring accurately the length of each scene. The exact number of feet (and frames) is carefully marked on the timing card, together with the matte number chosen for each scene. With this timing card, it would be possible to splice the mattes together on an ordinary splicing machine by merely measuring the length of matte for each scene. Of course, owing to the fact that the matte film runs at one-quarter of the speed of the negative, a special measuring machine would have to be made to avoid the necessity of calculating the length of each matte.

SETTING UP THE PRINTER

First of all, a small crank is inserted in the socket *12* (Fig. 1) and turned until the footage pointer *13* is at zero. The interlocking reverse rod *6* is moved to the right when doing this and prevents the machine from running except from right to left. This avoids any possibility of running the films off the machine. Frame counter *7* and the totaling feeder counter *10* are now set at zero and the two negatives and their mattes are threaded so that the starting lines are all in position at the aperture (*cf.* Fig. 8). The setting of the starting lines is facilitated by turning on the lights. With the ruby masks automatically in front of the printing lights, the starting marks on the leaders can be seen quite easily.

It is possible for the set-up man to operate the printer without the lights or without film. To do this, the lamps are turned off at the switch and the trip release *33* pushed in as the starting handle is moved over. The only reason for operating the machine this way would be to check the setting of the trips at the end of the run. The operator could not run the machine with the lamps off except by holding the handle over all the time or deliberately locking the handle with the trip—something that the operator would never have occasion to do. The set-up man is the only one allowed to release trips. In normal operation, it is impossible to open any of the gates unless the starting handle is in neutral. In that position, the ruby safelights are masking the printing lights. The positive stock can not be fogged by the operator, no matter how careless.

After threading the machine, the set-up man sets the trip pointer *14* at the footage of the negative and runs the printer to make sure that the printer stops at the end of the negative. The printer is then operated in the reverse direction (left to right) to check the stopping of the machine as soon as the pointer *13* reaches zero. In making these tests, the operation of all lamps and trips is automatically checked also. If one of the printing lights or one of the small lamps used for edge printing happened to be out, the machine would not start. The printer is mechanically interlocked so that it can not be started when any of the gates are open or when any of the negatives or mattes are broken or not threaded into position. The next test is to set the master control mattes to match each head with the laboratory standard. (This test is necessary only after changing lamps and when checking the condition of lamps.) A short length of positive is threaded, so as to print only through the clear negative and the sensitometer matte. The test is developed in the regular way and the H & D curve is plotted. Comparison of the curves for the two heads with the standard shows exactly how many stops up or down each control matte must be set. The printer is run back to zero and is now ready for production printing.

All the operator has to do is to thread the printer with positive stock. Even the threading is self-evident, as the weighted tension rollers have indicators (*26*, Fig. 1) that show when they are threaded properly. Then the operator pushes the starting lever and walks away to the next machine. If anything should happen to go wrong, the machine will stop; the only mistakes the operator can make is to put on too small a roll of positive or to thread incorrectly, either of which are unlikely to occur. In discussing the matter of mistakes it is, of course, possible that the set-up man can make a mistake in setting. However, he is the only man who is supposed to be sufficiently responsible that such errors do not occur. If he does make a mistake, the responsibility can be placed without question—there is no argument. The advantage of this from an executive standpoint is considerable.

INTERLOCKING

At this point we will consider the interlocking features, mechanical and electrical, incorporated in the design

(*a*) *Mechanical Interlocks*

(1) Starting handle with tripping mechanism; impossible to run machine wrong way.
(2) Starting handle and lights; ruby safelights always over printing light when starting handle is in neutral.
(3) Gates and starting handle; impossible to open gates while running; impossible to start if any gate is open.
(4) Reflector (*18*, Fig. 1) and gate (*19*, Fig. 1); impossible to remove reflector with gate closed.
(5) Filter slides and matte gate; filters can not be removed if gate is closed.
(6) Forward and reverse switch; impossible to close both switches at same time.
(7) Water and lamps turned on together.

(*b*) *Electrical*

(1) Voltage and motor; machine stops when power fails.
(2) Lamps and motor; impossible to run when any lamp burns out.
(3) Film and motor; machine stops when film breaks.
(4) Automatic air-pressure gauge and starting handle; machine stops when air fails.

SAFETY FEATURES

(1) Safety type fuses.

(2) Doors protect negative and matte films; operator's clothes can not catch in trips or take-ups.

(3) Mechanical filters project far enough to keep operator's sleeves away from sprockets even if operator is likely to be near enough.

(4) Convenient and accessible trip (*4*, Fig. 1) enables machine to be stopped quickly if necessity should arise.

(5) The motor is equipped with a clutch that will slip should anything happen to jam the machine.

MISCELLANEOUS MECHANICAL REFINEMENTS

An important consideration in a continuous printer is the evenness of the speed at which it runs. Any slight variation in speed will change the exposure. Variation of the speed of the positive film at the aperture is not only caused by slight fluctuations of motor speed, but also by the sum of the tolerances in the gear train. These are all taken care of by mechanical filters that operate directly on the main printing sprockets. The covers over the filter flywheel, in the front of the machine, unscrew to allow access for adjustment. The filters are set at the factory, but can be reset easily at any time.

One of the most difficult "slippage points" to control is the main printing sprocket. Minute variations in the pitch or shape of the sprocket teeth affect the results. The printing sprockets are made on a special machine, which is used only for this work. Even after the sprocket teeth are made in this machine, they are individually finished to within a tolerance of 0.0002 inch. The combination of critically accurate control sprockets with efficient mechanical filters is such that a fog test moved past the eye discloses no bands of varying density. Such a test is extremely delicate and shows up differences in density too small to be detected in the ordinary densitometer. The practical result of this is that the higher frequencies registered on the sound negative are printed on the positive. Naturally the fine detail of the picture is likewise reproduced so that prints made on the new printer are much crisper and clearer than obtainable heretofore.

SUMMARY

The following give the outstanding technical details of the new printer:

(1) *Fully Automatic.*—After being set up, the machine needs only to be threaded with fresh positive stock at the completion of the printing of each reel. It runs equally well in either direction (absolutely no rewinding of the negative or attention of any kind).

(2) *Fool-Proof Interlocking.*—One handle starts the machine forward or

backward, and controls everything: motor, brake, air, lights, water, vacuum, tension, weights, trip locks on all gates, *etc.* It is impossible to start the machine when any gate is open, or when any lamp is burned out. The automatic stop and motor clutch mechanisms prevent film waste and damage of any kind to machine. A hand trip is provided, and also a means of turning the machine over by hand for setting up. The hand setting mechanism is provided with a device that prevents insertion of hand crank when machine is running. An automatic stop at each end of the negative and an automatic interlock prevent the machine from being operated in the wrong direction.

(3) *Water Cooling of Motor and Printing Lamp Housings.*—No temperature rise; the importance of this in maintaining even temperature printing conditions is evident.

(4) *Specially Designed Mechanical Filter on Each Head.*—Assures particularly even speed, resulting in a much crisper print and enabling the higher sound frequencies to be registered on the positive print.

(5) *Fully Automatic Oiling by Automatic Drip Feed Oil Pump.*—Great care has been exercised to prevent oil from coming near the films. This is in addition to the provision for cleaning.

(6) *Air Pressure on Both Top and Bottom of Films.*—Assures perfect contact at printing apertures.

(7) *Combination Compressed Air and Vacuum Devices.*—Assure perfect cleaning of picture negative, sound negative, positive, and both "traveling matte" films.

(8) *Ample Light Capacity.*—The printer is recommended for use with 250-watt lamps in prefocused bases; lamps up to 500-watt capacity can be used, if desired; machine runs at normal printing speed of 60 feet per minute.

(9) *"Traveling Matte" between the Printing Light and the Negative Film.*—Controls the printing value of the light without the use of notches on the film and similar devices; the "traveling matte" runs at one-fourth the speed of the negative.

(10) *Densitometric Control of Printing Light Values for Any Given Development Gamma.*—The control is exact enough so that the same negative and "traveling matte" can be used in *any* printer, irrespective of location, with the positive assurance of *exact* duplication of print densities after one preliminary setting to compensate for developer differences.

(11) *"Master" Shutter on Each Head.*—To facilitate the matching of one printer with another and to match each head quickly and accurately.

(12) *Economy of Labor.*—One operator can operate several printers; one set-up man should be able to handle 6 to 25 printers, depending on the nature of the work and the number of set-ups required.

(13) *Tension of Weighted Rollers on Films Automatically Arranged according to the Direction in Which the Printer Is Run.*—The weights are adjustable and calibrated in ounces of tension, should any laboratory desire to change the tension to meet local conditions of humidity, *etc.*

(14) *Key Printing.*—Can be done on either head or either edge of film.

(15) *Provision for Equalizing Air Pressure at the Printing Head.*

(16) *Positive Drive Throughout.*

(17) *Printer Can Be Speeded Up.*—If necessary, with perfect safety, although this is not recommended.

(18) *A Separate Printing Head.*—Can be provided to print the black lines on either side of the sound track.

(19) *Provision for Adding Two Additional Take-Ups, etc., for Duplex Printing.*

(20) *Provision for Printing where Sound and Picture Are on the One Negative.*

In conclusion, the new printer introduces many totally new conceptions of printing practice. It will doubtless be of great value in enabling the laboratory to turn out consistently uniform prints of higher quality, and also to maintain a more dependable printing schedule than previously possible.

DISCUSSION

MR. JAS. CRABTREE: Since the printing sprocket and gate were apparently essentially the same as in the old model *D* printer, has the negative shrinkage for which the sprocket was originally designed been confirmed recently by measurement of present-day negative film?

MR. MITCHELL: Yes, the sprocket is designed for present-day film, allowing for 0.368 per cent shrinkage of the negative and a slight shrinkage (0.079 per cent) that has been found to occur in undeve oped positive film.

MR. JAS. CRABTREE: How was the contour of the sprocket tooth arrived at; was there any relation between the height of the aperture and the sprocket pitch?

MR. MITCHELL: There is no relation between the width of the aperture and the sprocket pitch. We consider that the width of the printing aperture is a function of printing light intensity, slippage, and resolution of detail. The aperture must be wide enough to allow sufficient light to pass to expose the positive film correctly. At the same time, it is desirable for the aperture to be as narrow as practicable, in order to resolve the most critical definition of detail. However, the smaller the aperture, the more critical becomes the matter of minute speed variation in the film past the aperture. In the model *D* printer, we have standardized on an aperture of $^5/_{16}$ inch. The original aperture on the new printer was $^5/_{16}$ inch, but we hope to be able to cut this down to $^1/_8$ inch in order to resolve the finest detail, especially for the sound track. This will mean the ability to print the highest frequencies that can be recorded on the negative. To this end, we are working on still further improvements in the optical system.

MR. JAS. CRABTREE: What are the manufacturer's recommendations with respect to gate setting, and what happens if they are exceeded?

MR. MITCHELL: There seems to be considerable difference of opinion in the matter of gate setting. Theoretically, the clearance at the gate should be the thicknesses of the two films, plus about 0.002 inch clearance, making a total of about 0.014 inch.

In practice, it is found that negative splices are not always made as they should be. Many laboratories have a practice of using the regular positive splice on negative film. If the gate is set too close, these splices tend to produce fine scratches in the gate which, in turn, eventually mark the films. It is therefore customary to set the gate between 0.018 and 0.020 inch clearance. In the model *D* printer, the gate was ground with a slight bulge opposite the aperture to force the films to better contact at this point. In the new printer, this is omitted and the use of compressed air on both sides is substituted.

THE BELL & HOWELL COOKE VARO LENS*

A. WARMISHAM** AND R. F. MITCHELL†

Summary.—*A variable focus, variable magnification lens of new and outstanding design is described. The Varo is a "zoom" type lens, introducing the conception of a variable three-element system in place of the two-element variable telephoto system previously used for this type of work. A summary of the optical problems involved is presented, and a description of the lens showing how the mechanical design has been fitted to the optical specifications is given, together with a discussion of the relation of the rate of "zoom" to the loss of definition. The paper closes with a brief outline of the use of the lens in practice.*

This paper describes a new type of variable focus, variable magnification lens, generally designated as the "zoom lens," which is critically sharp at all phases of the zoom and very simple to operate. Experimental zoom lenses of different kinds have been made previously and had a maximum aperture of $f/11$ or $f/8$. Apart from not being fully corrected at all positions of the zoom, they often required several pairs of hands working in unison to operate them.

The optical problem of a zoom type of lens is to alter the equivalent focal length of the system in such a manner that the back focal plane remains undisturbed. The way in which this has always been done previously was to alter the separation of the two elements of an inverted telephoto system. The telephoto type of lens was used because in it the rate of variation of equivalent focal length is most rapid, and the inverted form is especially useful because it gives maximum clearance at the back.

The difference between the Varo and previous lenses is that in the Varo the simple two-member system has been abandoned in favor of a three-member system. This change was made with the object of correcting the lens more completely for the optical aberrations, especially for coma, at a higher aperture than has been previously attempted. This makes the mechanical problem more severe, but it gives much more command over the optical aberrations.

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* Presented at the Spring, 1932, Meeting at Washington, D. C.

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Fig. 1 shows graphically the loci of the three elements plotted against the phase angle of rotation of the zooming handle or of the index dial.

The interpretation of the curve *D* is that with the relative motions of the three elements as defined in curves *A*, *B*, and *C*, the focal length increases rapidly at first, but later the rate of increase is reduced. These curves relate to an early experimental adjustment of the lens; in the units made, up to the present, the rate of increase of the image at the start is ten per cent faster than the average rate

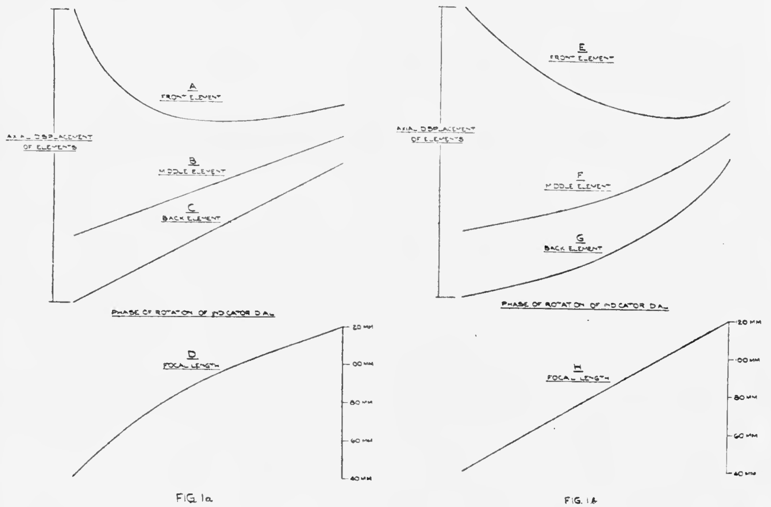


FIG. 1. Charts showing loci of the three elements of the Varo lens, and the change of focal length with respect to the phase of rotation of the zooming handle; (*a*) present arrangement; (*b*) suggested arrangement.

of increase, while the rate of increase at the long focus end is ten per cent slower than the average rate of increase.

The suggestion has been made that it would be better to make the rate of increase of the image uniform. If necessary, this can be done by redesigning the cams so that the front element would follow the law shown by curve *E* (Fig. 1*b*) instead of that shown by curve *A*; the middle element would follow the law shown by curve *F* and the back element by the curve *G*.

The question as to the proper rate of zooming is fundamental, and it is important to weigh carefully the various factors involved. Ideas on this question can be divided into three classes: (1) the rate of zooming should be uniform; (2) the rate of zooming should be logarithmic; (3) the amount of zooming blur should be proportional to the scale of the picture, *i. e.*, to the focal length. Let us analyze these separately to determine which is actually the best.

Critical definition will be affected by the speed of zooming. Careful photo tests of a chart have shown that with a zoom as fast as would ordinarily be used, fine lines in the chart can still be distinguished on critical examination of single frames. By cutting down the shutter or making a slower zoom, tangential lines are rendered satisfactorily sharp.

The rendition of tangential lines shows up a characteristic property of a zoom lens that is not encountered in the ordinary type of lens; namely, that these tangential lines show a zooming blur in each frame when the focal length changes too much while the shutter is open. This is obviously independent of the lens construction, and is a function only of the rate of the change of focal length.

The following brief mathematical analysis indicates the conditions required to make the zooming blur proportional to the scale of the object, *i. e.*, to be proportional to the instantaneous focal length. It is assumed that the zooming crank is turned at a constant speed and that therefore all differentials can be taken with respect to time.

F = the instantaneous focal length of the lens.
θ = the angular radius of a concentric circle (in the image).
x = the linear radius of the image of that circle.
dx = the zooming blur.

Now $$x = F\theta$$

Therefore $$\frac{dx}{dt} = \theta\frac{dF}{dt}$$

Since the zooming blur is proportional to the scale of the subject,

$$dx = KFdt$$

from which, by integration, $$F = F_0 e^{a(t-t_0)}$$

where F_0 is the instantaneous value of the focal length at the time t_0, and, in terms of the other constants,

$$a = \frac{K}{\theta}$$

Now the assumption that the zooming blur is constant means that we can write

$$\frac{dx}{dt} = \text{a constant; hence } \frac{dF}{dt} = \text{a constant} = C$$

from which

$$F = Ct + F_0$$

where F_0 is the focal length at the low limit, from which at time $t = 0$ (t_0), the image began to grow. This implies a regular increase of the linear dimensions of an image as the crank is turned with constant speed.

From the foregoing analysis, it is apparent that the reasonable assumption of the blur's being proportional to the image scale, that is, to the instantaneous focal length, would give such a rapid expansion of the image at the long limit, that the image would appear to burst, and it is possible that the blur at the long limit would be objectionable while at the short limit it would be less objectionable.

For the case in which the zooming blur is the same at all focal lengths, we have now deduced the law that the linear dimensions increase at a uniform rate with time, as shown in Fig. 1*b*.

The tendency of the zoom blur in this case is to affect the definition more at the short limit than at the long limit. On reviewing everything involved, it seems that this is the least objectionable of the various alternatives, so it has been suggested as being the best possible compromise.

The arrangement actually adopted is sufficiently close to the mathematical ideal for all practical purposes—in fact, many competent critics feel that it represents a still better balance of all the mechanical, optical, and psychological factors involved.

With the loci of the separations of the three optical members settled, the next problem was to design cams to move those members in the prescribed paths. Furthermore, the sum of all tolerances in the cams, *etc.*, must be kept very small so that the lens members will move at all times within minute variations from the ideal. Additional complications were imposed by the requirement of ease and convenience of operation by the cameraman.

The nature of a zoom shot is such that the camera is nearly always set at a fixed distance from the subject and stays there. This is the principal difference between a zoom shot and a dolly or crane shot. Attempting to focus the lens by further alterations of the positions of the lens element has seriously affected the efficiency of previous types of lenses. Considerable mechanical simplifications were effected by calculating the Varo so that the focus is set by attaching auxiliary lenses to the front element. The lens itself is focused at infinity; auxiliary lenses can be furnished to focus it at 50 feet, 30 feet, *etc.*, down to 1 foot, if desired. It is interesting to note that some of the auxiliary lenses have a focal length of over 100 feet.

To obtain the zoom effect, the effective focal length of the lens is progressively changed. This means that the physical diameter of the iris must be varied accordingly to keep the *f*/value of the lens constant. This means that the iris diaphragm must be operated by a cam in harmony with the moving elements.

Inasmuch as the *f*/value must be adjustable, a means had to be provided for operating the diaphragm from any one of several cams, all of which must operate the iris in synchronism with the change of focal length. The change-over must be possible without delay at any time, and the whole arrangement must also be fool-proof to avoid any possibility of setting the lens incorrectly or of damaging the iris leaves.

Other problems, which, although minor, caused considerable difficulty, are those of air displacement caused by the moving elements and halation from cam surfaces and other parts of the interior mechanism.

DESCRIPTION OF THE VARO LENS

The rear of the Varo is arranged to be seated into the regular lens hole in the standard camera turret. To hold the lens and, more important, to align it properly with the camera, a special adapter is used. Fig. 2 shows how the adapter fits between the tripod and the camera; the lever at the rear of the adapter locks it firmly on the tripod.

The lens slides in from the end of the arm; a tongued piece on the bottom engages grooves on the arm and holds the lens in alignment. At the bottom of the slide is a bevelled plunger that engages the under side of the lens. The plunger is held in position by a spring which is sufficiently strong to hold the lens firmly in position. For removing the camera, the lens is retracted into a second position, where the pin engages the lens again and holds it in place. Fig. 3 is a close-up of the Varo, and shows one auxiliary lens in position on the front element of the lens, and another one lying alongside. Fig. 3 also shows the plunger on the adapter slide.

When the lens is not in use, metal dust caps are screwed on the front and back to protect the elements. Fig. 4 shows the rear dust cap in position, and also shows the interior cam assembly. Note particularly the iris operating cams set on the under side of the top cover. The four cams on the cover operate the iris lever for the stops *f*/3.5, 4.5, 5.6, and 8, respectively, from top to bottom in the illustra-

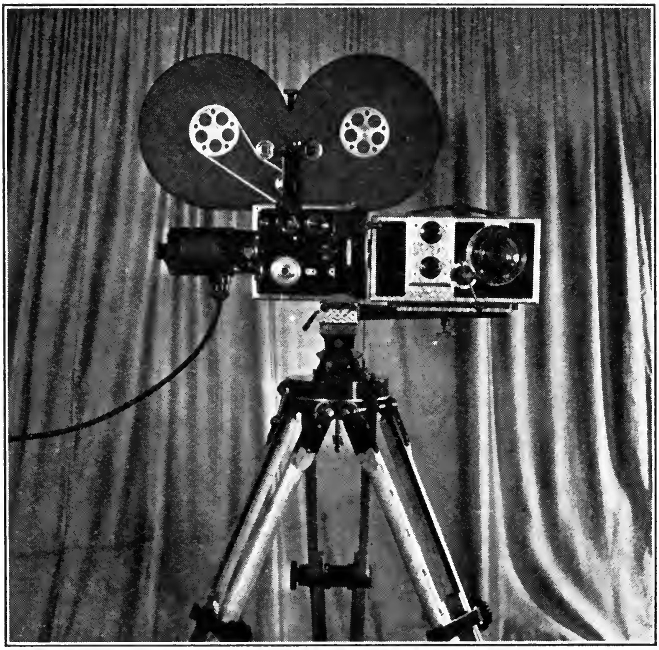


FIG. 2. Varo lens on tripod with camera and cinemotor, ready to operate.

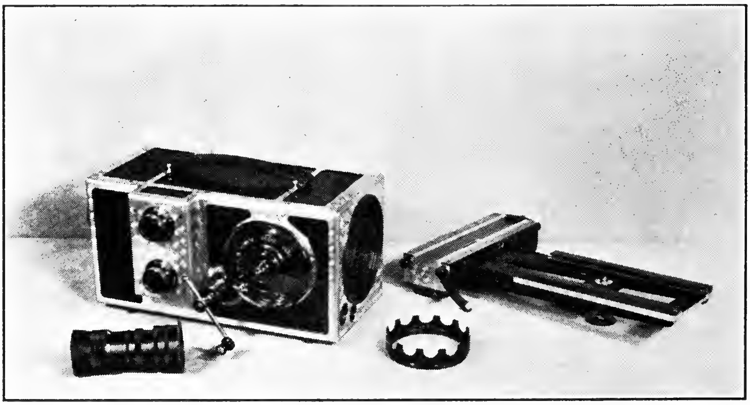


FIG. 3. Close-up of Varo lens showing, from right to left, visual eyepiece, diaphragm setting knob, iris lever release knob, operating handle, main index dial, auxiliary focusing element, and tripod adapter.

tion. The illustration shows graphically the range of the lens at the different stop settings.

f/Value	Range in Millimeters
3.5	40 to 50
4.5	40 to 85
5.6	40 to 120
8.0	40 to 120

To change the *f*/setting of the Varo, the lower of the two knobs is turned. This removes the diaphragm lever from the cam. While the lower release knob is held in the off position, the diaphragm knob is turned to the stop to be used. Then the lower knob is released to

FIG. 4. Close-up showing interior of Varo lens. Note the four cams set in the cover, which operate the iris lever. These cams, from top to bottom, are for the settings of *f*/3.5, 4.5, 5.6, and 8, respectively.

set the iris operating lever on the new cam. This release knob is connected to a dashpot, so that, on being released, the diaphragm lever will not be jarred when it hits the cam. This is necessary to protect the rather delicate iris parts.

The mechanism is arranged so that the stop can not be set at $f/3.5$ with the lens at the 120-mm. focal setting. Furthermore, with the lens set at $f/3.5$, it is impossible to zoom it beyond the range for that stop (50 mm.). The lens is fool-proof in this respect.

The end of the operating crank shaft is grooved and acts as a spring so that the crank will not fall out if the lens should be tipped. The "throw" of the crank is also adjustable.

When the operating crank is turned, the various cams inside the lens move the elements in their predetermined paths. At the same time, the large dial (Fig. 4) rotates. A pointer shows the focal length

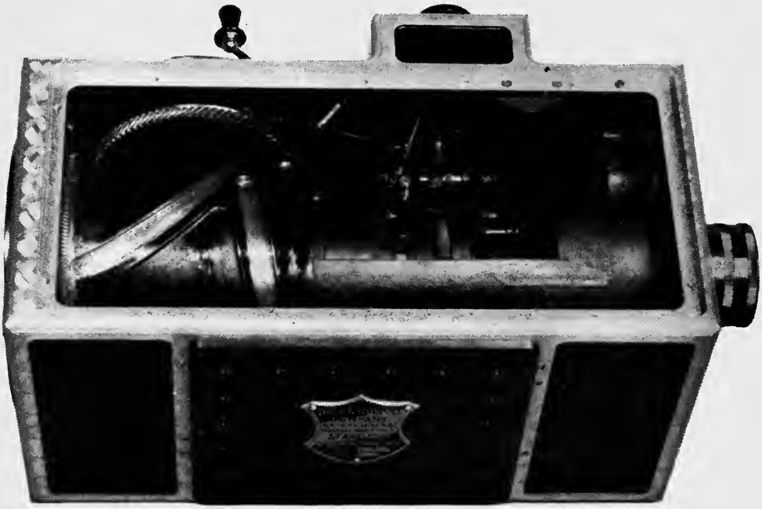


FIG. 5. Close-up of Varo lens from reverse side, showing further details of interior and the breather fitted on side of lens.

and the equivalent lens magnification (with respect to the short end, 40 mm.). For convenience, the outer dial is marked for the positions of 40, 60, 80, 100, and 120 millimeters, equivalent to 1, $1^1/_2$, 2, $2^1/_2$, and 3 times magnification, respectively.

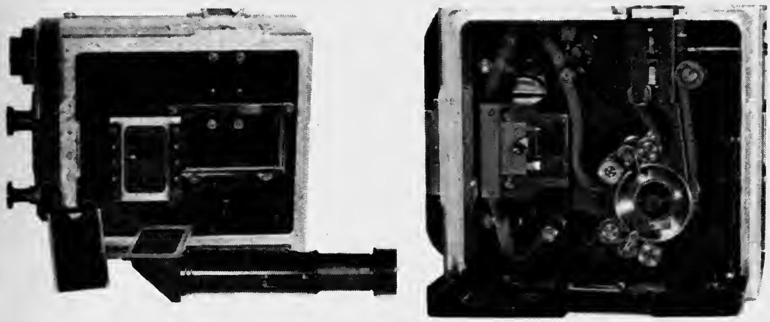
Limit stops are provided on the rotating dial, so the lens can be set to operate within any range desired.

As mentioned previously, halation caused by reflections from cam surfaces caused considerable trouble. Collapsible shields were fitted over the moving elements and effectively removed this difficulty.

When the elements move back and forth, they naturally displace air; owing to the size of some of the moving parts, there is enough air displacement to necessitate installing a "breather." Fig. 5 shows the breather arrangement and further details of the interior assembly. Behind the plate with the holes in it is a fine wire mesh, which is moistened with glycerine so as to act as a dust trap. It is recommended that this mesh be cleaned occasionally and that care be taken to remoisten it with glycerine; otherwise, dust may get inside the lens. With ordinary care, the lens should not need cleaning until after several years of use.

USING THE VARO LENS

The Varo is furnished with a visual eyepiece so that the lens can be set up, less the camera, and the action can be rehearsed. This assists the director in establishing the limits of the set and zoom to secure the desired effect. Then the camera can be set up without changing the alignment. It is suggested that "high key" lighting



(*a*) (*b*)

FIG. 6. (*a*) Camera with focusing-on-film attachment with adjustable 5× and 10× magnifier for bringing image to rear of camera; (*b*) close-up of interior of camera showing prism mounting behind aperture, arranged to prevent fogging more than one frame when focusing.

be employed and that the negative be developed a little longer than normal.

The focusing of the Varo, as previously mentioned, is taken care of by auxiliary lenses. The only problem of operation is that of following a moving object. There are several ways of doing this. A variable finder geared to the Varo mechanism would be ideal; it is under consideration, but as it involves considerable complication, we do not know yet just what can be done in this direction.

A celluloid matte can be used in the regular camera universal finder. This can be cut to match the 120-mm. opening, and have lines ruled on it to match the 100-, 80-, 60-, and 40-mm. fields. This method is all right if a little care is taken. In both these methods, parallax tends to be a little troublesome.

A convenient accessory for use with the Varo is the focusing-on-film attachment (Fig. 6), which can be installed on the camera. The viewing device permits checking the action at any time without moving the camera. Furthermore, it is possible to fit the eyepiece of the viewing magnifier with a larger rubber eyepiece so that the action can be seen through the film while actually photographing. Of course, the eye would have to be held tightly against the eyepiece

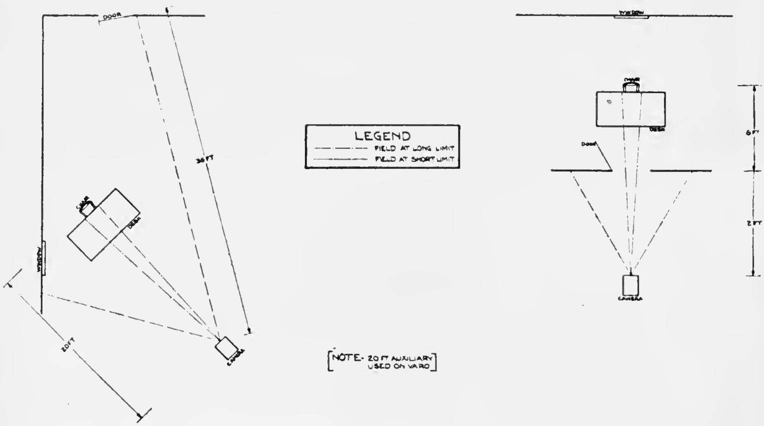


FIG. 7. Diagram showing two typical set-ups with the Varo lens.

to prevent the leaking of light and fogging of film. The advantages of watching a zoom shot during the filming more than outweigh the very slight objection to this procedure.

It may be of interest to describe a few typical effects obtained with the Varo. Fig. 7 illustrates two set-ups. In taking the picture, the man came through the door, walked to the desk, sat down, picked up a letter, and began to read. The lens was started at 40 millimeters and zoomed slowly as the man approached the desk and sat down. Then a faster zoom was used to bring the view to a close-up of the man reading the letter. Now, as the focal length of the lens was changed, the depth of field changed accordingly. The slant of the rear wall was such that, as the rear depth of field fell off, the view took in only that part of the wall that was still in sharp focus. The effect was that of giving to the scene remarkable depth; and, the close-up making the subject appear to stand out from the background, the final result was particularly striking. In the second shot, the subject walked into the set from the side near the door, and through the open doorway to the desk. The lens was zoomed from short to long. The effect was that of following the man right through the door to a close-up at the desk, and the subject was sharp at every step. In both these shots, the 20-foot auxiliary lens was used on the front of the Varo.

Some interesting shots have been made with the Varo from an aeroplane. The effect of a zoom shot to a plane from one flying alongside is very striking. Direct vertical zooms from a plane flying fairly low over tall buildings are also very striking, but oblique shots seem much preferable from the air.

The standard filters, as used on the regular 7 × 9 aero cameras, will fit into an adapter that screws on the front element. Therefore, any filters used on such cameras are readily interchangeable on the Varo.

To summarize, the principal advantage of the Varo lens lies in eliminating dolly shots and in obtaining zoom effects in locations where a dolly or crane shot could not be used. It is ideal for use in aeroplanes, towers, and the like. With the Varo lens, it is possible to follow an actor through a door or window. It has exceptional possibilities for process work and in conjunction with rear projection and projection printing.

The ease and smoothness of operation and the critical definition at all phases of the zoom, together with the speed of the lens, are its outstanding attributes. The Varo lens is a splendid example of the efficient coöperation of the research departments of two different organizations—one specializing in precision optics, the other in precision mechanisms. The development will make it possible to obtain special effects economically and effectively. As the possibilities become more fully realized, the greater will be the value of this new tool to the director and to the cinematographer.

DRYING CONDITIONS AND PHOTOGRAPHIC DENSITY*

D. R. WHITE**

Summary.—*A sensitometric study is presented of the effect of varied drying conditions on positive film. It is found that the gamma changes considerably with drying conditions. At 86°F., for instance, an increase from 36 to 80 per cent in relative humidity increased the gamma from 1.97 to 2.45. The effect appears to be concurrent with softening of the gelatin during drying.*

A series of sensitometric tests has shown that the conditions of temperature and humidity surrounding film while drying can very materially affect the final photographic densities appearing on it. The effect of uneven drying in producing correspondingly uneven densities has been noted by a number of workers, and some hints of the need of control and standardization of drying conditions have appeared. A number of photographic workers have found that slow drying in warm air produces an increase of density, tending to give an impression of overexposure and high contrast on films that would not have so appeared with other drying conditions. Although considerable effort has been expended in studying means of eliminating drying marks on film, there are little or no published data on the gross changes in density resulting from variations of drying conditions. The experiments presented here show that this gross effect, not a drying mark in the commonly accepted sense of the term, is by no means negligible.

The experimental work so far conducted has been limited to positive film. A series of developments were made with duplicate exposures. After development the tests were split, half being put into hypo with no hardener and half into hypo with chrome alum hardener. After fixing, the tests were washed together, and samples that had received treatment in each fixing bath were placed in a dryer operated under constant conditions, while other samples were placed in air that was conditioned specially as desired for that stage of the test. All these dryings were carried out in an air stream, not in stagnant

* Presented at the Spring, 1932, Meeting at Washington, D. C.

** Du Pont Film Manufacturing Corp., Parlin, N. J.

air. Typical data are presented in Table I. The columns headed E_1 and E_2 give density values resulting from two original exposures.

TABLE I

Effect of Drying Conditions on Contrast of Positive Film

Special Drying Conditions					Standard Drying Condition (Approx. 82°—40%)		
Temp., °F.	Rel. H., %	E_1	E_2	Gamma	E_1	E_2	Gamma
Hypo—No Hardener							
72	63	0.23	2.02	1.97	0.22	2.00	1.90
87	36	0.20	1.97	1.96	0.18	1.96	1.93
86	70	0.21	2.36	2.36	0.18	1.99	1.98
86	80	0.20	2.41	2.42	0.18	2.02	1.99
95	26	0.21	2.06	1.99	0.20	1.98	1.95
95	55	0.22	2.34	2.42	0.19	1.93	1.93
100	56	0.22	2.30	2.27	0.20	1.97	1.95
Hypo—Chrome Alum Hardener							
72	63	0.23	2.01	1.93	0.26	2.08	1.98
87	36	0.21	1.98	1.98	0.20	2.04	2.02
86	70	0.24	2.34	2.29	0.20	2.02	2.04
86	80	0.21	2.44	2.49	0.18	2.00	1.99
95	26	0.22	2.04	1.95	0.20	2.02	2.01
95	55	0.21	2.34	2.28	0.18	2.00	1.98
100	56	0.22	2.31	2.30	0.20	2.02	2.00

The first and most important thing that this table shows, is the wide range of densities and gammas produced by the variation of drying conditions. While the control samples, dried under constant conditions, had ranged about 6 per cent in density and contrast, the specially dried samples had varied about 25 per cent. Second, the presence of hardener in the hypo did not affect these values, the two fixing formulas resulting in essentially identical results.

Fig. 1 presents these data in a graphical manner. Values of gamma are placed close to the circles indicating the temperatures (plotted horizontally) and relative humidities (plotted vertically) at which the drying took place. These data, then, show that the density and gamma resulting from a development depend on the conditions surrounding the film while drying after development. High humidity and high temperature give greater density than lower values. The array of points plotted in Fig. 1 is not great enough to permit the complete determination of all the various combinations of temperature and humidity giving equivalent results, but lines drawn to represent such "equal effect" conditions would be of the nature shown dotted in the figure.

In the past, this drying effect, when considered at all, has apparently been considered primarily as a rate-of-drying phenomenon. These data show why this is so, since the higher humidities result in slower drying, other conditions being equal, and correspondingly higher densities result at temperatures of 85°F. and possibly lower. However, separate tests, in which the difference in drying rate was obtained by changing from moving to stagnant air, did not show any difference at about 72°F., although the drying time was some twenty times that used in drying the standard comparison samples. Thus the results here presented can not be explained primarily as a rate-of-drying effect.

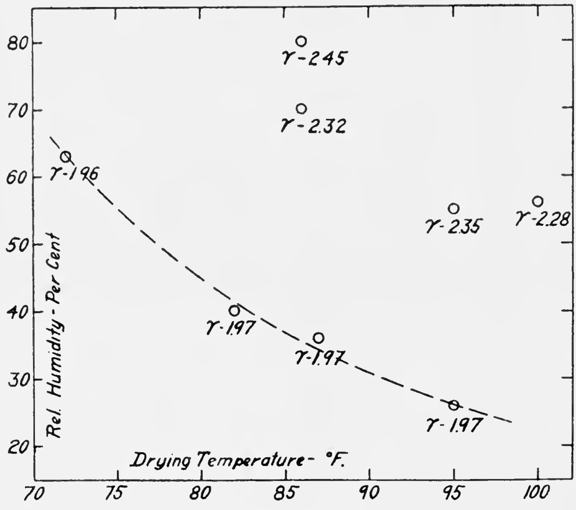


FIG. 1. Effect of drying conditions on contrast of positive film.

All these data, however, conform to the view that higher densities result when drying takes place under such conditions as to soften the gelatin during the process. On this view, the cooling due to evaporation becomes an important factor. When the humidity is low, the cooling is great enough to keep the gelatin firm even at the higher air temperatures; but when the humidity increases, the cooling is not as great and a corresponding softening of the gelatin takes place. This permits a rearrangement of the somewhat plate-like grains, and results in higher density from the same amount of silver. This view is at least qualitatively in agreement with Crabtree's suggestion[1] that softening of the gelatin is an important factor in the "drying down" effect that he notes, which appears to be the same effect described here in greater detail.

As a further test to determine the effect of softening of the gelatin, strips were developed and fixed in the usual way, but were washed in water of different temperatures before drying. Table II shows the results of this test. Of course, the action of the water does not accurately parallel the effect of the varied drying conditions, but it is very suggestive to note that similar differences in final density resulted from these treatments.

TABLE II

Effect of Washing Conditions on Contrast of Positive Film

Washing Conditions	E_1	E_2	Gamma
40′ at 52°	0.18	1.93	1.97
10′ at 52° + 30′ at 75°	0.20	2.03	2.06
30′ at 60°	0.19	1.89	1.82
30′ at 80°	0.19	2.10	2.07
30′ at 52°	0.17	1.90	1.92
10′ at 52° + 20′ at 85°	0.18	2.12	2.20

This drying effect is important both to scientific and commercial workers. It is evident from these data that the photometric constant, usually expressed in milligrams of silver per unit area for unit density, is dependent upon the drying conditions of the film. This fact may account for some of the differences in published values, although other factors, such as the variation of grain structure, may account for much of these differences. Again, standardization of sensitometry from place to place and time to time should recognize, and remove or allow for, this effect as a source of error. Recent literature on sensitometry is silent on this point, in spite of the fact that the suggestion of the need of standardization of drying was made at least seven years ago.[2]

Commercially, with present-day processing technic, this work emphasizes the need of maintaining uniform drying conditions at some one level in order to achieve uniformity of results. Again, in order that tests and experiments may parallel routine procedure, the drying must be kept similar to the routine drying. It is probable that at the lower temperatures and humidities relatively stable conditions are reached, such that small variations of temperature or humidity have less effect than at the higher values. If so, there would be some advantage in using those conditions for drying film, as departures from the intended values would have correspondingly less effect there.

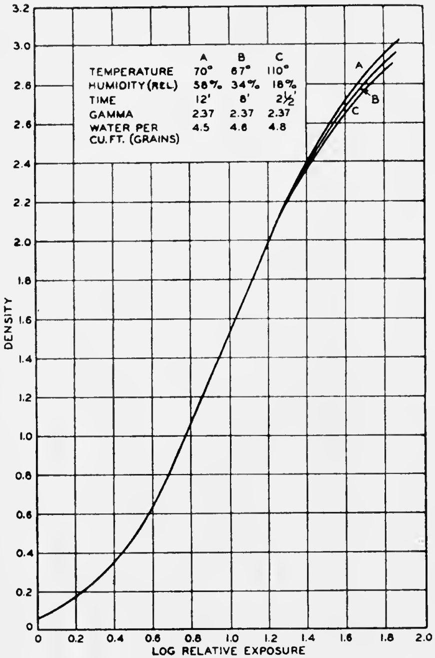


FIG. 1. (Of discussion) Effect of drying in air of low absolute humidity.

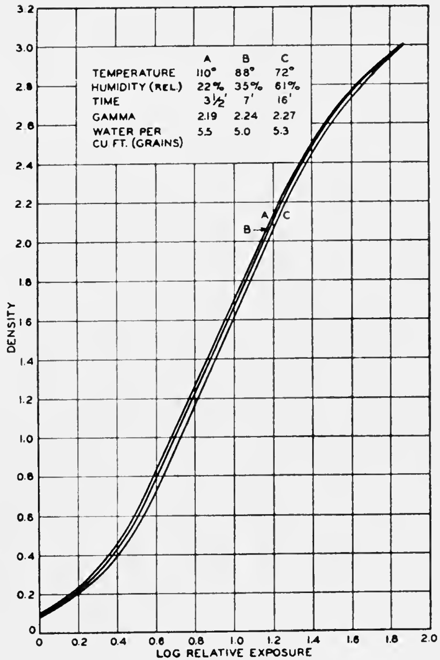


FIG. 2. (Of discussion) Effect of drying in air of moderate absolute humidity.

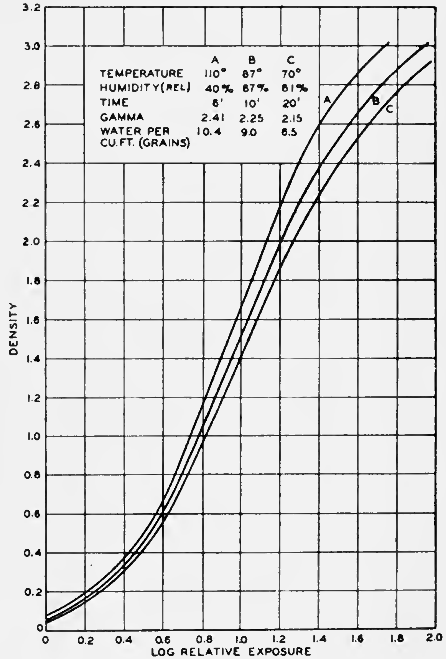


FIG. 3. (Of discussion) Effect of drying in air of high absolute humidity.

REFERENCES

[1] CRABTREE, J. I.: "The Development of Motion Picture Films by the Reel and Tank Systems," *Trans. Soc. Mot. Pict. Eng.* (May, 1923), No. 16, p. 163.

[2] CLARK, W.: "Standard Development," *Phot. J.*, 65 (1925), p. 76.

DISCUSSION

MR. JAS. CRABTREE: Figs. 1, 2, and 3 show the results of a few tests conducted in an industrial type of film processing machine having air conditioning equipment. The range of humidities obtained in this machine was not as great as that obtained by Mr. White so that the results did not vary as widely as his. On the whole, they confirmed Mr. White's results. It was not found possible to correlate them with drying time or the degree of relative humidity. When the tests were grouped according to absolute humidity, however, some correlation was found. Fig. 1, showing the effect of drying at low absolute humidities (4.0 to 5.0 grains of water per cubic foot), indicates that variations of temperature from 70° to 100°F. had no effect on the photographic results. Fig. 2, showing a group dried in air, the absolute humidities of which varied from 5.0 to 6.0 grains per cubic foot, indicates slight irregular changes due to variations of temperature. Drying in air of high absolute humidity (6.0 to 10.0) (Fig. 3), however, resulted in an increase in density and gamma as the temperature was raised.

This means that in industrial processing of film it is probably preferable to dry film in air having a low absolute humidity. If these conditions can not be adhered to, then it is necessary to keep the drying conditions reasonably uniform. When air conditioning equipment is not available and the operator has to offset increased humidity by increased temperature, the resulting increase in density and gamma should be recognized and allowed for. The results obtained when using air of certain humidities would probably vary with the design of the drying cabinets, depending upon the ratio of the volume of air to the footage of film dried.

WAVE FORM ANALYSIS OF VARIABLE DENSITY SOUND RECORDING*

O. SANDVIK AND V. C. HALL**

Summary.—*The harmonic content of variable density sound records, made under a wide variety of conditions, has been investigated by means of a microdensitometer and harmonic analyzer. From these results the conditions of exposure and development giving minimum harmonic content were deduced. These results have been correlated with results obtained by means of photographic tone reproduction diagrams. It has thus been possible to determine the effective emulsion characteristic under various conditions and to determine what changes in the characteristic curve are necessary to bring about further improvement in tone quality and wider latitude in recording and processing conditions.*

There are, as is well known, two general methods of photographic sound recording, with various ramifications of each with regard to varying the exposure or the distribution of exposure of the film. The present paper considers only certain phases of the photographic sound recording process with the light valve. The scope has been limited essentially to a study of the applicability of the theory of photographic tone reproduction to this particular sound recording process, avoiding the more complex phenomena which appear in the more general case.

The present investigation has been restricted, therefore, to sinusoidal exposures of low frequency where these more complex phenomena, although not strictly absent, may be considered second order effects. When, however, the scope of investigation is extended to include complex wave forms and higher frequencies and a study not only of nonlinear distortions but also of amplitude or frequency distortions, generally called "film loss," certain secondary effects become important. These secondary effects may be photographic, optical, mechanical, or electrical in nature. There are, for example, properties associated with the microscopic structure of the photographic image due to development phenomena, such as the too much

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* Presented at the Spring, 1932, Meeting at Washington, D. C. Communication No. 498 from the Kodak Research Laboratories.

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

discussed "Eberhard Effect;" or a broadening and non-proportionality between the optical image and photographic image, due to the scattering of light in the optical system or within the emulsion. Moreover, the distribution of intensity of the optical image changes with variation in the slit width, due to both changing diffraction patterns and failure of the optical system to resolve the smaller slit widths. In fact, below a certain slit width the objective becomes incapable of further reducing the slit image, and only the intensity of the exposure varies. In other words, the exposure becomes an intensity scale rather than a time scale exposure. There are introduced other distortions of mechanical origin due to certain mechanically moving members in the sound recording system.

The theory underlying the reproduction of sound on film has been a subject of considerable interest to many investigators, and has been treated at length in a number of articles in the literature. The theory of photographic tone reproduction as applied to sound recording has been carried out primarily from the point of view of the corresponding problem applied to pictures. Due to the fundamental difference between the response-to-radiation characteristics of the final receiving elements in the two cases, namely, the eye, which has an approximately logarithmic relationship between light input or stimulus, and sensation, and the photoelectric cell with a linear relationship between radiant input and current output, the conclusions arrived at were not always in agreement with what was known to be true in practice. It has been found more satisfactory to treat the problem in terms of linear relationships; the method was followed by Nicholson[1] in connection with his work on recording sound by means of the flashing lamp.

In so far as the photographic process itself is concerned, a necessary condition for good quality in the reproduced sound is that the transmission of the print be linearly related to the exposure of the negative. If this were a sufficient condition, the problem would be simple; in fact, there would be no problem. On account, however, of parasitic noise, such as surface noise of the film and system noise due to the photoelectric cell and its associated vacuum tube amplifiers, it is desirable to have the transmission range of the sound print as great as possible without violating the above stated conditions of linearity; or at least not exceeding the conditions of linearity to such a degree that a perceptible amount of distortion is introduced. This distortion is measured by the harmonic content of the reproduced sound as compared with the amount of harmonics in the recorded sound. The problem, therefore, in the present case, where only a sinusoidal exposure of low frequency is being considered, is one of obtaining the maximum ratio of signal to surface noise without introducing a perceptible amount of harmonics. When the scope of the problem is extended to include higher frequencies, the fulfillment of additional conditions will be required.

The operator generally has at his command four variables to evaluate so as best to fulfill the above conditions, namely: (1) the intensity of the recorder lamp, which determines the average exposure or the operating point on the characteristic curve of the photographic material; (2) the modulation of the light valve, which determines the operating or exposure range on the negative for a given development; (3) the degree of development of the negative; and (4) the printer point, which determines the exposure range and therefore also the transmission range of the positive obtainable from a given negative for fixed print development time.

In order to find the most favorable set of conditions, the procedure that was followed was to make a series of records of pure sine waves, at a frequency of 100 cycles per second, on the film to be studied. These records were made at levels of 1, 2, 3, and 6 decibels below the clash point of the valve, and covered a wide range of negative exposure and development conditions. Four prints were made from each negative so as to cover a range of average print transmissions. The print development was constant, and was such as to conform to normal picture print practice.

After the records were completed, they were analyzed in a recording microdensitometer.[2] In this instrument a microscope objective projects an enlarged image of the sound track on a slit, behind which is a lens imaging the principal plane of the microscope objective on the photoelectric cell surface. This insures a uniform distribution of illumination on the photoelectric cell surface at all times. The cell operates into a strictly linear direct-current amplifier whose power output actuates a galvanometer of fairly low period. The microscope stage carrying the film is driven at a constant speed by means of a train of gears and a precision screw. The image of the sound track moves across the slit, varying the illumination of the photoelectric cell and, therefore, its current output, in accordance with the transmission of the sound track. The amplified photoelectric current actuates the galvanometer whose angular movements are recorded on a continuously moving strip of film $6^1/_2$ inches wide and driven at a constant ratio of speed with respect to the sound record. The ratio of sound track speed to recording film speed was adjusted so that the amplitude and the wavelength of the record are each about five inches, a convenient size to handle and sufficiently accurate for all purposes.

One such record is shown in Fig. 1. Superimposed on the curve are shown points obtained when the same record was run through a sound film densitometer containing a standard reproducer optical system and photoelectric cell. The photoelectric cell current was read directly on the galvanometer at various points along the curve.

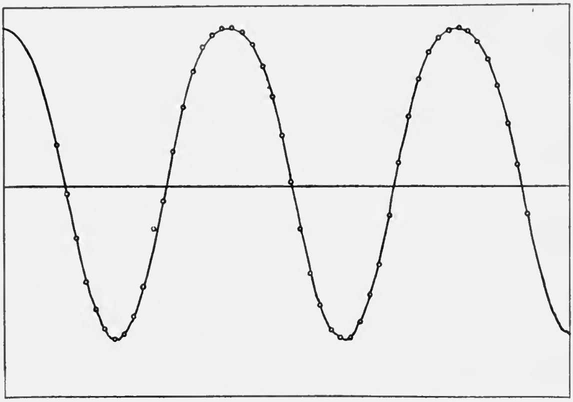

FIG. 1. Microdensitometer record of positive print; points are corresponding readings on sound film densitometer.

The correspondence between the two has been checked in a number of cases, and the results have been found exactly comparable with those obtained in the continuously recording microdensitometer.

These records were enlarged to a standard wavelength of 40 centimeters, this being the required base line for the harmonic analyzer. The analyzer is of the Henrici type, made by Coradi. It normally gives the first five terms of the Fourier series, although the next five terms may be obtained by a second reading, giving, in all, the first ten harmonics. A complete description of this instrument, together with valuable comments on its operation, is given by D. C. Miller.[3] The results are accurate, with a single tracing of the curve, to the order of 0.5 millimeter of amplitude for the lower harmonics, and a slightly greater accuracy can be obtained for the higher terms because the repetition of the values gives a better average. Since the curves are about 300 millimeters in amplitude the harmonics are determined to about 0.2 per cent. In order to decrease accidental errors, the average of four successive cycles was taken in most of the work. This was found to be sufficient to give an accurate analysis of the wave form, even when the modulation was low. In order to be able to correlate the two fundamental quantities of *modulation* and *harmonic* content, the amplitude was measured on the identical cycles of the wave.

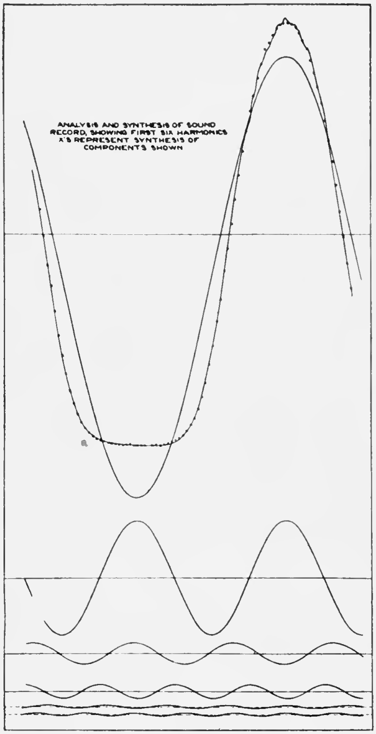

FIG. 2. Badly distorted wave form and the components as found by analyses; X's represent synthesis of components.

Fig. 2 shows the results of analyzing a very distorted sound wave, the negative having an average density of 1.00 (diffuse) at a gamma of 1.25. The print shown has an average density of 0.60, and on analysis was found to have the relative amplitudes of harmonic shown. Components as far as the sixth harmonic have been drawn, although the amplitudes of the fifth and sixth are only 0.7 per cent that of the fundamental, corresponding to 43 decibels down. The actual amplitude of the fundamental component is approximately equal to that of the composite wave. Since the photographic distortions entering into the process are due to curvature of the characteristic curves involved, the effect must be the same on both sides of the peak and valley of the wave, respectively. Since this is true, each component must have its phase relation such that the peak or valley corresponds exactly to the peak or valley of the fundamental. There is no noticeable departure from this condition in the present case, as can be seen. When the actual components are added, the resultant curve is indicated by the points along the original curve. The failure to correspond exactly is due to lack of small terms of very high order, the lower terms not being quite sufficient to follow variations such as those at the peak of the wave, caused in this case by film surface dirt or scratches. The illustration shown contains more harmonic than any other print encountered in the course of the work. The accuracy with which it can be synthesized with a relatively small number of terms indicates that under even slightly more favorable conditions a perfectly satisfactory representation can be given with four or even three terms of the Fourier series. This has been shown to be true by actually synthesizing several curves made during the course of the experiments.

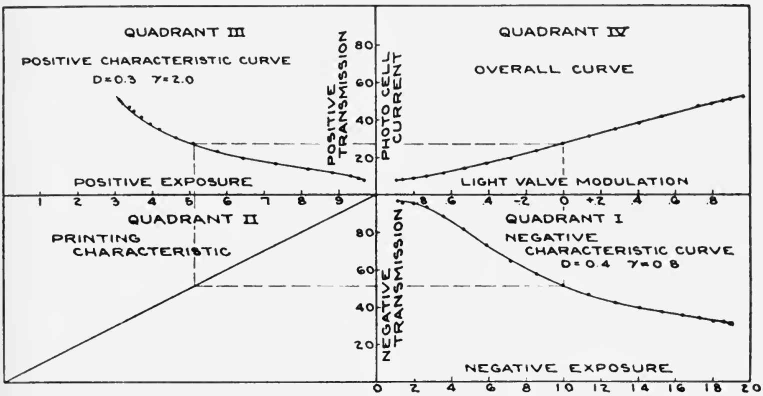

FIG. 3. Schematic tone reproduction diagram for sound films.

The results obtained perhaps can be represented most satisfactorily by the aid of a tone reproduction diagram such as that shown in Fig. 3. This is a schematic diagram of the process involved in sound reproduction. Quadrant I shows the negative characteristic; the upper scale represents light valve modulation, and the lower scale represents relative negative exposure. The particular curve shown corresponds to an operating range of 90 per cent modulation, or approximately one decibel below the clash point of the light valve. The percentage transmission of the negative is given in terms of diffuse transmission and corresponds closely to conditions obtaining in contact printing. Quadrant II represents the printer characteristic by a straight line connecting the percentage transmission of the negative with exposure of the positive, a change in slope changing the average exposure of the print. Since in this case relative exposure only is desired, the line is drawn to give a convenient scale to the positive characteristic in Quadrant III.

The positive transmission values were measured in a collimated beam of light identical to that used in a sound projector. These values are similar to those of strictly specular transmission, and are considerably lower than the diffuse value for the same area.

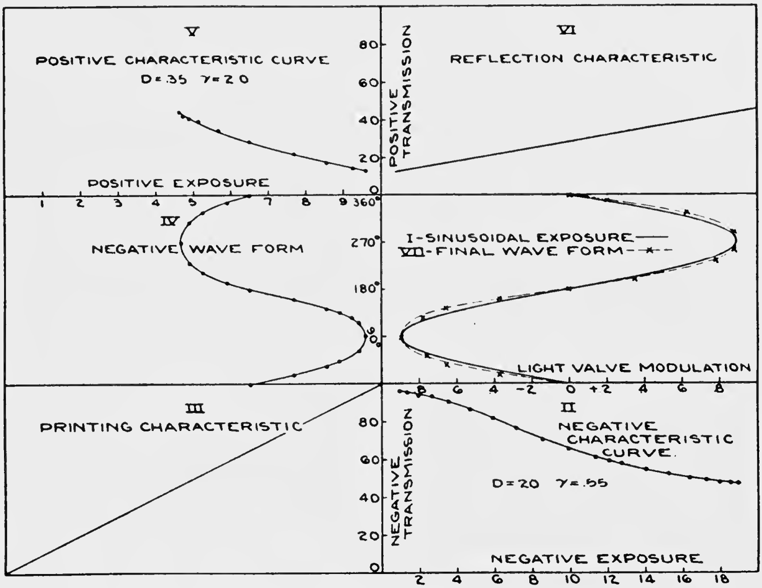

FIG. 4. Sound reproduction with low negative density and low print density; normal gammas.

The transmission of the positive was measured by the amount of change in photoelectric cell current, caused by its being placed in the light beam, which in turn is proportional to the voltage developed in the associated amplifier in a reproducer, and becomes the ordinate in Quadrant IV. Since the light valve opening is assumed to be proportional to the input voltage, the curve of Quadrant IV connects input to the light valve with input to the reproducing amplifier, thus completing the photographic cycle. The particular over-all curve shown is rather typical of those encountered in practice. It has some curvature in the toe, or region of low transmission, a practically straight central portion, and is curved again at the knee or high transmission region. Some distortion will be introduced by exposures covering the entire curve, and there is evidence of increasing curvature toward the ends of the swing, indicating that modulation greater than 1 decibel below the clash point would result in a very distorted record.

If, on the other hand, the conditions shown in the diagram be followed, and the modulation is decreased to, say, 6 decibels below the valve clash point, nonlinear distortion due to the photographic process will be nearly, if not completely, absent. Even at 75 per cent modulation, that is, 3 decibels below the clash point, the harmonic content will be very small.

Any straight line in Quadrant IV will give reproduction free from nonlinear distortion provided that the modulation and other conditions are so adjusted that the operating range lies within the boundary of the linear segment of the line. On account of practical considerations, it is desirable that the vertical component of this linear segment be as large as possible; that is, the vertical component determines the change in the photoelectric current and, therefore, the signal level entering the amplifier. The higher this level is, the less is the amplification required to meet any given requirement of volume output from the speaker and, therefore, the more favorable the ratio of signal to surface and system noises. This is an extremely important consideration in sound reproduction processes.

The horizontal component of the linear segment of the curve in the fourth quadrant determines the modulation level necessary to cover the permissible operating range; that is, the range leading to an imperceptible amount of distortion. Since it is desirable to keep the level of modulation reasonably low, it is desirable that the fourth quadrant curve should have a large slope. There are, however, other factors to be considered in connection with the properties of this curve that will be discussed later.

As stated above, the departure from linearity, of the curve showing the relation between negative exposure and positive transmission, is a measure of the nonlinear distortion that is introduced. This can perhaps be illustrated more clearly by applying the above method to a few examples of recordings of pure tones under various negative and print sensitometric conditions. In each case the prints have been analyzed for the harmonic content present. The continuous line in Compartment I, Fig. 4, represents a negative exposure of sinusoidal distribution and a valve modulation of 90 per cent. The unmodulated diffuse density of the negative was only 0.20 when developed to a gamma of 0.55. This negative density is much lower than that ever used in practice. The negative exposure operates over that portion of the negative characteristic curve shown in Compartment II. The resultant negative record as determined on the microdensitometer is shown in Compartment IV. Compartment III serves no other purpose than that of reflecting this resultant curve into the fourth compartment. As shown by the figure, this curve is considerably different from the original sine wave. When this curve was printed on the positive whose characteristic is shown in Compartment V, the printer setting was adjusted to give an average specular transmission of 30 per cent (diffuse density of 0.3) at a gamma, based on diffuse density, of 2.0. The amplitude of the resulting wave is always less than that of the original. For ease of comparison, however, the slope of the reflecting line in Compartment VI has been chosen so that the original waves superimpose in Compartments VII–I. This reflection does not affect the wave form but simply its amplitude. In fact, it corresponds to increasing the fader setting in the reproducing amplifier.

Comparison of the reproduced wave form with that of the original shows that the distortion can not be very great. The fact that both the crest and the trough are flattened indicates that a considerable fraction of the harmonic content present is due to the odd harmonic terms in the Fourier series. The analysis gives about 2.5 per cent of second harmonic and 5 per cent of third harmonic, with no appreciable amount of the higher terms. The second harmonic is therefore 32 decibels and the third 26 decibels down, with respect to the fundamental. Thus, even at the very high modulation level of 90 per cent, the harmonic present is probably negligible.

Fig. 5 shows the effect of printing the same negative as in Fig. 4 on a positive film developed as above to a gamma of 2.0, but printed with a somewhat higher printing intensity, such that the average transmission corresponds to a diffuse density of 0.6. This leads to a final curve, Compartment VII, which is somewhat more distorted at the low than at the high transmission end, indicating an increase in second harmonic. The analysis of this gives about 5.0 per cent each of second and third harmonics, that is, each is 26 decibels down, as compared with the fundamental.

Fig. 6 shows a similar set of curves under somewhat different sensitometric conditions; namely, a negative diffuse density of 0.73 and a gamma of 0.55. These conditions correspond approximately to current average recording practice. The microdensitometer tracing of this negative record, Compartment IV, shows extreme flattening of the wave; this is typical of all low transmission negative records. The wave form of a print of this record, made according to the sensitometric conditions designated in the diagram, in Compartment VII, is similar to those of Fig. 4, and the analysis shows an almost identical harmonic content, namely, −32 and −26 decibels, of second and third harmonics, respectively.

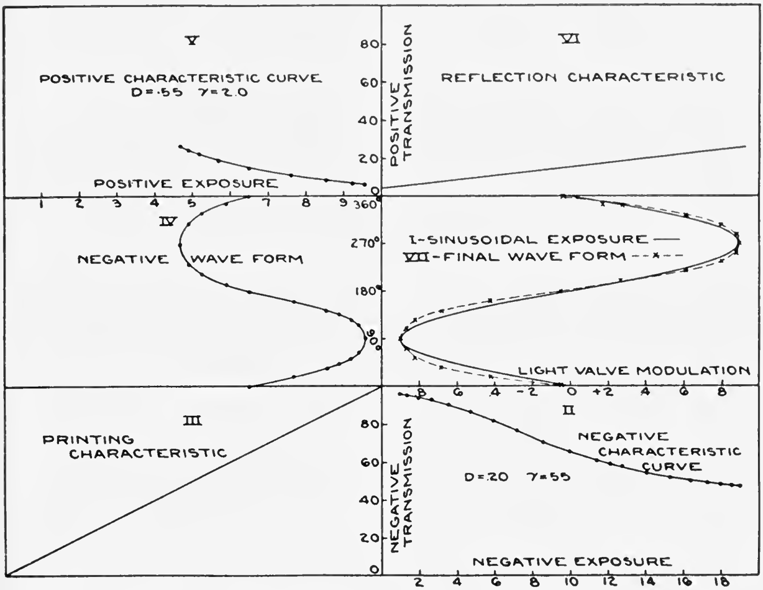

FIG. 5. Sound reproduction with low negative density; normal print density and normal gammas.

The characteristic curve of the positive under "normal" printing conditions is shown in Compartment V, Fig. 7. When the negative record in Fig. 6 is printed on this positive characteristic curve at a normal print diffuse density of 0.6, the maximum print transmission is low, never exceeding 30 per cent specular or 50 per cent diffuse; and a comparison of the original and final Curves I and VII shows the latter to have a decided asymmetry with respect to the wave axis, indicating a presence of even harmonic terms. Analysis of the record shows 9 per cent of second and 6 per cent of third harmonic, a total of 15 per cent. Even with this large amount of second and third, the fourth harmonic is only about 0.5 per cent; and the amount of higher terms is correspondingly less. The presence of a large amount of harmonics in the last print above indicates that as the print transmission decreases, the harmonic content, particularly that of the second, increases.

Fig. 8 shows the effect of increasing the negative density and gamma considerably. In this case the average density of 1.07 and gamma of 0.85 give a print having harmonic levels of −31, −21,

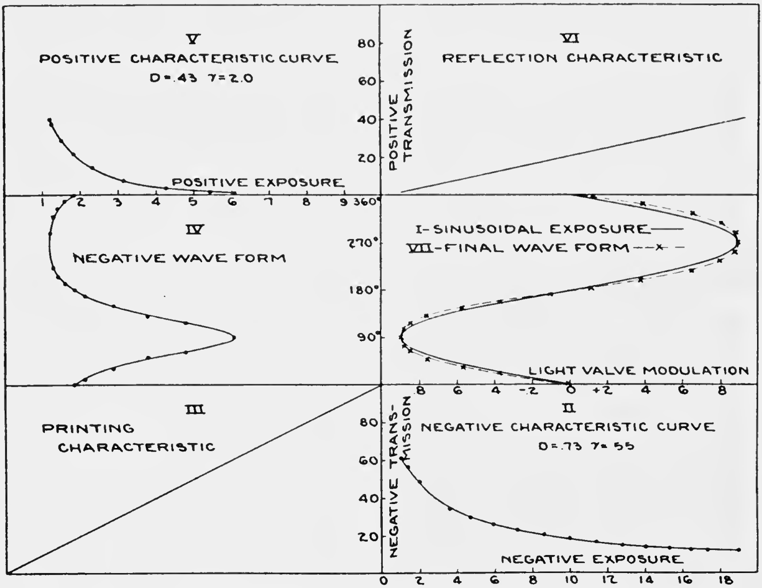

FIG. 6. Sound reproduction with normal negative; low print density.

and −35 decibels for the second, third, and fourth harmonics, referred to the fundamental. As shown in Fig. 9, a reduction in modulation to 50 per cent instead of 90 per cent eliminates nearly all the distortion even in this case, so records made would be of satisfactory quality except at the peaks of modulation.

The conclusion drawn from the foregoing results, in so far as non-linear or harmonic distortion is concerned, is that there are a number of sets of conditions that give nearly equally satisfactory results. These are distributed over a considerable range of exposure and de-

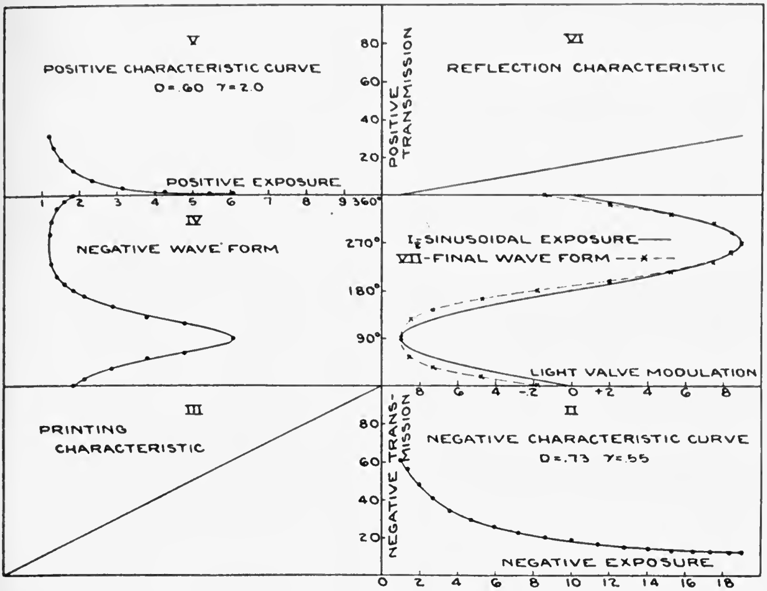

FIG. 7. Sound reproduction with approximately normal negative and positive conditions.

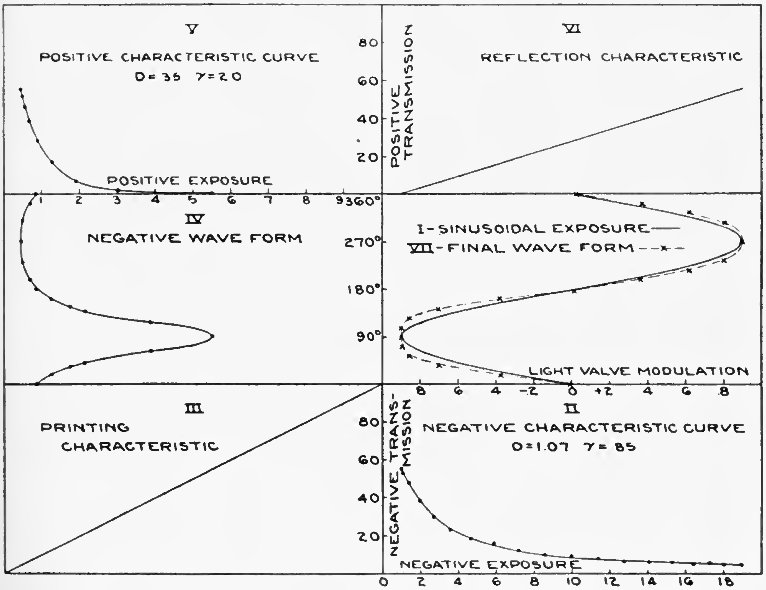

FIG. 8. Sound reproduction with high negative density, high gamma, and low print density, showing considerable distortion.

velopment. Table I shows the ratio of fundamental to total harmonic at different modulation levels. It will be observed that under certain sensitometric conditions, a modulation 6 decibels below the valve clash point gives more volume for a fixed amount of distortion than another sensitometric condition with a modulation only 1 decibel below the clash point. For any given amplification the ground noise increases with the print transmission, and, in order to render the results directly comparable, the volume of the prints whose density is 0.4 has been reduced 4 decibels, the volume of the prints whose

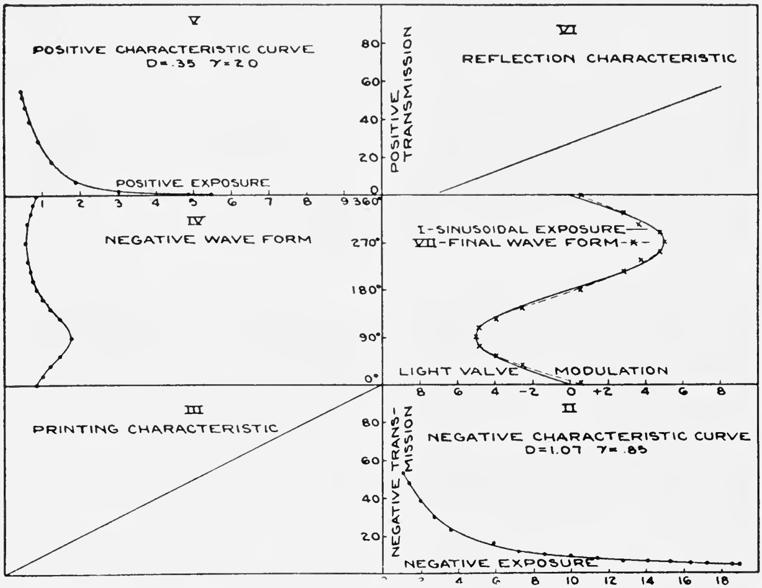

FIG. 9. Same conditions as Fig. 8 showing great improvement in reproduction with lower modulation (−6 db.).

density is 0.3 has been reduced 6 decibels, while those having a density of 0.7 were *increased* 1.4 decibels.

The data show that sets of conditions considerably different from the normal give less signal but much less distortion. If a harmonic level of about −15 decibels can be tolerated, then the generally accepted recording and printing conditions give about the most favorable ratio of signal to surface noise. The actual signal level of a print with an unmodulated density of 0.3 is considerably higher than a print whose density is, say, 0.6. Since scratches, dirt, and other imperfections of the film surface, however, give rise to greater parasitic modulations in the case of the lower density print, the ratio

TABLE I

Harmonic Level in Decibels below Fundamental Amplitude. Modulation in Decibels below 100 Per Cent Transmission Change Adjusted to 0.60 Density as Standard

Neg. D	Neg. γ	Pos. D.	1 Db. Down Mod.	1 Db. Down Harmonic	3 Db. Down Mod.	3 Db. Down Harmonic	6 Db. Down Mod.	6 Db. Down Harmonic
0.35	0.50	0.30	13.7	21.5	15.2	25.0	17.4	27.8
		0.40	12.5	23.6	14.2	24.4	16.9	27.2
		0.60	10.1	21.3	12.0	22.6	15.0	23.9
		0.75	11.6	16.5	15.3	18.8	18.0	20.8
0.55	0.50	0.30	13.0	21.6	14.4	21.6	16.8	22.5
		0.40	11.1	22.0	12.9	22.4	15.8	25.0
		0.60	9.7	18.8	11.3	21.5	14.0	25.0
		0.75	11.0	15.8	13.2	18.8	16.0	20.6
0.75	0.50	0.30	12.2	16.8	13.6	19.4	15.7	20.2
		0.40	10.1	20.9	11.8	20.9	13.9	24.0
		0.60	9.5	17.8	11.1	21.5	13.4	24.4
		0.75	10.4	15.8	11.6	18.5	13.8	20.4
0.35	0.65	0.30	13.3	20.1	14.7	24.7	16.8	27.6
		0.40	11.8	20.4	13.4	24.4	15.8	26.4
		0.60	9.7	17.6	11.0	19.5	13.3	23 1
		0.75	11.1	15.2	13.4	17.5	16.2	20.6
0.55	0.65	0.30	12.4	20.0	13.8	22.4	16.0	23.6
		0.40	10.6	19.6	12.2	23.0	14.6	26.0
		0.60	9.0	16.7	10.6	18.2	13.1	20.0
		0.75	10.3	14.8	11.7	17.5	14.4	20.3
0.75	0.65	0.30	11.7	17.2	13.0	20.9	15.0.	22.0
		0.40	9.9	18.6	11.4	21.4	13.3	22.8
		0.60	8.7	16.0	10.3	19.1	12.6	21.0
		0.75	10.0	14.8	10.7	17.2	13.3	20.1
0.35	0.80	0.30	12.8	18.8	14.4	24.3	16.3	27.0
		0.40	11.1	18.1	12.6	24.2	14.7	25.5
		0.60	9.4	15.0	10.5	17.3	12.4	22.0
		0.75	10.5	14.1	11.0	16.3	14.2	20.3
0.55	0.80	0.30	11.9	18.6	13.1	23.6	15.1	24.6
		0.40	10.2	17.7	11.6	23.1	13.7	26.8
		0.60	8.3	15.0	9.9	17.2	11.4	22.6
		0.75	9.4	13.9	9.8	16.3	12.9	20.0
0.75	0.80	0.30	11.2	18.6	12.4	23.0	14.4	23.0
		0.40	9.7	16.7	11.0	21.4	12.8	22.0
		0.60	8.0	14.6	9.6	17.3	11.8	19.0
		0.75	9.5	13.9	9.6	16.0	12.8	19.8
0.35	1.00	0.30	12.2	16.5	13.6	23.0	15.6	25.7
0.55	1.00	0.30	11.1	17.0	12.3	23.1	14.1	25.0
0.75	1.00	0.30	10.5	16.4	11.6	21.4	13.5	24.4

of signal to noise is generally greater in the higher density print, and the additional amplification necessary is usually available.

The table shows that by going to higher print density than 0.6, no further gain is effected in the ratio of signal to ground noise. It also shows that the harmonic content increases very rapidly when going to these higher print densities. What the most favorable conditions are can not be decided until it is known how much harmonic can be tolerated. The data to be found in the literature on this subject appear to be rather meager. MacKenzie[4] stated that more than 5 per cent becomes objectionable, whereas Ceccarini[5] more recently stated that 8 to 9 per cent is negligible. The latter value appears to be more nearly in agreement with what has been observed in connection with the present work.

A factor that may be of some importance concerns the relative amounts of the second and third harmonic components present. It is a well-known fact that when two simply related harmonics whose frequencies are, say, 200 and 300, are received by the ear, the ear itself supplies the missing 100-cycle component. As has been shown in the figures, at relatively high print density, say, 0.6 or higher, the amount of second harmonic is greater than the third. At a print density of about 0.4, the two have approximately the same amplitude; while at lower densities the third harmonic tends to be higher than the second. Now, if the ear is less sensitive to a total distortion in the form of approximately equal amounts of second and third harmonics than to unequal amounts, then the apparent distortion would be somewhat less than the values in the table indicated.

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THE PRECISE MEASUREMENT OF FILTER FACTORS AND PHOTOGRAPHIC REFLECTING POWERS*

L. A. JONES AND J. W. McFARLANE**

Summary.—*An instrument is described in which the theoretically correct conditions for precise photographic photometry are realized. It permits the measurement of filter factors, photographic reflection and transmission of coefficients of colored materials, and the photographic intensity of light sources with higher precision and greater repeatability than it has been possible to realize with the majority of other methods commonly used for these purposes. The method of procedure and the results obtained are illustrated by the projection of motion pictures showing the changes that occur in the photometric field during the process of making the determinations.*

In the evolution of photographic practice there has been a marked tendency during recent years toward the elimination of uncertain and laborious "trial and error" methods. As a substitute for these, many processes involved in photographic technic are now controlled precisely and are carried out in accordance with predetermined schedules. Thus, scientific control methods are rapidly replacing the older procedures based largely upon the personal experience and the judgment of individuals gained through long years of experience.

The aim of the present photographic process is the reproduction in the final positive, whether it be printed upon paper or projected upon a screen, of the gradations in brightness in the object photographed. This object, of course, may consist of variations not only in brightness but also in color. All these variations in the visual appearance of the object must be translated by the photographic process into terms of a gray scale, since it is not within the power of our present photographic process to reproduce variations in color.

In order to predict at what point on the tonal scale of the final reproduction a given color will be rendered, a knowledge of the photographic reflecting power of the variously colored objects within the field of view of the camera objective is of prime importance. Since the spectral sensitivity of photographic materials varies widely from

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* Presented at the Spring, 1932, Meeting at Washington, D. C. Communication No. 499 from the Kodak Research Laboratories.

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that of the normal human eye, the visual appearance of an object, that is, its brightness, may differ widely from the analogous photographic characteristic, its photographic brightness, or photiveness.

Now, assuming that a group of variously colored objects is uniformly illuminated, it being understood, of course, that this uniformity refers both to the intensity and the quality factors of the illumination, the relative photographic brightnesses of the various individual objects will be directly proportional to their ability to reflect the radiation to which the photographic material is sensitive. This characteristic we refer to as the photographic reflection factor, *photic reflectivity,* of the object in question. A precise knowledge of the photic reflectivity of various objects, such as colored wall draperies, floor coverings, make-up, costumes, *etc.*, should be of great value to those individuals who are responsible for the proper tonal composition of the final picture. A study of this subject is only another step in the evolution of the photographic technic which enables the operators to predict the final result on the basis of precise information, rather than making it necessary for them to rely upon experience or upon uncertain and laborious trial and error methods.

In a previous communication[1] the author has dealt with this subject at considerable length. The theoretical considerations involved have been treated, and numerous data relating to the photographic reflection factors of variously colored objects have been published. It will be unnecessary at this time to repeat all this treatment. It may be advantageous, however, to review briefly some of the more salient factors involved in a thorough understanding of the subject.

A reflection factor in the broadest sense is defined as the ratio of reflected to incident radiant flux. This is strictly true in any case where a single wavelength of radiation is concerned and is applicable when it is desired to express the reflection factor in terms of radiant flux. In the case of objects which reflect equally all wavelengths incident thereon, and within those wavelength limits which embrace the spectral sensitivity of the photographic material and that of the human eye, the photographic reflection factor is identical to the visual reflection factor; in this case probably the simplest method of obtaining the desired value is by a visual measurement made according to well recognized principles of visual photometry. Such objects are known as nonselective absorbers, and are generally referred to as the gray series. Many objects which appear colorless or gray to the eye, however, are far from nonselective throughout the wavelength region to which photographic materials are sensitive. Even with this class of materials, measurements of reflection factor made visually may be very misleading when applied to photographic tone reproduction work.

In this field we are vitally concerned with the relation between the visual and the photographic evaluation of the heterogeneous radiation reflected by objects to be photographed. While it is true that a spectrophotometric curve is probably the most direct and most precise method of defining the selective absorption of any reflecting or transmitting material, such data are not readily interpreted

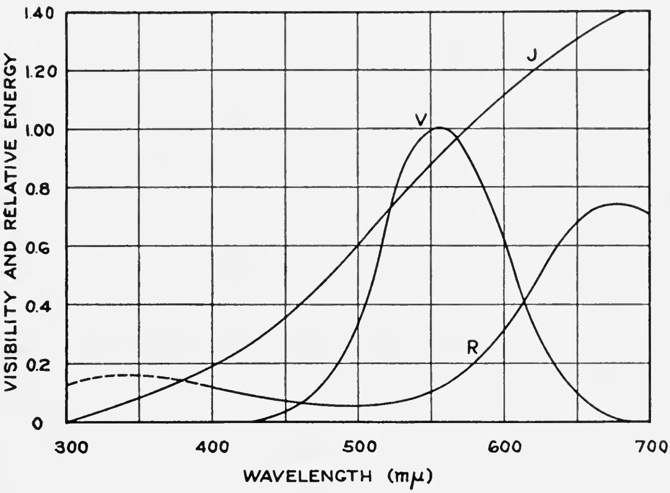

FIG. 1. Spectrophotometric functions involved in the evaluation of visual reflection factor.

in terms directly useful in deciding upon the relationship between the visual and photographic brightness of the objects in question. The brightness of an object as seen by the eye depends upon the quality of radiation which is incident thereon and upon the selective absorption of that object. For our purpose, therefore, it is necessary to define the visual reflection factor as the ratio of the reflected luminous flux to the incident luminous flux.

In order to show clearly the significance of a visual reflection factor Fig. 1 is presented. Curve V represents the sensitivity of the eye to radiation of different wavelengths. This is commonly referred to as the *visibility curve* and is plotted with its maximum ordinate equal to unity. Curve J shows the *spectral distribution of energy* from the radiation of an assumed light source which, in this case, is incandescent tungsten operating at a color temperature of 3200°K. The ordinates of this curve are relative, and show the relative amounts of radiation emitted at various wavelengths between 300 mμ and 700 mμ. Curve R is the *spectrophotometric reflection curve* of an assumed colored object. The curve shown applies to a surface painted with the pigment known as vermilion. The ordinates of this curve are directly proportional to the amount of energy reflected at various wavelengths.

The visual evaluation of radiation is given by a curve obtained by multiplying the ordinates of curve J by those of curve V, wavelength by wavelength. This curve is known as the *luminosity curve* of the source, and the area which it encloses may be taken as directly proportional to the brightness factor of the radiation. After reflection from the object, represented by curve R, the visual evaluation of the reflected radiation is given by multiplying the luminosity curve of the incident radiation by the spectrophotometric reflection curve, and the area enclosed by the curve thus obtained, when compared with the area under the luminosity curve of the source, gives the visual reflection factor for the colored object. This may be expressed formally by

$$R_V = \frac{\int_0^\infty J_\lambda \, V_\lambda \, R_\lambda d\lambda}{\int_0^\infty J_\lambda \, V_\lambda \, d\lambda}$$

where J_λ, V_λ, and R_λ represent values of the various functions at the wavelength λ.

The manner in which the photographic reflection factor must be evaluated and the functions upon which it depends are shown in a similar manner in Fig. 2. The J and R functions are the same as those shown in Fig. 1. The curve A represents the *spectral sensitivity,* that is, *photability,* of a panchromatic material. The photographic evaluation of the radiation represented by J is obtained by multiplying the ordinates of curve J by those of curve A. This gives a relationship which is called the *photicity* curve, and is directly analogous to the luminosity curve previously referred to. In case pictures are being made by means of a camera equipped with a glass lens, a certain amount of short-wave radiation is selectively absorbed, and hence to obtain an *effective photicity curve* for this case it is necessary to introduce one other function shown as curve

C in Fig. 2. This is the *spectrophotometric transmission curve* of a well-known motion picture objective. Thus, the effective photicity curve for this case is obtained by multiplying the ordinates of curves *J*, *A*, and *C*, and the area enclosed under this curve is directly proportional to the photographic brightness of radiation.

The photographic evaluation of the radiation reflected by an object, of which *R* is the spectrophotometric reflection curve, is given by a curve obtained by multiplying together the ordinates of the curves *J*, *A*, *C*, and *R*. The relative area included under this curve, as compared with the effective photicity curve, gives the photographic

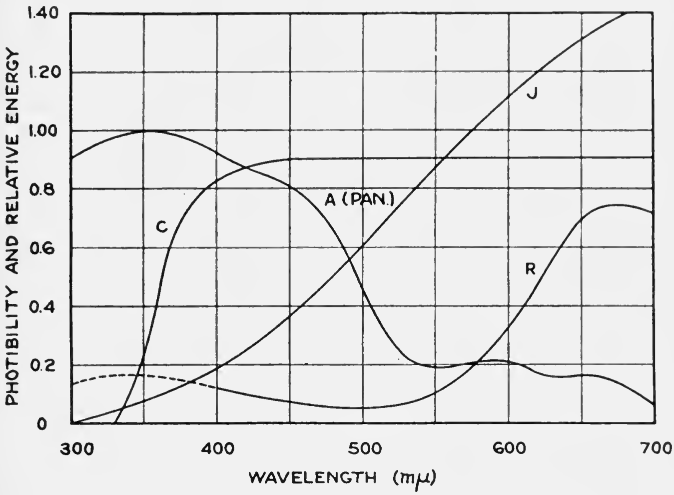

FIG. 2. Spectrophotometric functions involved in the evaluation of photographic reflection factor.

reflection factor, photic reflectivity, of the object in question. Thus, photic reflectivity may be defined in terms of these fundamental characteristics by the equation

$$R_P = \frac{\int_0^\infty J_\lambda A_\lambda C_\lambda R_\lambda d\lambda}{\int_0^\infty J_\lambda A_\lambda C_\lambda d\lambda}$$

It is quite possible to compute the photic reflectivity of any colored object provided all the necessary fundamental information is available. In practice, however, it is found that this method is very laborious and, moreover, the values obtained in this manner are not as precise as those which can be determined by a more direct method.

In the communication already referred to,[1] a direct method of measuring photographic reflection factors is described and the results obtained are given. This method is based essentially upon the determination of the visual reflection factors of a series of gray objects. It is then assumed that these reflecting surfaces are non-selective, both visually and photographically. This assumption is justified only to a certain extent, since it is exceedingly difficult to prepare surfaces which show no selective absorption throughout the wavelength range required, which, in this case, extends from 300 mμ to 700 or 800 mμ. Moreover, the method involves the measurement of densities in the resultant negatives, the plotting of the characteristic log E-density curve of the photographic material being used, and the interpolation on this curve of density values obtained from the negative of the various colored objects in question. It has been found almost impossible to obtain results by this method which are repeatable with the desired precision. This follows probably from the necessity of distributing the densities which must be measured over a relatively large area of photographic film or plate. It is extremely difficult to obtain absolutely uniform development over a relatively large area and while, for all practical purposes, a photographic material may have a uniform sensitivity, there are measurable departures from such uniformity when attempts are made to do photographic photometry in which only a fraction of one per cent of error is tolerable.

Since the determination of photographic reflecting factors is of considerable importance in tone reproduction work and in the determination of precise orthochromatic rendering of colored objects, it seemed desirable to develop a more convenient and more precise method. This led to the design and construction of the instrument to be described in this communication. The problem involved is one essentially of photographic photometry, and before proceeding with the description of the method and instrument, it may be well to state briefly some of the peculiarities of photographic materials which may give rise to errors when these materials are used in the measurement of radiation intensities.

In a previous communication[2] the author has attempted to set forth the various pitfalls which may be encountered in using photographic materials for photometric purposes, and while the discussion presented at that time applied specifically to spectrophotometric work, it applies in general with equal force to photometric work.

Intermittency Effect.—A photographic plate does not in general integrate correctly an intermittent exposure. An exposure (Exposure, E = Intensity, $I \times$ Time, t) of definite magnitude given as a series of intermittent flashes generally yields, upon development, a lesser density than the same exposure applied continuously. Hence, only under certain conditions will correct values of intensity be obtained if the exposing mechanism is of the intermittent type.

Failure of the Reciprocity Law.—The density produced by a given exposure, E, is dependent not only upon the value of exposure $E = I \cdot t$, but upon the magnitudes of intensity, I, and exposure time, t.

Gamma-Wavelength Effect.—The contrast (gamma, γ) produced in a fixed time of development is dependent upon the wavelength of the exposing radiation, and may vary to a great extent for a relatively small difference in wavelength.

Nonuniformity of Effective Sensitivity.—The most carefully made photographic materials may show measurable differences in sensitivity at various points, even when the area used is relatively small. These variations in effective sensitivity may be due to such factors as inequality in the thickness of coating, variation in the specific sensitivity of the emulsion, or slight differences in the rate at which development takes place at different points on the plate. While these inequalities are, in general, too small to be of consequence in the practical work to which these materials are usually applied, they may become of great importance and of sufficient magnitude to introduce serious errors when an attempt is made to use these materials for the purposes of quantitative scientific measurement.

Errors of Development.—It is very difficult to develop two samples of photographic material to exactly the same extent. This is due to many factors, such as the variation in the rate of circulation of the developing solution over the surface of the plates or films, variation in temperature and time of development, *etc.* It is inadvisable and unnecessary for the purpose of this paper to discuss these factors in detail.

From a consideration of these characteristics the conditions under which two radiation intensities are equal may be rigidly specified. Let two immediately adjacent small areas, A and B, on the surface of a photographic material, be exposed to the two intensities to be compared. Let this exposed material be developed in such a way that the two areas receive precisely the same treatment in developing, fixing, washing, drying, *etc.*, and the resultant density be measured under identical conditions of illumination and observation. Let the various factors involved be designated for convenience as follows:

Area	A	B
Intensity of incident radiation	I_1	I_2
Wavelength of incident radiation	λ_1	λ_2
Exposure time	t_1	t_2
Density	D_1	D_2

In general, I_1 is equal to I_2 only when both exposures were made nonintermittently and when $t_1 = t_2$, $\lambda_1 = \lambda_2$, and $D_1 = D_2$.

The requirement that λ_1 must be equal to λ_2 may be replaced by the condition that the *spectral composition* of the two radiations under comparison shall be identical. Obviously, in the measurement of the photographic reflection factor of colored objects, it is impossible, in general, to meet this requirement. In fact, the problem by its very nature precludes this, since it essentially deals with the evaluation of the photographic reflection factor of objects which reflect *different* spectral qualities of radiation as compared with each other and with those objects which reflect nonselectively, that is, the white-gray-black series. It is obviously essential, therefore, in dealing with this subject, to set up certain limitations of conditions under which the determined values remain valid. This will be discussed more fully when the data obtained are considered.

In Fig. 3 a schematic diagram of the arrangement of the optical parts of this photographic reflectometer is shown. The optical system consists essentially of two identical image-forming systems, the optical axes of which are represented by the lines *rmo* and *yzno.* The object planes of the two systems are coincident; this plane is represented by the line *ry.* The image planes of the two systems are perpendicular to each other, the intersection of these planes being a line perpendicular to the plane of the drawing and passing through the point *o*, which also lies on the dividing line of the Lummer Brodhun cube, *C.* This cube is of the simple two-part field type, and is made by placing in optical contact the hypotenuse faces of two isosceles right triangular prisms. A shallow groove, as shown in the figure, is ground in one of these hypotenuse faces so that, when the two halves are placed together in optical contact, a vertical strip is obtained from which the light entering the cube along the axis *mo* is totally reflected.

The optical system, of which the axis is *rmo*, will be referred to throughout as the *standard* system and its various parts will be desig-

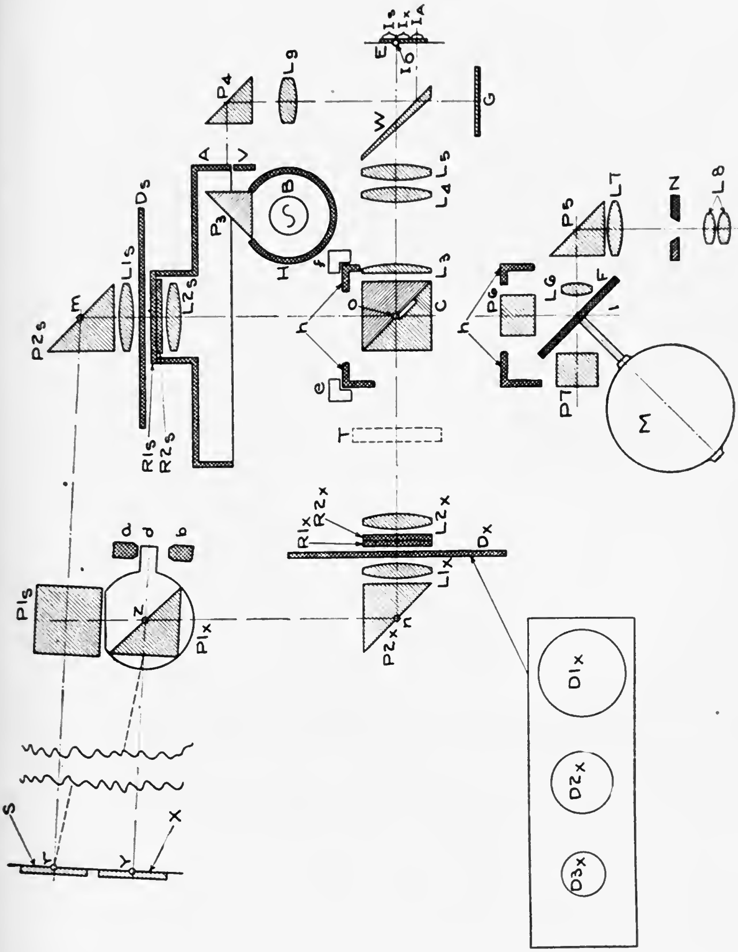

FIG. 3. Schematic diagram of optical system of photographic reflectometer.

nated by the subscript *s*. The other of the two optical systems, of which the axis is *yzno*, will be referred to as the *test* system, and its various parts will be designated by the subscript *x*.

In the standard system the two-component lens, $L1_s$ and $L2_s$, is the image-forming element, and forms an image of the point *r* at the point *o*. The powers of these two components are so adjusted that the light between them is practically parallel. In the other system an identical two-component lens, $L1_x$ and $L2_x$, forms an image of the point *y* at the point *o*. The length of glass path in one

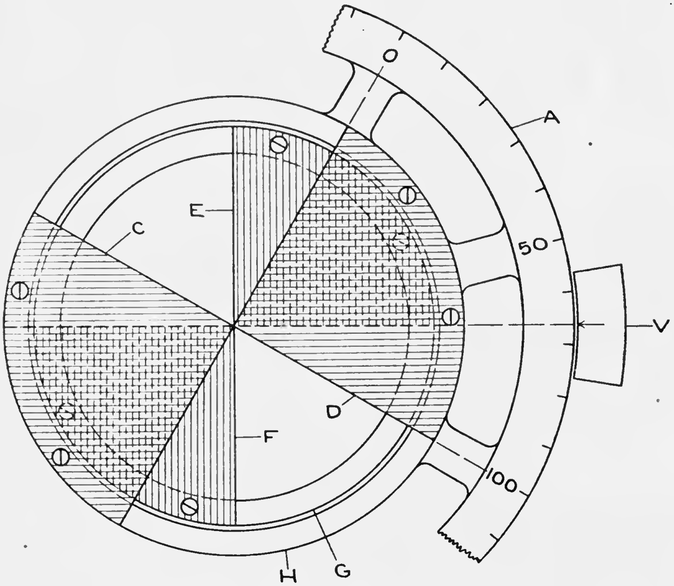

FIG. 4. Adjustable radial sector diaphragm.

of these systems is exactly the same as the length of glass path in the other system. Likewise, the lengths of air paths in the two systems are identical. Furthermore, the number of free glass-air surfaces in each of the two systems is identical. The magnifications of the two systems are also identical. Thus, if two surfaces, *S* and *X*, of identical brightness are placed as indicated in the object plane, *ry*, their images formed at *o* by the two systems will be identical in size and brightness.

The brightness of the image formed at *o* by the standard system is controlled by means of a radial sector diaphragm placed between the lenses $L1_s$ and $L2_s$. The stationary part of this radial sector diaphragm is designated as $R2_s$, the moving part as $R1_s$. The moving blades are carried by a rotating element mounted in a suitable bearing. Scale drum A is attached rigidly to the rotating element.

The construction of this radial sector diaphragm is illustrated in Fig. 4. The blades E and F, indicated by the vertical hatching lines, are mounted on a ring, G, which is fixed with reference to the framework of the instrument. The other pair of blades, C and D, indicated by the horizontal hatching lines, is mounted on the ring, H, which is carried by a suitable bearing. Each of the blades E, F, and C, D are cut with great care so that each subtends an angle of exactly 90 degrees at the center of rotation. Thus, when the blade D is exactly superposed over E, C will be superposed over F, and the total unobstructed angular opening is exactly 180 degrees. When the blades C and D have been rotated 90 degrees from this position, the entire aperture is just filled, and no light is permitted to pass. Thus the angular opening may be varied from zero degrees to a maximum of 180 degrees, corresponding to transmission values for the standard system of 0 and 50 per cent.

A radial sector diaphragm of similar construction is mounted in the test system between the lens elements $L1_x$ and $L2_x$. This is designated in Fig. 3 by $R1_x$ which represents the adjustable blades and $R2_x$ which represents the stationary blades. This diaphragm is adjustable by means of a slow-motion screw through a relatively small range extending somewhat below and above the 180-degree value which is the maximum radial aperture obtainable with the diaphragm $R1_s$ plus $R2_s$ in the standard system. Under ideal conditions when the surfaces s and x are of the same brightness, when the radial sector diaphragm in the standard system is set for the 180-degree opening, and when the radial sector diaphragm in the test system is also set for the 180-degree opening, it is evident that a precise balance of brightness should exist between the images of s and x which are formed in the photometric cube at o. In practice, however, it is found convenient to have a slight adjustment in the test system in order to compensate for slight imbalance in the two systems which may be due to nonuniformity of illuminations on the plane ry or to other obscure causes.

The scale drum, A, which is attached to the moving elements of the radial sector diaphragm in the standard system is numbered from zero, at a sector opening of 0 degrees, to 100, at a sector opening of

90 degrees. In the figure only one quadrant of this scale is shown. Actually the scale is repeated four times, thus being laid around the entire circumference of the cylindrical drum represented in cross-section as A. The scale is formed by opaque figures on a transparent ground. (See Fig. 10.) The method of reading and printing this scale will be discussed later.

In order further to control the brightness of the images formed in the photometer cube, a diaphragm plate, D_s (Fig. 3), is placed in the standard system as shown, and a similar one, D_x, is placed in the test system. Each of these plates has three circular openings, the largest of which has a diameter just slightly less than the maximum free aperture of the compound lens $L1_x$, $L2_x$ (or $L1_s$, $L2_s$). They thus serve as the limiting stops of these systems, and determine the brightness of the images of X and S formed at o. The second opening, $D2_x$, has a diameter such that its area is approximately one-half that of $D1_x$. The third opening, $D3_x$, has an area approximately one-fourth that of $D1_x$. These diaphragm plates slide laterally in suitable slots, and are provided with register marks so that any one of the three apertures desired may be centered on the axes of the optical systems. In this way the brightness of the images of x or s formed at o may be reduced to one-half or one-quarter of their maximum value. In practice it is found desirable to have additional diaphragm plates similar to that shown in the figure, but with smaller apertures, in order to increase the range of brightness over which the measurements may be made.

In measuring the reflection factor of any surface, this surface is held in a suitable holder so that it lies in the plane ry and on the axis yz. The standard surface, in terms of which the reflection factor of an unknown is measured, is placed in the same plane but on the axis rm. This sample holder is assembled at a distance of about six or seven feet from the body of the instrument, thus allowing ample room for the manipulation of relatively large light sources, such as are commonly used in motion picture studios. The light source being used for illuminating the surfaces is so placed that the illumination is incident on the surface at an angle of 45 degrees from above. The surfaces are observed normally, that is, they are placed perpendicularly to the optical axes yz and rm. Thus, any specular reflection which may arise from the surface finish is thrown out and the values obtained are those of the diffuse reflection factor.

The photometric field, one-half of which contains an image of the standard surface, S, and the other half of which contains an image of the test or unknown surface, X, is now imaged by means of the two-component objective, *L4* and *L5*, on the exposure plane, E. A field lens, *L3*, forms an image of the lenses $L2_x$ and $L2_s$ in the lens system *L4* and *L5*. In the exposure plane, E, the line in the figure represents a cross-section of standard 35 mm. motion picture film which travels downward through the plane of the drawing at a uniform linear velocity. The motion picture film is carried by a sprocket of the usual type mounted in a film box on the top of which may be placed a standard Bell & Howell magazine carrying

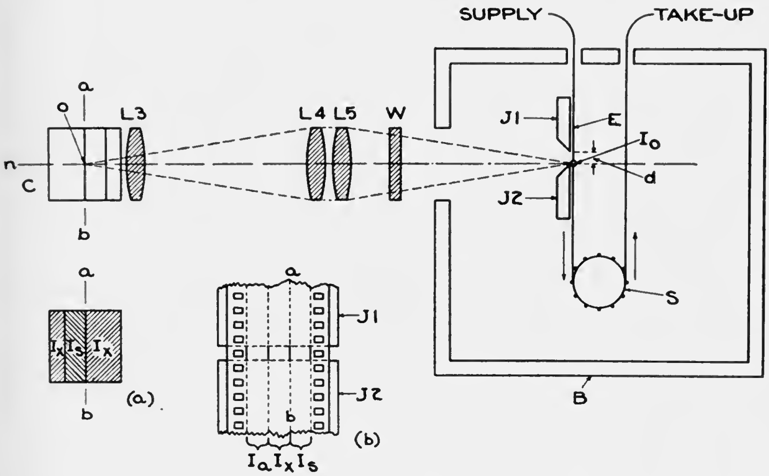

FIG. 5. Schematic cross-sectional elevation through the line noI_o of Fig. 3; (*a*) photometric cube as seen from *L4L5* of Fig. 3; (*b*) disposition of the images of the photometric field and scale on the photographic film.

an adequate film supply and providing take-up of the exposed film.

In Fig. 5 the arrangement of the photographic film relative to the photometer cube is shown in greater detail, this being a schematic cross-sectional elevation through the line noI_o, as shown in Fig 3. It will be noted that the unexposed film enters the film box, B (in Fig. 5), from above, is pulled down by the film sprocket S, and is taken out through the top of the box to the take-up reel. An adjustable slit consisting of two jaws, *J1* and *J2*, is placed immediately in front of the exposure plane which is occupied by the film. Since the film moves at a constant linear velocity past this slit, the variation in the slit width may be made to control the exposure time and, therefore, the density of the image formed on the film.

In Fig. 5 (*a*) is shown the appearance of the photometric cube as seen from the right, that is, from the position of the objective *L4L5*. The center line, *ab*, corresponds to a line perpendicular to the plane of Fig. 3 and passing through the point *o*. The portion of this photometric field occupied by the image of the standard surface, *S*, is indicated by I_s (Fig. 5); the portion occupied by the image of the unknown or test surface, *X*, is indicated by I_x. At (*b*), Fig. 5, is shown the disposition of the image of the photometric field on the photographic film. This is as it appears from the right, that is, looking at the image assembly through the photographic film. *J1* and *J2* again represent the slit jaws lying between the objective *L4L5* and the sensitive surface of the photographic film. The perpendicular line *ab* again corresponds to the line *ab* in Fig. 5 (*a*). The areas of the film occupied by images of the standard and test surfaces are indicated by I_s and I_x, respectively. The area of the film designated as I_a is that on which the image of the scale attached to the moveable blades of the radial sector diaphragm is automatically printed. This image is reflected by the front surface of the wedge-shaped glass plate *W* (Fig. 3).

It will be noted that the center line of the 35 mm. motion picture film is shifted laterally so that it does not fall upon the central line of the optical system noI_o, but is displaced laterally sufficiently to provide room for the printing of the reflecting power scale. The image of this scale is formed by the lens *L9* (Fig. 3). The scale is illuminated by an incandescent lamp, *B*, mounted in the housing, *H*. A total reflecting prism, P_3, the face of which is finely ground, provides satisfactory illumination. A small index line is provided by the element, *V*, which is a metal plate in which a very narrow horizontal slit is cut. The prism, P_4, and the wedge plate, *W*, serve to bend the rays in the required direction so that an image of the scale plate, *A*, is formed on the exposure plane occupied by the film in the position as indicated by I_a. The diameter of the cylindrical surface carrying the scale, *A*, and the velocity of angular rotation are such that with the magnification afforded by the lens, *L9*, the image of the numbers on the scale plate, *A*, move at exactly the same linear velocity in the exposure plane as that which is given to motion picture film by the driving sprocket, *S* (Fig. 5). Thus, the images of the scale numbers stand still with respect to the photographic film surface. They are, therefore, imaged with satisfactorily sharp definition on the photographic film as it travels past the slit through which exposure takes place.

The optical principle of the instrument is now fairly manifest. While the diagram may look somewhat complicated, the principle after all is relatively simple, and involves merely the formation of juxtaposed images of the standard or comparison surface, *S*, and the test or unknown surface, *X*, in the photometer cube at *o*. These images are then transferred to the surface of the photographic film, *E*, again in a closely juxtaposed position with a very fine and practically invisible dividing line between them.

Let us now turn to a consideration of the mechanical features of this instrument which are essential to its proper functioning. The various elements of the driving mechanism are shown schematically in Fig. 6. A synchronous motor operating at 1800 rpm. furnishes the motive power. This drives first through a reduction gear, *G1*, which is a worm and worm wheel giving a 15 to 1 reduction. An over-running clutch is placed at *R*, and, in order to obtain a satisfactory variation in the rate at which the film is driven through the film box, thus making it possible to obtain correct photographic exposures by controlling the exposure time, a set of change gears, *G2*, is introduced. These provide five different velocities of drive. *F* is a flywheel which serves to smooth out irregularities of angular rotation. *C* is a magnetic clutch, the energizing of which causes the driving motor to operate the rest of the mechanism. A worm and worm wheel reduction gear, *G4* (16 to 1), drives the shaft which carries the film sprocket, *S* (which is the same as that shown as *S* in Fig. 5). Another worm mounted on the same shaft engages the worm wheel, *G7*, the reduction here being 160 to 1. The worm wheel, *G7*, is an integral part of the rotating element which carries the movable blades of the radial sector diaphragm $R1_s$, $R2_s$ and its attached scale drum, *A*. The double reduction worm and worm wheel pairs, *G5* and *G6*, drive the cams, *C1* and *C2*, one of which automatically opens and closes the window in front of the film box at properly predetermined instants and the other of which operates an automatic switch which cuts off the electrical supply to the magnetic clutch, *C*, when the rotating radial sector diaphragm has made one and one-quarter complete revolution.

The principle on which the instrument operates should now be apparent. Thus, let us assume that as a standard, *S*, a magnesium oxide coated surface is placed at *r* (Fig. 3) in the object plane, *ry*, and that a surface, *X*, of unknown reflecting power, which will be assumed to be less than that of the magnesium oxide coated surface, is placed in the object plane at *y*. Further, let us assume that the radial sector diaphragm, $R1_s$, $R2_s$, is set for maximum transmission, that is, with the scale reading 100 at the index line. The image of this unknown surface, *X*, formed on the photographic film in the area I_x will be less bright than the image of the standard surface, *S*, formed on an immediately adjacent area of the film at I_s.

Now let us assume that the magnetic clutch, *C* (Fig. 6), is energized and that the motor begins to drive the mechanism. The film is

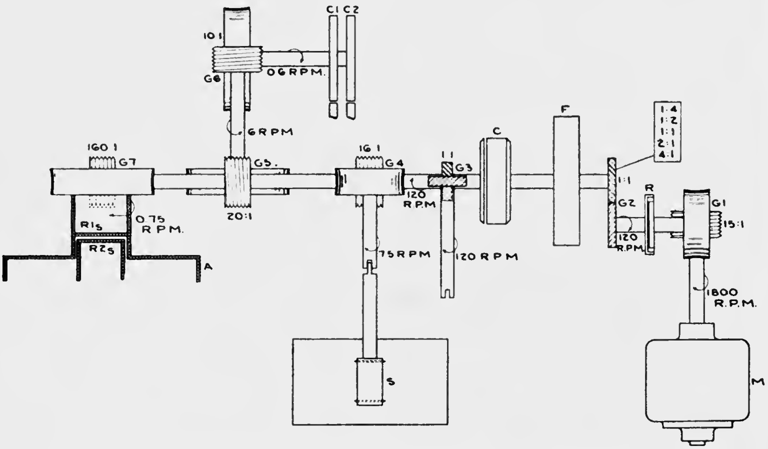

FIG. 6. Driving mechanism of photographic reflectometer.

drawn at a uniform linear velocity past the slit as shown in Fig. 5, and hence every point is exposed for a fixed time, dependent upon the slit width and the film velocity. No change in the adjustment of the test system is made; hence the brightness of the surface of unknown reflecting power remains constant and, therefore, the exposure on the area I_x remains constant. In the case of the standard system, however, this is not so. As soon as the clutch is energized and the film begins to move, the radial sector diaphragm in the standard system also begins to move and, since it started at maximum opening, it must begin to close; hence the brightness of the image of the standard surface formed on the film area, I_s, decreases. The exposure which this portion of the film receives decreases gradually, therefore, in a definitely known manner as the diaphragm closes. The decrease in exposure is achieved by a diminution of intensity. An intensity scale of exposure is therefore imposed upon the area I_s and at some point between the 180-degree opening and the 0-degree opening this exposure must be identical to that which is received by the film area I_x. The radial sector diaphragm continues to rotate past the 0-degree opening and gradually increases, ultimately reaching 180 degrees again. And again between these points at some instant the exposures on the two adjacent areas must be identical. For every complete rotation of the radial sector diaphragm on the standard side of the system four match points must exist. Since the dividing line between these two areas is very sharp, the position of these match points can be picked out very easily by direct visual inspection, no measurement of density being required.

While these two areas of the film, referred to as I_s and I_x (see Figs. 3 and 5), are being exposed, the scale, A (Fig. 3), is at the same time automatically impressed upon the film in area I_a. Thus, to determine the photographic reflection factor it is only necessary to read on this scale, which becomes visible when the film is developed, the position of the match point between the areas I_s and I_x.

It should be emphasized that this method of establishing the equality of two radiation intensities meets most of the rigid requirements previously set forth as necessary. Thus the exposures are nonintermittent. The film areas which are to be judged of equal densities are very small and are immediately adjacent to each other on the opposite sides of a very fine dividing line. Thus errors, due to possible variations in the sensitivity of the photographic emulsion from point to point, and also those due to lack of perfectly uniform development of a relatively large area, are minimized, and for all practical purposes completely eliminated. The quality of radiation intensity is based upon the production of equal densities for fixed exposure times, thus eliminating any error due to reciprocity failure.

The only condition which is not satisfied relates to the identity of the spectral distribution of the two radiations and, as stated previously, this is inherently impossible in work of this kind. In fact, this problem of measuring photographic reflection factors of colored objects may be likened to the problem of heterochromatic photometry, where the necessity of equating the brightness factors of two differently colored illuminants is unavoidable.

For the purpose of measuring photographic reflection factors, the instrument as described is complete. But since in many problems of tone reproduction it is desirable to determine how nearly the photographic reflection factor corresponds to the visual reflection factor of a colored object, and thus to determine the perfection with which orthochromatic rendering is being obtained, it is highly desirable to have some means for measuring the visual reflection factor under the same conditions of illumination and observation as existed when the photographic reflection factor was determined. To meet this need, additional elements have been built in as integral parts of the instrument so that such visual measurements may be made immediately prior to or following the measurement of the photographic reflection factor.

The photometric cube, *C* (Fig. 3), together with the field lens, *L3,* is mounted in a rectangular metal box, the walls of which are indicated as *h.* This box slides vertically in the guides *e* and *f.* In the lower portion of this rectangular box is assembled the flicker photometer, as shown in the lower part of Fig. 3 immediately below the photometer cube assembly. The walls of the rectangular box are again indicated by *h* and actually lie immediately below those shown in the upper part of the figure and are an integral part of the housing enclosing the photometer cube, *C.* A small motor, such as is used in driving dental drills, is mounted rigidly on the side of the housing, and on the shaft is mounted directly the flicker disk of two highly polished stellite blades. Each blade at the axis of rotation subtends an angle of exactly 90 degrees, and they are so mounted that the two reflecting surfaces lie in a plane perpendicular to the axis of the motor shaft.

In order to compensate for the glass path of the two parts of the photometer cube, glass compensating blocks, *P6* and *P7*, are mounted as shown. This is necessary so that when the photometer housing is raised to bring the flicker disk into proper position, the effective path length is not changed and the images of the standard and test surfaces are imaged at the same point as when the photometer cube is in position.

A specially designed eyepiece consisting of the lenses *L6*, *L7*, and *L8*, is used for viewing this flicker disk. The total reflecting prism *P5* is used so that the eye position will be in a convenient place for observation. The stop *N* limits the field to prevent undue parallax effects.

The flicker photometer assembly may be brought into position on the optical axis noI_o by simply raising the assembly a fixed distance determined by a stop pin. The eyepiece assembly, *P5* to *L8*, is mounted permanently in the same horizontal plane as the principal axis of the instrument, but is slidable inwardly and outwardly so that, when photographic measurements are being made, it may be pulled out so as not to obstruct the light in traveling from o to I_o. When visual flicker photometer measurements are being made, this eyepiece is pushed in to occupy the relative position as shown in the lower part of Fig. 3.

In order to make visual measurements, the moving part of the radial sector diaphragm, $R1_s$, is disengaged from the driving mechanism which moves it during photographic operations. It then can be operated manually by means of a conveniently placed handwheel connected to the moving element through a leather belt. The operator adjusts the flicker field to a minimum flicker by setting the radial sector diaphragm so that the image of the standard surface has the same brightness as the image of the test surface. The flicker disk must of course be operated at the critical frequency, which is a function of field brightness and color. The motor speed is therefore made variable by means of a suitable adjustable rheostat which may be set by the operator.

Referring again to Fig. 6, it will be noted that immediately adjacent to the magnetic clutch, *C*, is mounted a pair of spiral bevel gears having a ratio of 1 to 1 for driving a lateral shaft at 120 rpm. This provides motive power for a standard Bell & Howell 35 mm. motion picture camera. The film box, designated by the rectangle enclosing the film sprocket, *S*, may be removed from the assembly since it is mounted on a dovetail slide. A suitable stop is provided so that it can be removed from the assembly and replaced in exactly the same position with great ease and certainty. The Bell & Howell motion picture camera is also mounted in a dovetail slide and may be moved into position so that the shaft connects with the driving mechanism of the camera.

When the camera is in position a motion picture of the photometric field may be made, including the strips I_x and I_s, which are images of the test and standard surfaces, respectively. The scale, *A*, is also imaged, at I_a [Fig. 5 (*b*)], on the film, this image being spaced in relation to the photometric areas as shown in the figure. The camera is driven at a speed sufficiently high so that 320 pictures are taken for every quarter turn of the scale drum *A* (Fig. 3). When the images of the test and standard surfaces are not of equal photographic brightness, the exposures of the two areas of the motion picture frame covered by these images are necessarily different and, after the film has been developed, a different density is seen upon these two areas. There must be, however, at some point between 0 and 100 on the scale, a point at which equality of photographic brightness exists between these images. This is easily discerned when watching the screen on which this motion picture is being projected. Since the scale drum is also rotating with the radial sector diaphragm on the standard side of the optical system, the scale num-

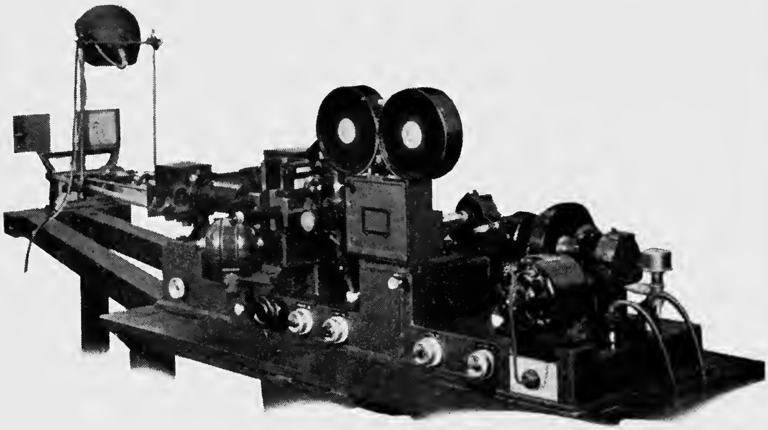

FIG. 7. Front view of photographic reflectometer.

bers, as the motion picture is projected, appear to move with respect to the index line, *V*, cut in the scale plate (Fig. 3). At the instant when the two parts of the projected picture appear of equal brightness, the reading of this index on the scale gives directly the photographic reflection factor of the surface being examined.

Thus, there are two methods of obtaining the desired result, and the two methods give identical values. For routine work it is more convenient to use the film box, since only a few feet of film are required to make four determinations of reflection factor. For demonstration purposes, however, the photography of the photometric field by means of a motion picture camera giving film, which can be developed, printed, and projected, is very advantageous.

Referring again to the method which involves the use of the film box with the motion picture film moving at a relatively low velocity past the slit, as shown in Fig. 5, it is evident that there will be a slit width error of a magnitude depending upon the width of the slit. This is of little consequence, since this slit width error, arising when the record is being made with the radial sector diaphragm closing, is exactly equal in magnitude but of opposite sign from the slit width error arising when the record is being made with the radial sector diaphragm opening. Since in one complete cycle of the scale drum four match points are obtained, two of which occur with the diaphragm opening and the other two closing, it is only necessary to take the average of these four values in order to eliminate completely any errors due to the finite width of the slit and to any eccen-

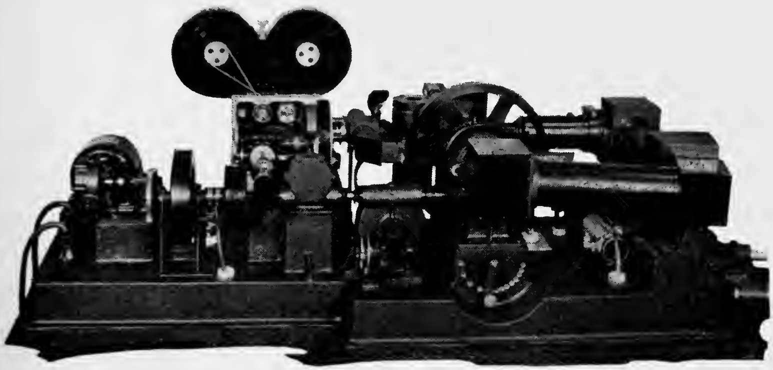

FIG. 8. Rear view of photographic reflectometer.

tricity which may exist in the mounting of the radial sector diaphragm.

In Fig. 7 is shown a photograph of the front of the assembled instrument. On the near corner may be seen the synchronous motor which provides the motive power. In the front center will be seen the film box on the top of which is mounted the film magazine. At the extreme left is the standard surface and test surface holder with a tungsten lamp mounted above for illumination.

In Fig. 8 is shown a rear view of the instrument, in this case equipped with the Bell & Howell camera in position for making motion pictures of the photometric field. At the extreme right are the housings enclosing the compensating prism $P1_s$ and the total reflecting prism $P1_x'$ (see Fig. 3). The wheel in the center carries the cylindrical scale drum, shown in Fig. 3 in cross-section at A.

In Fig. 9 is a third view of the instrument, taken from the front and above. At the extreme left are the rods which extend out to the sample holder. These are relatively heavy, and are cross braced to give ample rigidity so that the standard and test sample will be held in a fixed position relative to the instrument. The cylindrical scale drum is, in this view, quite visible in the center of the assembly. Here also may be seen the housings carrying the compensating prism, $P1_s$, and the total reflecting prism, $P1_x$ (Fig. 3). At the lower right may be seen the small ball motor for driving the

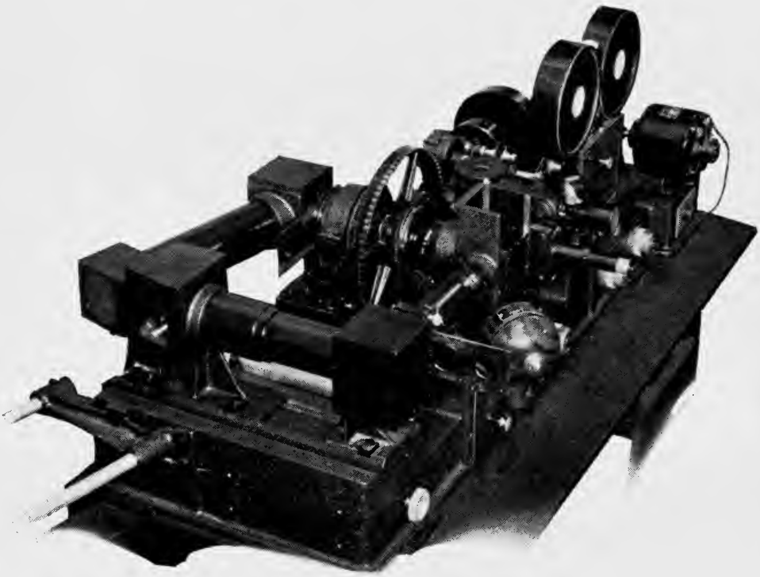

FIG. 9. Photographic reflectometer from front and above.

flicker disk. The cubical box immediately in the center and near the front houses the total reflecting prism $P2_x$ (Fig. 3), and immediately to the right of this may be seen the diaphragm plate D_x with the two smaller apertures quite distinctly visible.

This instrument may be used also for measuring the photographic transmission of transmitting materials, such as colored filters; and for this purpose it is admirably suited. In making measurements of photographic transmission the prism $P1_x$ (Fig. 3) is turned slightly so that the point r (instead of point y) is imaged through the test system at o. The change in position of this prism may be very easily made since two stops, *a* and *b*, are provided against which a lug, *d*, projecting from the table on which the prism $P1_x$ is mounted, may be set. As shown in the figure, the orientation of the prism is such that the point *y* is imaged at *o* in the center of the photometer cube, *C*. By turning the lug so that it comes in contact with the stop *b*, the point *r* is imaged by this optical system at *o* in the dividing line of the cube *C*. With this adjustment it is of course impossible for both lines *rz* and *rm* to be perpendicular to the surface of the standard sample. Since, however, the standard surface used is almost completely diffusing, this slight variation from normal viewing is of little consequence and, as a matter of fact, if there is any dissymmetry in the distribution of the light reflected from this surface, compensation is made by the manner in which this instrument must be calibrated prior to use. A transmitting sample may be inserted in a holder provided at *T*. The procedure for the determination of transmission factor is practically identical to that already described for the determination of reflection factor. The number which is usually referred to as a multiplying factor of the filter is, of course, the reciprocal of its photographic transmission.

In Fig. 10 are shown some typical records obtained with this instrument, using the film box rather than the motion picture camera. Four examples are shown. In each case the right-hand strip is the print of the radial sector diaphragm scale. The one immediately to the left of this scale is that portion of the film which has been exposed to the surface of unknown reflecting power. Every point on this strip is subjected to a constant exposure, both the time and intensity factors of exposure being constant throughout. The left-hand strip in each group is that exposed to the standard surface through the radial sector diaphragm of variable angular opening. It will be seen that this results in a wedged density strip due to a continuously variable exposure. This variation in exposure is due, of course, to the closing or opening of the radial sector diaphragm, and hence is due to a change in the intensity factor, thus giving an intensity scale effect. Black horizontal lines are drawn through the match points and the reading of this line on the scale gives the photographic reflection factor or, in case the instrument is set for transmission measurement as previously described, the photographic transmission factor of the material under test.

The instrument may also be used advantageously for measuring the *photographic intensity* of various light sources. For this purpose two identical standard surfaces are placed in the sample holder, one in the usual position as indicated at S and the other being substituted for the unknown surface, X, as shown in Fig. 3. The standard surface at S is then illuminated by a standard radiation, that is, standard in both quality and intensity, such, for instance, as that emitted by a standardized tungsten lamp operating at a known temperature

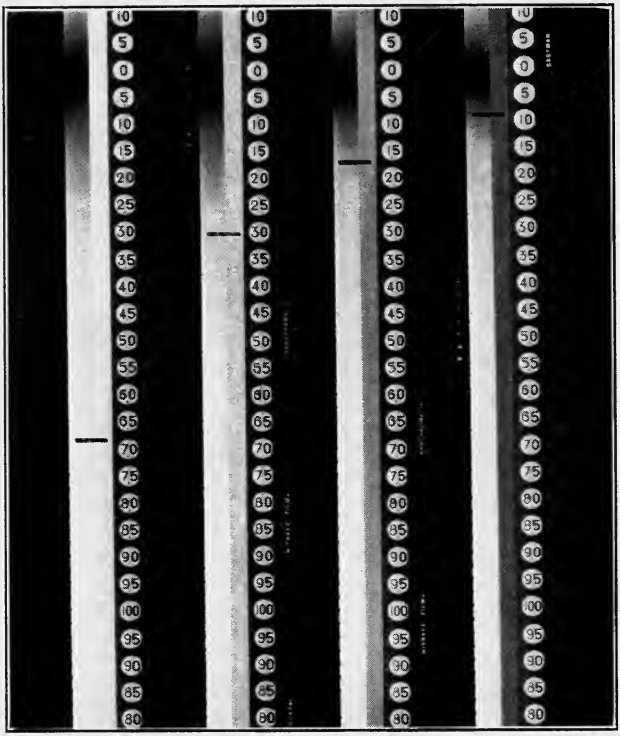

FIG. 10. Typical records obtained with photographic reflectometer.

and luminous intensity. The second surface, X, which is identical to the surface S, is then illuminated by the radiation to be measured photographically.

The relation between the illuminations as evaluated visually can be precisely determined by means of the flicker photometer or, if it is preferred, by an equality brightness method using the same photometer cube as is used for the photographic work. Then by following the same technic as that used for measuring photographic reflection or transmission factors, the relative values of photographic intensity can be determined with the same ease and precision as that obtainable in the determination of reflection and transmission values.

Since in work of this kind there are two sources of radiation, it is of utmost importance that both be operated to give the greatest possible constancy of illumination. In the case of the comparison standard this problem presents little difficulty, but in the case of some commercial sources it is quite impossible to obtain perfectly constant illumination. Under these conditions it is necessary only to continue the operation over several revolutions of the scale drum and thus obtain a large number of match points which, when averaged, should give a very satisfactory value of the mean intensity at which the variable source has been operating through a definite time period. Here again, the fact that both the visual and photographic measurements can be made with the same instrument and under identical conditions is of great value in eliminating experimental uncertainties.

This communication is intended primarily as a description of an instrument and a method of obtaining precision results in certain fields of photographic photometry, and it is not proposed at this time to present comprehensive data relating to reflecting powers of colored objects, filter factors, orthochromatic rendering under various practical conditions, and other subjects of interest in practical photography. In order to illustrate and emphasize the precision which may be obtained by this method, a few data will be presented.

TABLE I

Photographic Reflection Factors of Sample No. 4

Set No.	Quadrant				Mean R	ΔR
	1st	2nd	3rd	4th		
1	42	49	42	50	45.8	+0.2
2	41	50	42	50	45.8	+0.2
3	42	49	43	49	45.8	+0.2
4	42	49	41	49	45.2	−0.4
				Mean	45.6	0.25
						0.55%

In Table I are shown the values obtained with four independent measurements of the reflecting power of a yellow silk fabric. Each set of measurements was made entirely independently on different days, and each strip of exposed film was processed independently of the others. The values given show the actual match point read in each of the four quadrants. It will be noted that those obtained in the first and third quadrants agree quite closely, while those in the second and fourth agree with each other but are different from those obtained in the first and third. This is due to the finite width of the slit in the film box. This was mentioned previously, and these values illustrate the difference in reflecting power values as determined in adjacent quadrants. By taking the mean of the four values this slit width error is completely eliminated. In the next to the last column of the table, designated as *Mean R*, are the values of reflection factor as determined from each of the four sets, the mean of the four sets being 45.6. In the last column, ΔR, are the deviations of the individual set values from this mean. The mean of these deviations is 0.25 which, expressed as a percentage of the reflection factor itself, is 0.55 per cent. The value of 45.6 per cent for the photographic reflection factor of this particular colored material is subject to a mean deviational error of only 0.55 per cent, which we feel is sufficiently low for all practical purposes.

TABLE II

Comparison of Visual and Photographic Reflection Factor Values
Photographic Material: Type II Panchromatic Motion Picture Negative Film
Light Source: Incandescent Tungsten at 3200°K.
Eyes: Normal trichromats

	Sample		*A*				*B*		
No.	Color	I	II	III	Mean	JMcF	EML	LAJ	Mean
1	Deep red	16.5	16.8	16.2	16.5	12.4	14.1	13.5	13.3
2	Orange-red	19.0	18.8	19.0	18.9	15.6	15.3	16.4	15.8
3	Orange	24.5	24.5	24.8	24.6	29.3	31.8	29.7	29.9
4	Yellow	45.8	45.8	45.2	45.6	65.0	67.0	68.5	66.8
5	Yellow-green	27.8	28.5	27.8	28.0	44.9	46.5	47.0	46.1
6	Green	13.0	13.2	12.8	13.0	25.2	26.7	25.3	25.7
7	Blue-green	6.2	6.2	6.3	6.2	8.6	8.9	8.5	8.7
8	Blue	13.2	13.9	13.8	13.6	6.7	7.0	6.6	6.8
9	Violet	18.8	19.2	18.5	18.8	8.0	8.6	8.3	8.3
10	Magenta	21.2	21.8	21.5	21.5	13.3	14.6	13.2	13.7

In Table II are shown further data relating to a series of colored silk fabrics. Ten such samples were chosen so as to represent fairly equal steps throughout the visible spectrum. All of them are of relatively high color saturation, representing, in fact, about the most saturated colors that will probably be met with in average practice. The values shown in Table II were obtained by using regular panchromatic type II motion picture negative film, the samples being illuminated by incandescent tungsten radiation having a color temperature of approximately 3200°K. In section *A* of the table, under columns *I*, *II*, and *III*, are shown three independent sets of measurements on this group of ten test colors. In the column designated as *mean* are the average values of the three measurements on each. An inspection of this table will show that very good agreement is obtained in the three sets and that the deviation of any individual determination from the mean is relatively small.

In the second section of the table, designated as *B*, are measurements made by three experienced observers using the flicker photometer which is an integral part of this instrument. The surfaces in question were illuminated in exactly the same manner, both quantitatively and qualitatively, as that used when their photographic reflection factors were being determined. An inspection of the values in section *B* will show that the flicker photometer measurements are subject to deviations as great as or perhaps somewhat greater than those made by the photographic method. All the individuals who participated in making these measurements have had considerable experience in reading a flicker photometer, and while the results may not be as concordant as may be obtained in laboratories staffed by more expert photometricians, they represent a fair approximation to what may be considered repeatability in heterochromatic photometric measurements made by the flicker method. The authors feel that the photographic photometric values shown in the table under *A* compare very favorably indeed with these flicker photometer measurements. It is felt that by this method and technic, it is now possible to establish values of photographic reflection factor which are reliable and repeatable with sufficient precision for all practical and, in fact, for high precision research purposes.

Earlier in this paper mention was made of the difficulty of defining reflection factor in absolute terms. It is always essential, of course, in attempting to define a photographic reflection factor, to specify the quality of illumination and the photographic materials used in making the measurement. In addition to this it is at least theoretically necessary to define the extent to which development is carried (which can probably be most satisfactorily expressed by stating the value of gamma) and the density level at which balance between the known and unknown exposures is obtained. The necessity of expressing the last two conditions mentioned results from the well-known gamma-wavelength effect. For instance, if a photographic material is exposed sensitometrically to two monochromatic radiations of different wavelengths and the two exposed strips are developed identically, the resultant D-log E curves may have different slopes (γ). Now, if we base our definition of the equality of two radiation intensities on the condition that in equal times and for identical development conditions equal density shall be obtained, it is evident that the results will depend to a certain extent upon the absolute value of density at which the equality is obtained. If we are comparing two radiations of identical wavelength or of identical spectral composition, it makes no difference at what density the equality is adjusted; but in the case of heterogeneous radiations of widely different spectral compositions, this matter may be of importance. Fortunately the gamma-wavelength effect, in the case of most commercial materials, and within the wavelength region normally used for practical purposes, is not very great. Moreover, the composition of radiation reflected from most natural colored objects is far from monochromatic and, as a matter of fact, in the great majority of cases (even with colored objects of relatively high saturation) shows relatively shallow absorption bands. It is quite possible, therefore, that the theoretical difficulty may be of little practical importance.

TABLE III

Photographic Reflection Factor Values
Illustrating Dependence upon Extent of Development and Density Level

Sample No.	Color	*A*	*B*	*C*
1	Deep red	19.5	20.0	19.0
2	Orange-red	23.8	22.5	22.2
3	Orange	32.2	31.8	30.8
4	Yellow	54.2	55.8	50.0
5	Yellow-green	35.0	35.5	34.0
6	Green	16.5	17.0	18.2
7	Blue-green	5.8	6.2	6.2
8	Blue	8.5	8.8	8.0
9	Violet	12.2	13.2	12.5
10	Magenta	20.5	21.2	20.8

In order to test this point a preliminary set of measurements has been made, the results of which are shown in Table III. These pertain again to the same set of colored silks referred to previously and, as stated there, they are all of relatively high saturation; that is, they are vivid colors and represent, therefore, something approaching the maximum of selective absorption which we may expect to meet in practice. The photographic reflecting power values shown in column *A* were obtained by so adjusting exposure conditions that the color of a minimum reflecting power, namely, No. 7, was represented on the exposed film by a relatively low density when development was carried to the extent to which it is customary to develop motion picture negatives, that is, to a gamma of approximately 0.5. The values shown in column *B* were obtained by a set of identical exposures but development was continued so that a gamma of about 1.2 was obtained. This represents probably the maximum gamma that can be obtained with this material without running into undue fog. An inspection of the data shows that the differences between them and those in column *A* are of the same order as the experimental deviations between independent determinations. While some of the values show a decided tendency to be a little higher, we do not feel that the differences from those in column *A* are sufficient to be of any significance. The values in column *C* were obtained by increasing the exposures by a factor of approximately four times so that the density on the developed film corresponding to the color of lowest reflection powers was appreciably higher than in the case of column *A*. In other words, all the points at which balance was obtained were pushed upward on the *D*-log *E* curve. Moreover, development in this case was also carried to the extreme, so that if the gamma-wavelength effect is of any importance in this work, a very marked difference should be noted between these values and those in column *A*. As a matter of fact, the differences are small, and are not large enough to warrant a definite conclusion that the magnitude of the gamma-wavelength effect is sufficiently large to be definitely measurable.

As stated previously, this is only a preliminary study of this problem, and the authors do not wish at present to draw a definite conclusion. The indications are, however, that in practical photographic work the gamma-wavelength effect, in the case of type II panchromatic motion picture negative film, is not of sufficient magnitude under average conditions to affect seriously the validity of photographic reflection factor values made without definitely specifying density level and extent of development.

Sufficient data have been given to indicate that the instrument and method are capable of yielding results of a high order of precision and repeatability. It remains now to apply this method to the determination of the photographic reflection factors of colored objects which are of particular interest in various fields of practical photography; to the measurement of filter factors under certain specified conditions of photographic material, light source, *etc.*; to the measurement of the photographic intensities of the radiation emitted by light sources used in photographic practice; and to a detailed analysis of the quality of orthochromatic rendering which can be obtained with various photographic materials, compensating filters, qualities of illuminating radiation, *etc.* The authors hope to publish in the near future papers dealing with these subjects.

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BOOK REVIEWS

Servicing Projection Equipment. *Mancall Publishing Corp.*, New York, N. Y., 1932, 146 pp.

A manual for projectionists, written in question and answer form, as a guide in trouble-shooting. Such a work naturally can give only a brief sketch of the common causes of breakdowns in the equipment of the projection room, and this brevity is rather noticeable in the present instance. Sound equipment, for example, is not mentioned throughout the whole book. Arc lamps, films, electrical apparatus, and the optical elements receive as fair a share of attention as can be expected in a work of this size. A. A. Cook

Projecting Sound Pictures. AARON NADELL. *McGraw-Hill Book Company, Inc.*, New York, N. Y., 1931, 256 pp.

The author defines this volume as a practical textbook for projectionists and theater managers, and his plan seems a very successful one. It avoids a multitude of details on the construction of all the various types of sound apparatus, develops the underlying principles of sound reproduction, and tells rather fully how they are applied in practice.

There are four chapters on reproduction from film and disk, outlining the mechanical requirements of each method; three chapters on amplifiers, rectifiers, and vacuum tubes; and one chapter devoted to each of the following: circuit drawings, acoustics, loud speakers, and speed control. The book concludes with two chapters on trouble tracing and the precautions necessary to prevent trouble. It is very readable, and should prove valuable to the theater man who is well acquainted with the details of his own apparatus and wants to know more about why it operates as it does. A. A. COOK

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SOCIETY ANNOUNCEMENTS

S. M. P. E. REQUESTS NATIONAL STANDARDS FOR MOTION PICTURE INDUSTRY*

National standards for all phases of the technical equipment and operation of the motion picture industry, from the lighting and acoustics of studios to the projectors and screens of picture houses, have been requested by the Society of Motion Picture Engineers. In a letter to the American Standards Association, Alfred N. Goldsmith, president of the Society of Motion Picture Engineers, asks for the development of uniform national standards to avoid the danger of confusion and waste resulting from the establishment of conflicting standards by different groups within the industry. If the request of the Society is approved, a technical committee representing all branches of the industry will be organized under the procedure of the American Standards Association.

A memorandum accompanying the Society's request follows:

Standardization projects, such as this proposed project on motion picture standards, grow logically step by step. Topics that initially seem of importance turn out to be not particularly susceptible to constructive and useful standardization; other topics, which would not be considered as suitable for standardization on preliminary consideration, afterward develop into topics of major importance. In the following it is possible therefore to consider only the general field of motion picture activities (so far as they are of technological character) and to mention some of the topics that might be suitable for standardization. The list must be regarded as entirely tentative.

1. *Definitions.*—The terminology of the motion picture field is confused at present. Such terms as "blimp," "zoom," "pan," "tilt," "projection angle," "wow," or "flutter," and the like, are used without official recognition. This situation requires correction so far as is feasible.

2. *Film.*—Measurement of characteristics of the base of the film, dimensions of the film and of its perforations, study of film shrinkage and permissible maximum shrinkage, photographic sensitometric tests, measurement and specification of "safety film," standard width of film of various types, standard containers for film for storage and for transportation, together with methods of preserving films (for archives, *etc.*).

3. *Studio.*—The acoustic treatment and illuminating methods for studios doubtless would admit of a considerable degree of standardization, both as to nomenclature, measurement, and specifications. Wide varieties of lamps are used, which are designated, for example, as "spots," "baby spots," "rifle spots," and so on. Light-diffusing media are used which are known by a variety of colloquial terms but are not definitely specified. For example, in what is known as

* Reprinted from *Industrial Standardization*, **3** (Sept., 1932), No. 9, p. 247, published by the American Standards Association, New York, N. Y.

"oil diffusion" a wide variety of characteristics can presumably be obtained under the same name. The acoustic characteristics of studios have not as yet been specified in a precise form in many instances, nor has measuring equipment for the purpose been adequately considered. Passing on to studio equipment, we find:

4. *Cameras.*—The amount of significant noise produced in these devices at certain distances and in certain directions (in free space), the tolerances in the dimensions of the various working parts, the tensions and pressures in various parts of the mechanism, the dimensions of the magazines and of the magazine hubs, the take-up tension, and numerous other characteristics of cameras require study for possible standardization. The mode of mounting the lenses, the possibility of standardizing focal lengths and apertures of lenses for motion picture practice, standardization of shutter aperture, definition of tripod arrangements, and nomenclature for devices permitting moving shots (traveling trains, and the like), require consideration. Measurement of the effectiveness of camera-silencing inclosures is required.

5. *Recording Equipment.*—Microphones, amplifiers, acoustic reflectors, recording equipment, and sound track measuring equipment fall under this heading. Numerous characteristics of these devices are measurable, might be specified to advantage, and may ultimately be suitable for standardization.

6. *Re-recorders.*—These are used for the introduction or modification of sound effects, and are rapidly becoming an important part of the studio technic. They are used for re-recording from 35 mm. film to 35 mm. film; and are now being produced as well for re-recording from 35 mm. film to 16 mm. film. The over-all frequency and volume characteristics of these devices, the amount of acoustic distortion that they produce, and certain other factors are of major importance.

7. *Photographic Printing Equipment.*—Classification of types of equipment of this sort (continuous and step printers, optical reduction printers, contact printers). Permissible speed variation. Definition of maximum desirable operating speed. Specification of illumination of the printing surface.

8. *Laboratory Processes.*—The development of film is now carried out in various ways by automatic machinery. The terminology requires study, and certain of the processes require precision measurement and definition. For example, methods of measuring developer concentration or speed, measurements of the effectiveness of processes for "hardening" or otherwise preserving film, and the like.

9. *Exchange Equipment.*—Films, after being returned from the theater, pass to the exchange, where they are inspected. Inspection methods have never been definitely specified or defined. Dimensions and mechanical specifications, as well as strength tests of reels and containers used by exchanges, require consideration, both for nitrate and safety stock.

10. *Theater Equipment.*—Projectors have numerous dimensions requiring standardization. The tension and pressure at various points of the mechanism, magazine dimensions, safety devices, contrivances to protect the projectionists' eyes from undue glare, take-up tension, and the like, may all be considered for standardization. Screens (both of the continuous type and of the perforated "sound-transmitting" type) merit study for standardization of their reflection characteristics and the specification thereof. The resurfacing of screens as they become worn brings up a similar series of problems. The amplifying and loud

speaking equipment give rise to the usual series of electroacoustic standardization problems ending with the frequency characteristic, distortion characteristic, and space distribution of the output of the loud speaker system.

11. *Miscellaneous.*—Such fields as color photography require study. The various processes have never been satisfactorily defined, nor have the various forms of cameras, lenses, processing equipment, and projectors been put on a suitably precise basis. Three-dimensional pictures require definition. Frequency systems that give perspective impressions are classified as three-dimensional or "pseudo-stereoscopic." A considerable amount of confusion exists here on terminology.

SUB-COMMITTEE ON LABORATORY PRACTICES

At a meeting of this sub-committee of the Committee on the Care and Development of Film, held recently in the general office of the Society, various phases of laboratory practice were assigned to the several members of the sub-committee to be studied and reported on. These subjects were as follows: standardization of developing solutions, processing film for requirements of machines, emulsion requirements for prints, requirements for drying negative and positive, sound requirements for prints, standardization of gamma and density of sound track, requirements of prints for theaters, requirements for negative developers, requirements for duplicating negative, standardization of printers and printer lights, handling negative in laboratories, standardization of developing solutions, requirements for film printers, sensitometry in the laboratory.

Another meeting of the sub-committee is scheduled to be held on September 21, at which time the reports on these subjects will be collected and arranged to form the basis of the final 1932 report. Particular attention is being paid to those features of laboratory practice that might be found to be amenable to standardization, particularly as regards the control of development and printing. Recent additions have been made to the membership of the sub-committee in order to make it more representative of the entire field, including sound recording and reproduction, in order to correlate the problems of those who supply exposed film to the laboratories for processing and of those who use it after the laboratory has finished its work.

SUB-COMMITTEE ON EXCHANGE PRACTICES

The work of this sub-committee of the Committee on the Care and Development of Film has progressed to the point of submitting to the membership of the sub-committee a tentative report based on the contributions of the several members. This report deals with (*a*) the maintenance of film, (*b*) the storing of film, (*c*) shipping routines and records, (*d*) housekeeping and control of fire hazards, (*e*) equipment, and (*f*) home office control. At another meeting of the sub-committee, to be held in the near future, this report will be discussed in its entirety, and after making whatever changes may be found necessary, it will be submitted to the Committee on the Care and Development of Film as the final report of the sub-committee. It is felt that this report will embody in a single essay a considerable amount of information concerning the problems of film exchanges that can not be found elsewhere in the literature of the art. The report will contain not only an exposition of the current routines followed by existing exchanges, but will contain, as well, recommendations of changes of routine based on the collective opinions of representatives of all the important distributing companies.

PROJECTION THEORY COMMITTEE

Although quite complete information on the optical theory of projection is available, it is unfortunately scattered throughout a great many sources, and is difficult of access to those whose principal work is not directed toward optical problems. For this reason, the Projection Theory Committee plans to prepare a monograph on the theory of projection, which monograph will represent a single source from which may be obtained all important information pertinent to the theory of projection. Due to the magnitude of the work, this monograph will not be completed for some time to come; but when completed, it is expected that it will represent an important contribution of the Society to the motion picture art.

MUSEUM COMMITTEE

Work has been begun on the construction of a series of miniature dioramas, enclosed in glass, depicting the progress of the motion picture art from its inception to the present sound sets in operation. These exhibits are about 3 by 4 feet, made to exact scale. When finished, they will represent the making of an early motion picture, the making of an animated picture, and an up-to-date sound set in operation with its sound equipment and lighting apparatus. A miniature set will be lighted by miniature lights that are but slightly greater than two inches in height. The Bausch & Lomb Optical Company and Carl Zeiss, Inc., are coöperating with the Museum Committee in constructing an exhibit depicting the history of lens grinding and the making of precision glass. This exhibit will show the evolution of the photographic objective from the first lens to the present highly corrected anastigmat. Special lenses are being ground for this exhibit by the Bausch & Lomb Optical Company. The Pittsburgh Plate Glass Company is supplying its latest products of the glass-making art, including samples of bullet-proof, safety, and other types of glass used in motion picture studios.

Models of the more popular of the early devices designed to show motion by hand-drawn pictures before photography came into use, are being made by one of the studios in Hollywood. Several manufacturers of equipment are coöperating with the Museum Committee in collecting samples of early sound equipment and various archives and historical records.

SUSTAINING MEMBERS

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Bausch & Lomb Optical Co.
Bell & Howell Co.
Bell Telephone Laboratories, Inc.
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Eastman Kodak Co.
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RCA Photophone, Inc.
Technicolor Motion Picture Corp.

HONOR ROLL

OF THE

SOCIETY OF MOTION PICTURE ENGINEERS

By action of the Board of Governors, October 4, 1931, this Honor Roll was established for the purpose of perpetuating the names of distinguished pioneers who are now deceased:

LOUIS AIMÉ AUGUSTIN LE PRINCE
WILLIAM FRIESE-GREENE
THOMAS ALVA EDISON
GEORGE EASTMAN
JEAN ACME LE ROY

PAMPHLETS, BOOKLETS, AND CATALOGUES RECEIVED

Copies of the publications listed here may be obtained free of charge by addressing a request to the manufacturer named. Manufacturers are requested to send new publications to the General Office of the Society immediately upon issue.

Bausch & Lomb Optical Co.: Leaflet describing the *Biophor* projection lenses, including a table showing the relation between projection distance, focal length, and size of picture for 16 mm. film; a leaflet describing the *Raytar* series of lenses, and a booklet describing the *Super-Cinephor* lenses and condensers. The latter describes the characteristics of such lenses, and contains instructions for choosing the proper focal length, and tables of projection distances and size of picture for 35 mm. film for picture apertures of 0.825 × 0.600 and 0.906 × 0.6795 inch. Address: Rochester, N. Y.

G. M. Laboratories, Inc.: Leaflet describing the *G-M* cell coupling cable, to be used for connecting the photoelectric cell to the head amplifier of projectors. Made in various lengths, supplied with suitable sockets and plugs; frequency and impedance characteristics given. Address: 1731 Belmont Ave., Chicago, Ill.

Hoffman-Soons Electrical & Engineering Corp.: Leaflets describing *Perfection* rheostats for projectors, and wiring accessories; a booklet illustrating the uses of *Perfection* rheostats in arc circuits, with wiring diagrams showing the control steps and switching arrangements. Address: 387 First Avenue, New York, N. Y.

Moviola Company: Leaflet describing the model *C* (cutting room model) *Moviola* for viewing short lengths of 35 mm. film before assembly; and model *D* for viewing standard film in 1000-ft. lengths; models *K* and *L* similar to models *C* and *D*, but designed for 16 mm. film on 400-ft. reels. Leaflet describing models *UC* and *UD*, for synchronizing picture films and separate sound films. Leaflet describing model *MT*, designed for viewing and reproducing sound from composite or movietone film; leaflet describing *Moviola* synchronizers and multiple rewinders. Address: 1451 Gordon St., Hollywood, Calif.

Victor Animatograph Corp.: A booklet entitled *Where to Buy, Rent, and Borrow 16 Mm. Films, Silent and with Sound;* a directory of film sources. A booklet describing the *Animatophone*, a 16 mm. sound-on-disk projector, and its application in the home, in industry, salesmanship, education, *etc.;* it describes also the Victor 16 mm. camera, and various accessories for camera and projector. Address: Davenport, Iowa.

Weston Electrical Instrument Corp.: Leaflet describing the new Weston exposure meter for use with still and motion picture cameras, consisting of an electrical indicator connected to two *Photronic* photoelectric cells, measuring brightness up to 1300 candles per sq. ft.; includes a mechanical calculator for determining correct combinations of shutter timing and aperture for any plate or film speed. A booklet of instructions for operating the model *617* exposure meter. Address: Newark, N. J.

JOURNAL

OF THE SOCIETY OF

MOTION PICTURE ENGINEERS

Volume XIX **NOVEMBER, 1932** **Number 5**

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JOURNAL
OF THE SOCIETY OF
MOTION PICTURE ENGINEERS

Published monthly at Easton, Pa., by the Society of Motion Picture Engineers

Publication Office, 20th & Northampton Sts., Easton, Pa.
General and Editorial Office, 33 West 42nd St., New York, N. Y.

Subscription to non-members, $12.00 per annum; to members, $9.00 per annum, included in their annual membership dues; single copies, $1.50. A discount on subscriptions 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 33 W. 42nd St., New York, N. Y.

Entered as second class matter January 15, 1930, at the Post Office at Easton, Pa., under the Act of March 3, 1879.

EXTENSION OF THE FREQUENCY RANGE OF FILM RECORDING AND REPRODUCTION*

G. L. DIMMICK AND H. BELAR**

Summary.—*Improvements have been made in the recording of sound on film, and in the reproduction of sound from film, that have resulted in an extension of both the frequency and the volume ranges. The low-frequency range has been extended by using a loud speaker unit that responds well at frequencies from 60 to 10,000 cycles per second. The high-frequency range has been extended by using a microphone of the ribbon type and by reducing the attenuation of the film. By using a narrower recording slit and a large mirror galvanometer the high-frequency response has been improved. The system for reducing ground noise has been simplified and made more effective.*

Improvements that have been made recently have materially extended the volume and frequency ranges of sound recorded on film and reproduced from film. The loud speaker has in the past been the principal factor in limiting the low-frequency response. One type of loud speaker, employing a dynamic cone and a directional baffle, and which responds well at frequencies from 60 to 10,000 cycles per second, has been designed (Fig. 1). This speaker is of the exponential type, is 10 feet long, and has a mouth 75 inches square. The driving unit consists of a cone 6 inches in diameter, with a voice-coil wound with aluminum wire.

The film presents no serious difficulties in recording low frequencies; however, it has been the principal cause of attenuating the high frequencies. For any given speed of film and width of recording light beam, a cut-off occurs at a definite high frequency when the width of the recording beam is equal to one wavelength. The limitations of the resolving power of the film usually cause considerable attenuation at a frequency much lower than that at which cut-off theoretically occurs. The resolving power of the film depends upon the emulsion; and for a given emulsion is a function of the manner in which the light beam enters the film, the stray

* Presented at the Spring, 1932, Meeting at Washington, D. C.

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

light incident upon it, and the method of processing. As the result of having made a careful study of each of these factors, it has been found possible to reduce considerably the attenuation of high frequencies. By using a galvanometer having a large reflecting mirror, the stray light ratio has been greatly reduced and the available light has been increased; thus making it possible to reduce the

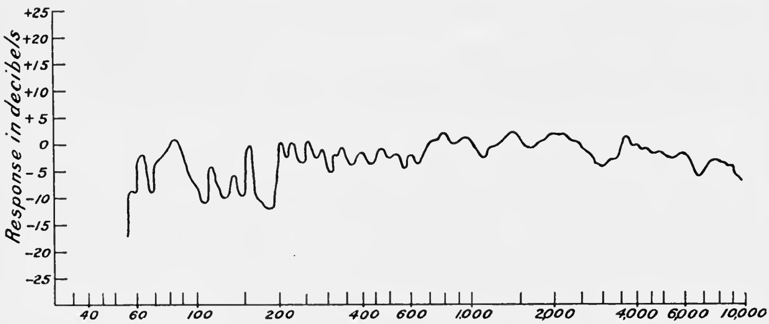

FIG. 1. Response-frequency characteristic of loud speaker.

width of the recording slit and to increase the depth of focus of the objective lens in the optical system of the recorder. The residual loss due to the film is compensated for in the recording amplifier.

Fig. 2 shows the construction of the new dry type of recording galvanometer. A silicon steel armature, *a*, is clamped between

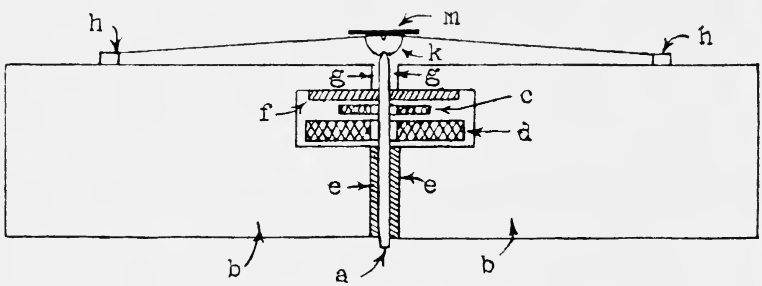

FIG. 2. The recording galvanometer.

two laminated silicon steel pole pieces, *b*, being separated from the pole pieces by two nonmagnetic spacers, *e*. The free end of the armature is ground to form a knife edge, which fits into a groove in the semicylindrical mirror plate, *k*. A phosphor bronze ribbon is fastened to two prongs, h, and passes over the mirror plate. The two prongs press against the pole pieces and tend to spring apart, providing a small tension in the ribbon. The slight angle between the ribbon and the face of the pole piece results in a component of force tending to hold the mirror plate against the armature. A plane silvered mirror, 0.125 inch long by 0.100 inch wide, is cemented to the mirror plate, the cement also preventing relative motion between the mirror plate and the ribbon. A force applied near the end of

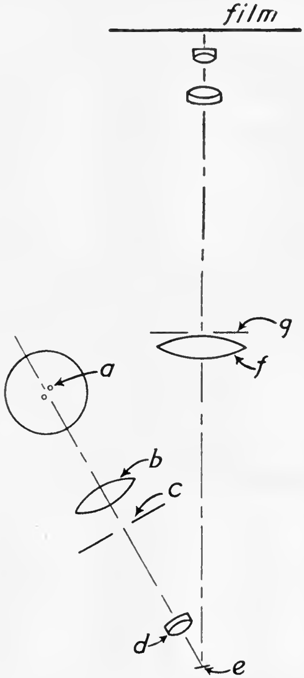

FIG. 3. Optical system of recorder.

the armature deflects it in a manner similar to a cantilever beam. Since the phosphor bronze ribbon prevents lateral displacement of the mirror plate, the latter is free to vibrate only rotationally about a center through the ribbon. A major part of the controlling stiffness is due to the armature itself, the remainder being in the ribbon. A portion of the flux from the two cobalt steel magnets passes through the two air gaps, g. Two coils, c and d, surround the armature, but are not in contact with it. Coil *c* carries the voice current from the recording amplifier while coil *d*, wound with many turns of fine wire, carries the biasing current required in eliminating ground noise. A rubber pad, *f*, provides the desired damping at resonance, which occurs at 9000 cycles.

Fig. 3 shows schematically the recording optical system of the recorder. Light from the recorder lamp, *a*, is collected by means

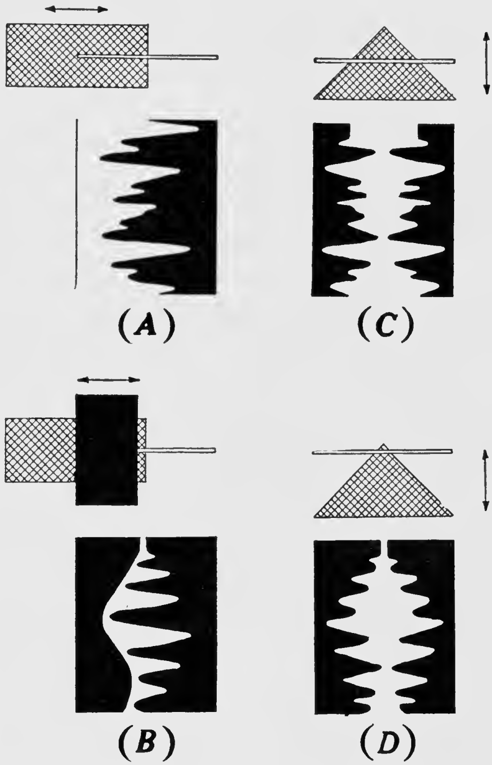

FIG. 4. Four types of variable amplitude track.

of a condenser lens, *b*, and is brought to focus on the galvanometer mirror, *e*. A triangular aperture placed at *c* is focused by means of the corrected lens, *d*, upon the mechanical slit, *g*. A condenser lens, *f*, concentrates the light passing through the slit, *g*, to form an image of the mirror, *e*, upon the back lens of the microscope objective. The objective lens, in turn, forms an image of the slit upon the film. The galvanometer mirror vibrates about an axis parallel to the slit.

This new optical system for recorders produces a symmetrical double-edged variable width track, as shown in Fig. 4. The cross-hatched portions of Fig. 4 represent the beam of light reflected from the mirror of the recording galvanometer, and the narrow rectangles represent the recording slit. The arrows indicate the direction of

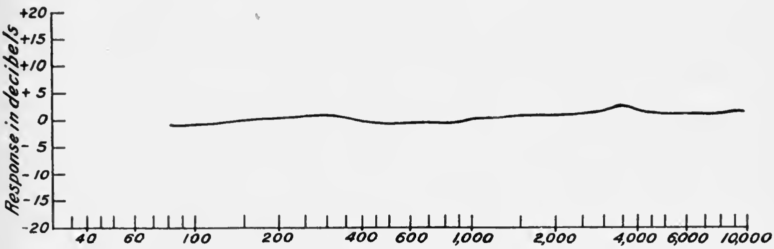

FIG. 5. Response-frequency characteristic of ribbon microphone.

vibration of the light beam. Fig. 4 (A) illustrates a normal variable width track. The average transmission of such a track is 50 per cent, regardless of the amplitude of the recorded wave. Fig. 4 (B) illustrates the kind of variable width track now being used, which utilizes a separate shutter for blocking a portion of the light beam when the recording level is low. The black rectangle in this figure represents

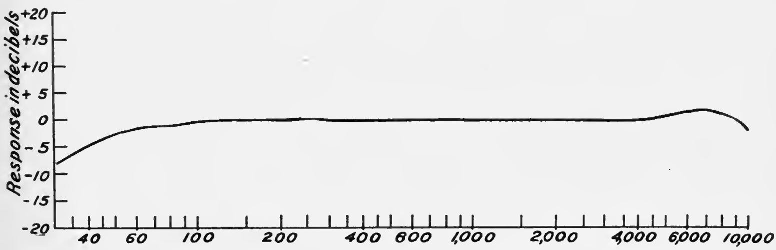

FIG. 6. Response-frequency characteristic of reproducing amplifier.

the shutter vane. The current that actuates this vane is obtained by rectifying and filtering a portion of the signal. Fig. 4 (C) shows how the double-edged symmetrical track is made. The triangular beam of light moves at right angles to the axis of the slit, so that as it vibrates, the length of the illuminated portion of the slit varies. As in Fig. 4 (A), the average transmission of this track is 50 per cent.

Fig. 4 (*D*) illustrates a sound track made by this method, utilizing the biasing system of eliminating ground noise. The mean position of the triangle depends upon the current that is supplied to coil *d* (Fig. 2) by the biasing amplifier, which is controlled by the incoming signal. When there is no signal the triangular beam of light is biased to the position shown in Fig. 4 (*D*), producing a very narrow transparent line down the center of the track. When a signal is impressed upon the system, the biasing current is reduced, and the triangular beam of light is raised until the track is sufficiently wide to accommodate the signal. The symmetrical track may be reproduced by standard theatrical equipment without change.

The extension of the frequency range has made more urgent the necessity of maintaining accurate constancy of film speed in both recording and reproducing machines. Variations of the speed of either the recorder or the reproducer produce the so-called "wows." When the variation of speed occurs at a high frequency, due, perhaps, to gears or sprocket teeth, a more harmful kind of distortion is introduced. Due to speed modulation the high frequencies are distributed into several side-bands, and the reproduced notes sound rough or "wheezy." Variations of speed have been reduced to a minimum in the new recorder and in the reproducer.

Another important improvement made in the system lies in using a microphone of the ribbon type, which furnishes uniform response at frequencies from 40 to 10,000 cycles per second (Fig. 5). The directional characteristics of this microphone are independent of frequency.

The new high-quality recording and reproducing equipment was demonstrated at the Spring, 1932, Meeting of the S. M. P. E. on May 11, 1932. Two loud speaker units similar to the one described were employed, being placed behind a perforated screen. The reproducing amplifier had an undistorted power output of 40 watts. It was operated completely by alternating current, and was assembled on a single rack that contained all the necessary electrical equipment. Fig. 6 is the frequency-response curve of this amplifier. The demonstration records were reproduced on a film phonograph that employed a magnetic drive similar in principle to the one previously described by E. W. Kellogg.[1]

REFERENCE

[1] KELLOGG, E. W.: "A New Recorder for Variable Area Recording," *J. Soc. Mot. Pict. Eng.*, **15** (Nov., 1930), No. 5, p. 653.

THEATER PROBLEMS OF THE RELEASE PRINT*

AN ADDITIONAL CONTRIBUTION TO THE REPORT OF THE PROJECTION PRACTICE COMMITTEE

Summary.—*This paper, presented separately during the symposium on the release print, at the Spring, 1932, Convention at Washington, D. C., is part of the report of the Projection Practice Committee, the main portion of which was published in the August, 1932,* JOURNAL. *It was deemed advisable, however, to present this particular section of the report at the Release Print Session in order that it might receive the fullest attention and discussion together with related problems of production and distribution branches of the industry. The present paper deals with the problems encountered by the theaters in relation to* (*a*) *the processing of film,* (*b*) *buckling of film,* (*c*) *dense positive prints,* (*d*) *film cutting for change-overs,* (*e*) *uniformity of volume level of reproduction, and* (*f*) *standard release print markings.*

The problems of the release print as they affect the theater, although comparatively few, are nevertheless of the utmost importance in attaining a high degree of excellence in screen results. The Projection Practice Committee of the S. M. P. E. has, in its previous reports, called attention to the shortcomings of the various methods of treating finished positive prints so as to facilitate the passage of the film through the projector under ordinary projection conditions. The Committee has also directed attention to the problems of film buckling, film mutilation, the responsibility of the projectionist in handling prints, and the responsibility of the theater manager in reporting faulty condition of film.

Processing of Film.—In respect to the problem of processing film, the Committee has found that some of the methods employed were not entirely satisfactory, inasmuch as in some instances emulsion continued to accumulate on projector parts during the early showings of film, and in other instances the preparations used in the processing methods accumulated in the projector and caused faulty sound.

From experience and tests, the Projection Practice Committee has found it undesirable to apply even minute amounts of wax or oil preparations to the film and that the use of unprocessed film is undesir-

* Presented at the Spring, 1932, Meeting at Washington, D. C.

able. The Committee advises against the foregoing, but is in favor of a process by means of which the emulsion is hardened sufficiently to avoid the difficulties encountered in the early projection of film. Such a process has been used for the past several months by certain producers, and has been found entirely satisfactory.

Buckled Film.—Buckling of film prevents proper visual and sound presentation, and was a serious problem until recent months when complaints of this nature became less frequent. Apparently some improvement has been made in the film, or in the laboratory methods, that accounts for the elimination of these difficulties. The Committee recommends that a constant check be maintained on this point in order that the present improved product may be continued.

Dense Positive Prints.—Prints are sometimes received in theaters that are printed too densely for best screen results, perhaps as a result of judging the density of the print in a studio where the illumination projected on the screen was in excess of what can be obtained in the average theater. On the other hand, prints are occasionally received that are too light in density, causing a lack of proper contrast.

The Projection Practice Committee is at the present time taking readings of illumination of screens in various theaters, and it is hoped that a recommended level for screen illumination can be arrived at and the studios be requested to determine the best print density for such conditions.

Film Cutting for Change-Overs.—Occasionally, it is impossible to accomplish proper picture and sound change-over between reels, due to the fact that the sound essential to the action continues to the last frame of the outgoing reel and begins with the first frame of the incoming reel. Owing to the displacement of the sound track in relation to the corresponding picture, such cutting of film results in a loss or confusion of sound.

The Committee recommends that, in determining the beginnings and endings of reels, a point be selected for change-over that will be satisfactory from a visual *and* sound standpoint; and further recommends that suitable leeway be allowed so that sound essential to the action shall not occur at the extreme end or beginning of the reel.

Uniform Volume Level.—At the present time, theaters frequently receive film having widely varying levels of recorded sound within single reels, a greater variation between reels of the same picture, and still greater variation between subjects. Under such conditions, it is difficult to maintain the proper sound level in the theaters. As the theaters are continually striving to maintain their several projectors and their sound equipment in an equalized condition for presentation of sound pictures at the proper level, it is highly desirable that the producers and the laboratories coöperate in providing film free from wide variations in recorded sound level that are not intentional.

Standard Release Print.—The objects of the standard release print are to reduce the mutilation occasioned by the punching of film by projectionists for change-over purposes, and also to permit accurate change-overs to be made between reels. To be properly effective it is necessary first, that the indicating marks for motor starting and film change-over be accurately placed, both with respect to the end of the reel and with respect to the individual picture frame; second, that the indicating marks be sufficiently conspicuous to be conveniently noticed by projectionists.

This second point is made for the reason that in many instances a black spot without the surrounding white circle appears upon a dark background. This seriously reduces the visibility of the indicating marks when viewed from the projection room, and thereby contributes to the uncertainty of the projectionists in starting the motor and in making the change-over. It would be preferable to have a white circle surrounding the black spot.

The Committee feels that only by rendering the indicating marks reliable in one hundred per cent of the cases can the element of uncertainty be removed and the punching of film by projectionists be eliminated. The Committee is of the opinion that the new reduced size of the indicating marks is an improvement over the original size, and where this present size of black mark is applied to a light background, the reduction in size has not affected the visibility. (NOTE: One suggestion for overcoming this lack of visibility is to apply a narrow concentric ring of opaque material around each indicating mark on the negative film. This would result in a narrow white circle around each black dot on the positive print, which indication should be visible against a dark background. This ring might be stamped on the print in the same operation as in punching the negative.)

H. RUBIN, *Chairman*

RELEASE PRINT PROBLEMS OF THE DISTRIBUTOR*

JAY A. GOVE**

Summary.—*The release print problems of the distributor are divided into (1) general, or those common to all distributors; and (2) special problems, those that result from endeavors to assure reproduction on the screen of the original qualities recorded on the negative in the studio.*

General problems are divided into processing difficulties, drying and brittleness of film, consolidation of reels, film cutting operations in the projection room, worn sprocket teeth, and methods of cleaning and splicing film. The special problems are those that give rise to special operations of maintenance, inspection, and repair of film by exchanges.

I. General Problems

Trouble begins in the film exchange when the new print is received. Actually, the difficulty antedates receipt, and a distinctly marked trail can be perceived extending from the laboratory to the exchange. The first difficulty results from the fact that the surface of the print is too soft and tender to withstand the heat of the light and the rough usage to which it must be subjected. The film coating (emulsion) requires to be aged, naturally or artificially, in order to harden it sufficiently to insure that it will endure under use. The demand for films outweighs other considerations, however, so that sufficient time is not provided for them to age properly before being put into service.

If a new print be given to an exhibitor for projection in the identical condition in which the film exchange receives it, the surface may be scraped by the shoes and gates of the projector. These scrapings accumulate at the points of contact, harden, and begin to scratch the surface of the film, seriously affecting the projected images and perhaps the quality of the sound as well.

In order to avoid this trouble with so-called "green" film, a number of preventives are employed, each of which is claimed to possess superior merit. The manufacturer perhaps waxes the edges (sprocket holes) of the film; or the laboratory uses a private method that it calls

* Presented at the Spring, 1932, Meeting at Washington, D. C.

** Metro-Goldwyn-Mayer Pictures, Inc., New York, N. Y.

processing, conditioning, curing, treating, or seasoning. But it is always the projectionist, the operator in the projection room, who applies the last treatment; and he usually has the last word. And he applies it with an oil can.

It is not the writer's intent to become involved in controversies; and it is therefore assumed that each of these methods of greasing or oiling, or otherwise protecting the film, accomplishes the purpose for which it was intended. That is, we graciously concede that the process, whatever it may be, prevents the emulsion from being scraped off the film during projection. If the process damage the emulsion, that, of course, has nothing to do with its efficiency in other respects. From the point of view of the exchange, however, what is desired is a method of protecting the emulsion that is harmless of itself; for oil, wax, and similar agents tend to grease the print, burr the sound, blur the image, and to accumulate dust and dirt that scratch the emulsion. Frankly stated, the inspection departments of film exchanges, having at hand from five to fifty complete solutions of the emulsion problem, are still confronted by the necessity of making extensive repairs of prints because *scratching of the emulsion results from the very method employed to prevent scratching.*

BRITTLENESS OF FILM

In attempting to place the burden of troubles of the film exchange on the shoulders of the manufacturer, the laboratory, and the exhibitor, it has been stated that the film exchange at the beginning of its work is handicapped by the softness of the print emulsion. Time and usage may overcome this difficulty, but unfortunately most trouble develops at the sources of greatest revenue—the large theaters that pay the highest rentals. By the time service is extended to the less important sources of revenue, the green film has begun to age; but by that time its most productive period has passed. Nor does its age of maturity last long, for almost immediately upon becoming properly conditioned, the film begins to become dry and brittle. Thus the exchange contends at the outset with *softness* and most of the remaining time with *brittleness.* Of course, there is a perfect defense to this broad and inclusive indictment. All that the distributor needs do to avoid brittleness is to make humidors of his storage vaults, inspection rooms, and film cans, and never to allow the prints to leave the balmy atmosphere.

Obviously, brittleness is a more difficult problem in some territories than in others. In the dry southern part of the United States, the difficulties encountered are greater than those found in a comparatively damp environment, such as Atlantic City. A constant temperature of about 70 degrees, coöperating with a reasonably moist atmosphere, will maintain ripened film in fairly good condition. What film exchanges need are emulsions that are aged naturally or artificially before being delivered; films that do not subsequently become dry and brittle, even under the hot light of a projection machine; prints that do not require an inordinate amount of care to prevent buckling, breaking, or scratching, and that fire can not destroy.

CONSOLIDATION OF REELS

Another problem common to all distribution offices that serve large theaters results from the extensive habit of projectionists of splicing two single reels so as to form one double reel, thus administering to the convenience of the operator by reducing the number of change-overs required. If the film were projected as delivered, the projectionist would thread a reel into each of his battery of machines, necessitating a change-over from one machine to the next after completing the projection of each reel.

In order to make the action and the dialog continuous, and to conceal the fact that a change-over is being made, the producer duplicates a fixed length of the end of the first reel at the beginning of the second reel. When a certain point near the end of the first reel is reached, the second projector is started. After it has attained sufficient speed, the first machine is stopped, and the second machine continues the projection of the picture. In an eight-reel picture, such a change-over occurs seven times; and while the producer spends a great deal of money on duplicated film footage, and sometimes works for days to "break" the picture at the correct places, the projectionist has learned by experience that his interests can best be served by using double reels.

In some instances, the distributor pays a premium to have prints made in unbroken, unspliced lengths. These prints include considerable footage of protective blank film at the beginning and end of reels. Often when an eight-reel production, thus specially printed, is delivered to a theater, the first thing the projectionist does is to unwind the first reel of virgin film and cut off the protective blank footage at the end. Then he cuts off the leader (protective film) and the duplicate first reel sequence from the second reel. He then splices the two ends together and reels the entire footage on one spool, which is then inserted into the projection machine.

In a similar manner, consolidations are quickly effected of reels three and four, five and six, and seven and eight; the eight-reel production thus being reduced to four double reels; or, more important to the projectionist, to three change-overs. In the projection room may be found eight strips of film cut from the reels, aggregating in length between 135 and 150 feet. These strips are often placed into the film cans and returned to the film exchange with the reels at the conclusion of the engagement.

As the film cans in which prints are delivered will not accommodate double reels, it is usually necessary for the projectionist to separate the reels before returning the production to the film exchange. Here all the loose ends must be trimmed and replaced in such manner as not to spoil synchronism of sound and action and all start and finish marks must be replaced accurately, involving many minutes of an inspector's time.

Why do distributors not avoid this annoyance by mounting film on double reels? A few of the reasons are: difficulty of inspection; material increase of fire hazard; greater liability of damage during shipping and handling; necessity of rebuilding racks in storage vaults; and of replacing existing film cans, shipping cases, and reel bands.

Whether or not this is an engineering subject is uncertain; but that it is an important, annoying, and extremely expensive problem of film handling and servicing there can be no quesiton. It adds substantially to the cost of operation—far more substantially than the added convenience of projection can possibly justify.

THE FILM OPERATING ROOM

For fear that one important point may not have been made quite clear, the projection room of the theater may be likened to an *operating room* and the branch office's inspection quarters of the film exchange to a *hospital.* Operations performed by projectionists cause much of the difficulty with which film exchanges have to contend. Not only does the cutting expert of the theater lop off fore, aft, and amidship, as suits his fancy, but not infrequently his artistic nature is so deeply touched by some stirring march or other music that he is constrained to appropriate a slice of sound track. In due time this piece is added to the musical library of the theater; and for the rest of its natural life it serves to exit customers into the night.

Another of the projectionist's major operations is performed when he repairs breaks. Despite almost superhuman care by the distributor, these breaks sometimes occur, being invariably traceable to defects in raw stock manufacture, to chemicals used by laboratories, to carelessness during projection, or to some combination of these factors.

Not having to pay the bills for raw stock, and recognizing only the urgency of getting along with his show, the projectionist, when a break occurs, quickly estimates how far the film must have been damaged on each side of the break, and promptly snips off eleven feet, more or less, from each of the two ends. Subsequently the distributor places an order with the laboratory for twenty-two feet of replacement film, and the laboratory orders twenty-two feet of raw stock.

There are occasions, however, when the projectionist performs only minor operations, such as when his diagnosis indicates that the film has only a torn perforation. The approved procedure of the projection room in this case is to lay the film on a flat surface and to cut a V-shaped notch in the margin, completely curing the trouble by eliminating the sprocket hole. When the film with its notched edge is returned to the film exchange, a second operation follows the emergency treatment; a strip clear across the film and of the width of the notch is removed, and the profits of the raw stock manufacturer are thereby fractionally increased.

DAMAGED TEETH IN PROJECTION MACHINES

The projectionist who is so quick to practice excision on defective film not infrequently contributes indirectly to the necessity of making such operations, such as when a rough or nicked sprocket in the projector damages perforations of the film. The damage may at first be so slight as scarcely to be detected, but weakness develops, which eventually results in splitting or enlarging of the sprocket hole and causing numerous subsequent complications.

These sprocket hole troubles, it will be noted, are among the many that challenge inventive genius. All sorts of strengthening devices and methods have been proposed, including metal reënforcements not unlike those used for shoe-lace eyelets. However, thus far no improvement has been made by the raw stock manufacturer in this part of his product that endures the greatest strain.

A FEW INCIDENTALS

Another cause of trouble for distributors lies in using high intensity lamps for projection. Every one except the projectionist agrees that there is no real need of the great intensity of light that is often used, and that causes the film to become so excessively hot that it buckles. Of course, this does not concern the projectionist more than momentarily, and his method does provide a well lighted screen.

FILM CLEANING

Film becomes dusty, and accumulates oil and grease. For cleaning the surface, carbon tetrachloride and other chemical compounds are employed. The difficulty in using some of these is that unless they are used carefully and unless the inspection room is well ventilated, the inspectors are liable to be overcome by the fumes. The use of gas masks probably would obviate this difficulty and so, too, would proper care; but a satisfactory and inexpensive cleaner that is not a menace to health would solve matters more certainly and conveniently.

SPLICING OF FILM

Every film exchange is confronted by the necessity of splicing film. The process involves scraping the coating of emulsion from the ends of the pieces to be joined and cementing these ends together. Naturally, every time a break occurs in a film, or every time a projectionist cuts a print so as to reassemble it in the form of double reels, there is some loss of footage. This happens also, and more extensively, when film is torn or when sprocket holes are damaged during projection.

Synchronization of the dialog and the action requires always that a print be maintained at approximately its original length. Splicing frequently involves deleting and replacing film footage numbers, laboriously comparing the print with one that is known to be correct, and measuring the footage or checking against the continuity. This takes time, and makes it necessary to employ a greater number of inspectors than would otherwise be required.

II. Special Problems

There is a theory that the money that a motion picture studio invests in a picture is wasted in proportion as the values that have been recorded on the negative fail to reach the screen and the loud speaker of the theater. Several intermediary factors are involved between production and reproduction, of which printing and projection are two. Others are the seating arrangements of the theater and the acoustical properties of the auditorium. But the direct responsibility of the film exchange is restricted principally to that of always maintaining the prints in the proper condition. Even in this, of course, there are limitations, but the exchange certainly is under obligation to avoid injecting defects of its own creation into the exhibition of a production. Such defects may arise from a great variety of causes, but they are most commonly contributed by inefficiency, carelessness, or a desire to save money. In this sense, the entire inspection department of a distribution organization may be involved. The problem of servicing and properly caring for prints may extend beyond the exchange to the home office. Policy rather than personnel may be the real issue.

One distributor adopted the thought, "Protect Our Product," as an inspection slogan. This affirmative attitude, rather than the negative one of avoiding complaints from exhibitors, is said to have contributed materially to the improvement of inspection standards. This organization, at the time that sound recording became a factor in motion picture production, established a school at its studio in which the proper care to be taken in servicing prints was taught. The graduates of this three-months course were later sent into the field as technical supervisors, and established the inspection standards and policies that were found essential to good service. An interesting result was that many changes were made in the methods that involved the general handling of film and that had no special relation to the new problems arising from sound recording and reproduction.

ESSENTIALS OF GOOD PRINT SERVICE

Most of the essentials of good print service relate to commonplace phases of inspection work. Emphasis is laid on those features that would seem to be obvious, that, in reality, can be made effective only through the persistent application of pressure. To quote from a modern manual of instructions:

> Use only perfect reels. A reel, that is out of line or widened or that has rough edges, a loose hub, or bent sides, is unserviceable.
>
> Be certain that splices are made "in frame." A splice that is "out of frame"

is one that has more or less than four sprocket holes to the frame or more or less than sixteen frames to a foot.

Every splice made in the inspection room must be identified by the exchange's embossing seal. When not so identified, the inspector shall assume that the splice has *not* been correctly made and that, in the case of a disk print, the proper footage of replacement film has not been inserted to maintain synchronism. The film at such point requires close examination to determine whether footage is missing or has been added.

Insistence that defective reels shall be discarded involves expense—unnecessary expense, perhaps, if quality of service be not a material consideration. The other quoted instructions affect both work and expense, and invite difficulties of performance that are certainly self-imposed by the distributor.

It is in replacing defects, however, that perhaps the greatest inspection costs can be incurred. One company takes the attitude that *exhibitors rent prints in the expectation of getting full reels. If footage has been removed, the exhibitor is not getting what he pays for. Each inspector should make a careful check of missing footage, and replacements should be ordered promptly so that the print can be maintained intact.*

Obviously, this is not an ordinary requirement. Also, it involves expense for replacements considerably beyond what is requisite to average service. Insistence that the small theater that is served last shall receive the same footage as the customers who first exhibit a print is a new standard, and involves the abandonment of the previous premise that prints should logically be expected to decline to lower levels of quality as the rental rate decreases.

These ideas are carried even further; to quote again:

Under no circumstances should only part of a sound scene be inserted; the replacement must always comprise an entire scene. Frame-line leader may be inserted only up to four frames in length; any damage in excess of four frames is to be replaced with the entire actual scene.

Here too we find departure from precedent—and with a protective purpose. To try to define a scene length is difficult. But, four frames, we know, represent about three inches. So the footage of replacements required by the foregoing standard may represent very materially more than the amount of damage done. On the basis of one replacement, this may not be an expensive item. On the basis of from 9000 to 12,000 prints a month, it rapidly becomes so.

One evil that the scene replacement method obviates is a multiplicity of splices. The important reason for its adoption, however, was to avoid repeated variations in film density. The original print, of course, is printed to a definite quality standard. It has proved discouraging to expect duplications of this standard for replacements. The result is that if only the damaged parts of prints be replaced, the varying densities of the original and the replaced sections may occasion sharp and sudden changes in the appearance of the screen image and in the tone or pitch of the reproduced sound.

If these variations occur only at the beginning of scenes, they are reduced both in number and in prominence; and, to this extent at least, the theater audience obtains a better reflection of the real values with which the studio originally endowed the negative. Hence, the policy of replacing an entire scene, when only part of it has been damaged, is a distinct contribution to better motion pictures.

THE VALUE OF NEATNESS

Organization policy, as affecting print service, may also express itself as insisting on neatness of the inspection room. Thus we find in the inspection manual of one distributor, the requirement that not only must work tables, splicing machines, and all other equipment be thoroughly cleaned every day, but that floors, ceilings, walls, windows, window sills, doors, cabinets, and pipes must have regular weekly attention. This prevents the accumulation of dust, which, being deposited on the film, causes scratches, produces distortion, and otherwise affects the quality of service that the print should render. This distributor specifies that parts of equipment that show signs of wear must be replaced promptly.

Time and expense figure clearly in the enforcement of such conditions—and from angles that probably were not anticipated when the policies were established. For example, it was found necessary to continue the employment of traveling technicians. Not only were these men needed at the outset to standardize the methods of handling film, but, because of the labor turn-over in inspection departments, they were subsequently required to maintain these standards.

Although this expense is avoidable, it provides a uniformity of service throughout the nation; it safeguards the studio investment, and insures a type of service to the small exhibitor that closely approximates that given to exhibitors who play the productions soon after release.

THE TREATMENT OF NEW FILM PRIOR TO RELEASE*

TREVOR FAULKNER**

Summary.—*The necessity of properly processing prints prior to projection and the conditions to be fulfilled by such processing are briefly described. The paper, in addition, points out the various causes of the damage sustained by film during projection, and concludes with a statement of the results to be expected from any processing or special treatment that might be applied to the film.*

The problem of treating motion picture film prior to releasing it for projection is a very important one for both distributors and theaters, referring particularly to the treatment of the film immediately after printing, developing, and drying.

This paper is constructed upon observations made of the work of the department of a major distributor responsible for the maintenance of film in thirty-nine branch exchanges scattered throughout the United States.

This department had been successful with its film maintenance problems to the point where the only serious difficulty that remained was the susceptibility of freshly developed film to become damaged prior to its having become seasoned by undergoing a sufficient number of screenings.

About ninety per cent of the damage sustained by new film occurs in the projection room. But although some projection rooms may be poorly equipped and operated by negligent or uninformed projectionists, I would state here emphatically that by far most projection rooms in which new film is used are well equipped and have competent men in charge of them. The damage, then, in some instances, is beyond the control of the projectionist in whose booth it occurs and can not be prevented by him.

New film may be damaged in three ways: by straining or tearing the perforations, by scratching the emulsion, and by the film's becoming buckled or warped, due to the shrinking or swelling of the gelatin when exposed to the heat of the projection lamp.

* Presented at the Spring, 1932, Meeting at Washington, D. C.

** S. M. Chemical Co., Inc., New York, N. Y.

The straining or tearing of perforations is, in most cases, due to the condition of the film itself, and can not always be averted by competent projectionists even when the projectors are in good operating condition.

This damage usually occurs during the first four or five passages of the film through the projector, and results from the depositing of emulsion on the shoes of the aperture plate. These deposits rarely accumulate to such an extent that the pressure between the aperture plate and the tension on the opposite side of the film is increased sufficiently to cause the teeth of the intermittent sprocket to tear the perforations by forcing the film down in front of the aperture; but the smallest deposit of emulsion on either of these shoes may, by baking, become so hard that its action on the emulsion of the film then passing over it is similar to that of passing a diamond over a pane of glass. When the diamond does not scratch the surface of the glass, it drags very little; but once it "bites" into the glass, the drag or traction may become considerable. This kind of effect occurs with film. Before the deposit of emulsion has acquired a "cutting edge," the film is permitted to slide over the deposit rather easily, and there is little probability of damaging the film. But once this smooth surface is changed, by further accretion of emulsion, into a cutting edge, it begins to cut into the emulsion, creating a resistance to the free passage of the film so that the teeth of the intermittent sprocket may tear the perforations in forcing the image past the aperture.

When such deposits of emulsion accumulate and interfere with the free passage of the film over the aperture plate, the projectionist is warned of the situation by the excessive noise made by the intermittent movement in protest against its overload. The projectionist can do only one of two things: either place a lubricant of some kind on the film before it arrives at the aperture plate, or stop the projector and remove the deposit that is causing the trouble. Neither of these procedures is followed by the average projectionist except in emergencies.

Scratches in the emulsion, in the picture area of the film, are nearly always caused by carelessness in handling the film, either in the projection room or in the exchange inspection room, or by improperly adjusting projectors or allowing dirt to accumulate in them.

Long runs of film, made under the best conditions of operation, have indicated that damage due to these causes can be reduced very considerably; but a visit to almost any theater in which is being projected film that has been booked once or twice before and which has not been properly treated prior to its initial run, will disclose a screened picture marred by many scratches.

The buckling or warping of film is no inconsiderable item of film damage. The buckling or warping is either so bad that the picture can not be kept focused on the screen, or is insufficient to cause any trouble at all.

This kind of difficulty is likely to occur only with new film, unless the new film has been properly treated to obviate it, prior to its first screening; for it is due to the sudden withdrawal of moisture from the gelatin, or the swelling of the gelatin from being heated by the projection lamp and is not likely to occur with film that has been properly seasoned.

It is evident that the efforts, artistic and technological, that have been made in producing a picture, will all be for naught if the effects produced are marred by physical defects of the film that prevent a satisfactory screening, but which could be prevented by proper treatment. Nearly all the difficulties described here are in connection with improperly treated, or untreated film and such defects do not occur in film, the gelatin of which has been chemically seasoned prior to its initial screening.

When film is sent to a theater in which it will be passed through a projector for the first time, that theater is certainly entitled to receive film that has been thoroughly prepared for screening; and it should not be necessary for the projectionist to wax, oil, or otherwise treat the film so as to assure himself of an uninterrupted screening. Nor should the projectionist be held responsible for the oil that he must necessarily apply to film that is improperly prepared for screening when the accretion of emulsion causes the projector to protest loudly against overloading when pulling the film past the aperture. Some of the largest producers and distributors have found a relief from these conditions by chemically treating the film at their laboratories; and it seems safe to say that it would be the wish of every projectionist in the country that all new film be given a treatment that would produce as good results for them as are enjoyed by these companies, so that they could feel reasonably sure that no film would be damaged while in their charge.

The distributor's interest in properly preparing prints for screening is restricted chiefly to that of assuring the satisfaction of the theaters; but the decrease in the amount of film that is damaged is incident to a like decrease in the number of controversies over the account, in the cost, and in the annoyance of making replacements; and the lengthening of the lives of the prints offers assurance that the final booking will be a satisfactory one because of the good condition of the print. All these factors figure in making the treatment worth while; but most important of all is the need of avoiding, so far as is possible, the loss of time on the booking records of prints that are withdrawn from service and are awaiting the replacement of damaged parts.

The revenue sacrificed by the distributor because of his inability to furnish prints of subjects that have been booked, or the expense and trouble involved in obtaining replacement prints either from the laboratory or some other exchange, assumes a huge amount, nationally; and is far in excess of the cost of treating film at the laboratory before shipping it to the exchanges. Such treatment not only assures the distributor of a positive saving, but also furnishes assurance that the theater will be supplied with film that can be screened as satisfactorily on the first booking as on the last. It avoids what is today the greatest cause of controversy between the distributor and the exhibitor: namely, the loss or change of bookings, due to the distributor's inability to furnish a satisfactory print when the print that has been booked has been damaged and no other print is available.

Before shipping film to the exchange, the laboratory should prepare it so that the booking department of the exchange could feel reasonably sure that the schedule of bookings arranged for the film would not be upset by the condition of any of the prints, especially during the "circuit" or "peak" period. As for the satisfaction derived from the film, whether on the first booking or on the last, the small exhibitors who pay minimum rentals are as entitled to satisfactory prints as the larger accounts, for the amount that the smaller accounts pay represents as great a percentage of their income as does that paid by the larger account; and their customers are certainly as entitled to the best film obtainable. The average motion picture patron is not aware of the causes of the "rain," or scratches, that appear on the screen, or of the in- and out-of-focus effect; but he does, perhaps unknowingly, appreciate the better quality of the picture when it is free from such defects.

It is highly desirable that film be treated by the laboratories in such a manner that the following objectives may be achieved:

(1) The film should be able to make its first passage through the projector with the facility and ease of a seasoned film, thereby eliminating the danger of pulling or tearing the perforations.

(2) The gelatin should be chemically cured, so as to be protected against the scratching of the surface that occurs with practically all film during its first few screenings, unless so treated.

(3) The buckling, warping, or curling of the film incident to its being heated by the projection lamp should be reduced to a minimum.

(4) The pliability of the gelatin and its binder should be as permanent as possible, thus assuring a longer and hardier life of the film.

Any treatment of film that is not satisfactory in these respects is inadequate and of little importance in its application to film. Any process of treatment for new film, other than that of aging during the use of the film in projection, must be either a surfacing or an impregnating process; surfacing processes consist in altering the existing surface, as by buffing, or in applying a new surface, as by coating. Coatings that are not made a permanent part of the film itself, and, as a result, may be left in the projector in the form of deposits, are, according to the size of the deposits, menaces to the correct reproduction of sound. Buffing will help new film to pass through a projector freely, but it can not offer definite assurance that the picture image or sound track will not be affected by alterations in the buffing surface, caused by the attachment of gelatin to it. Measurements made in ground noise tests readily prove this. Impregnation processes must refrain from using agencies that shorten the life of either the gelatin or the base, and must not alter the pliability of either of these.

Those who have been engaged in the endeavor to maintain prints in a satisfactory condition up to the time of the final booking date realize that it is now possible to achieve such a result, and that some of the major distributors are now preparing and maintaining their product so as to take advantage of this situation.

STANDARDS AND REQUIREMENTS OF PROJECTION FOR VISUAL EDUCATION*

CHAUNCEY L. GREENE**

Summary.—*In the development of visual education the choice of material, planning of sequences, photography, laboratory work, and editing of the finished product receive the most careful attention, but the projection of the finished product is very much neglected.*

The inevitable result is eye-strain, either severe or slight. The straining of eyes already taxed by constant study may easily lead to serious results. A slight strain may either induce drowsiness or otherwise retard the mental processes so that much of, if not all, the advantage of the visual method of presentation may be nullified.

The conditions for projection free from eye-strain are the same for educational as for theatrical projection, but conditions and limitations peculiar to the classroom, such as the shape and size of the rooms, lighting arrangements, lack of beam-power of the projectors necessitating the use of specular or semispecular screens, and the short projection and viewing distances frequently encountered assign a major importance to factors that are negligible in theatrical projection.

Particularly is this true of the projection of opaque objects where all these factors are evident simultaneously and all in large degree. Two experimental opaque object projectors are described, one of moderately high power and the other of extremely high power. Two opaque and five translucent screens are analyzed.

In recent years increasing attention has been paid to projected images as visual aids of teaching. The choice of the subject is given careful thought, the editing of the material receives expert attention, some of the photography stands out as a superb example of what can be done under extremely difficult conditions. The laboratory work represents an equally high standard of craftsmanship and scientific control, and then all attention ceases.

A typical example will illustrate: A few years ago an eminent metallurgist presented the results of some of his research work on stainless steels at a meeting of steel treaters. Many tedious hours had been spent in polishing and etching the specimens. Two continents had contributed the finest of their photographic microscopes, and all the photographic processes had been carried to perfec-

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* Presented at the Spring, 1932, Meeting at Washington, D. C.

** Minneapolis, Minn.

tion. But when the results of all this labor were presented to the steel treaters, the slides taken with the $1500 metallographic camera were placed in a $15 stereopticon; and a lens that was a shining example of every known aberration projected them on a patched and dirty sheet that hung in sagging folds, supported by strings at its upper corners. The finer details of the micro-structures were totally indistinguishable; and the eye-strain imposed by trying to distinguish details needs no comment.

There are varying degrees of intensity of eye-strain, and there are varying degrees of severity of effect. An extreme glare such as is encountered when attempting to look at the sun causes immediate physical pain; a lesser eye-strain causes immediate discomfort, the physical pain following after more prolonged exposure; while a still milder strain produces merely discomfort after prolonged exposure. Passing now to a consideration of still milder eye-strain, we come to the range of eye-strain with which we are mostly concerned. In the cases previously mentioned the strain is so severe that one instinctively avoids it. An eye-strain of lesser degree may produce no pain or discomfort, and thus by its very insidiousness may continuously sap one's energy until drowsiness and sleep result. This is simply nature's effective way of combating the irritation by excluding it. A still milder strain, insufficient to produce actual drowsiness, may merely dull the keen edge of the mental faculties and retard the mental processes of learning.

It is these two last-mentioned degrees of eye-strain that, because they may escape notice and correction, constitute a serious menace to visual education. Merely removing the more intense forms of eye-strain and putting projection on a plane of tolerably good quality are not sufficient to realize more than a small part of the possibilities of visual education.

All eye-strain must be considered relatively to the individual. Granting normal vision in each case, a condition that would produce but a mild eye-strain in a person of inferior sensibility might produce a severe eye-strain in the mentally alert, highly strung individual who, unhandicapped by eye-strain, would be far the better student.

Research might reveal a critical strain below which the mental processes are not affected, but until such time as that is established as a fact, and adequate data are at hand, the only right course is to strive for ideal conditions of projection. The theater patron paying his admission has a right to expect projection of the best quality, but he can attend the theater or stay away, just as he pleases; whereas the student is held accountable in examinations for the material presented on the screen, and has to look at the screen whether he wants to or not. Consequently, no educational institution has any right to impose, in the process of visual education, any eye-strain, however slight, that can be obviated by any means whatsoever.

The steps necessary to avoid eye-strain are almost self evident, but their execution under the limitations and handicaps usually encountered is not so simple. The avoidance of eye-strain calls for:

(1) Proper choice of screen.
(2) Proper illumination of screen and room.
(3) Proper contrast in the brightness of all objects within the field of view.
(4) Clear definition of the screen image.
(5) Absence of graininess.
(6) Steadiness of the screen image.

To obtain ideal conditions under all six of these headings calls for careful consideration in theaters specifically designed for projection purposes, but in most cases the classroom imposes in addition the following handicaps:

(A) Short viewing distance.
(B) Unfavorable viewing angles.
(C) Unfavorable equipment locations.
(D) Improper illumination due to:
  (*a*) Location of lighting units.
  (*b*) Location and curtaining of windows.

Items 1 to 6 have been investigated before and have been reported on at length before this Society and the Illuminating Engineering Society. Therefore, only such phases of these matters will be discussed here as are influenced strongly by the limitations and handicaps peculiar to visual education.

The matter of the projection angle has been previously reported on by the Projection Practice Committee, and a maximum angle of 18° has been recommended. Distortion, however, increases much more rapidly than the angle, and the angle should be kept as small as possible, with 18° as the absolute maximum. The effect of extremely large angles may be lessened or nullified by using plane first-surface mirrors. If the beam be twice reflected at an angle of 90° the resultant image will be free from distortion.

Fig. 1(*a*) illustrates projection at an angle, and Fig. 1(*b*) distortionless projection, with the projector and screen in the same position. Such an arrangement would be impracticable in most theaters, but there are instances in educational work where the small images projected would make the scheme entirely practicable.

It is highly important that neither the images of individual emulsion granules nor the texture of the screen be discernible, and due to the short viewing distances usually encountered, this calls for fine-grained emulsions and but moderate magnifications compared to those used in theaters. Only very little magnification should be attempted with certain types of projectors that have but limited beam power. The futility of attempting to cover a 12- by 16-foot screen with a film slide projector having a 21-cp. Mazda bulb as a light source is apparent, yet it has been repeatedly tried. There is also a strong tendency to extend the use of 16-mm. motion picture

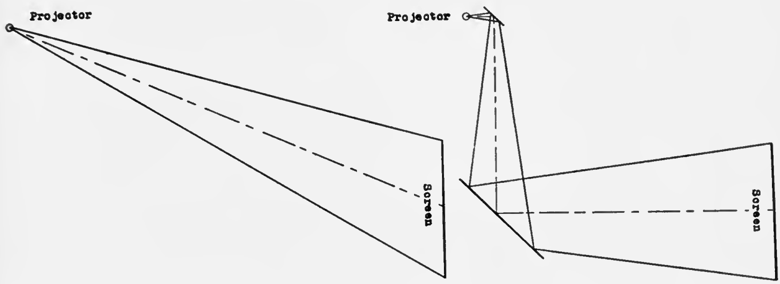

FIG. 1. (*a*) Projection at an angle resulting in distortion: (*b*) same position of projector, using first-surface mirrors to eliminate distortion; for the same location of screen and projector the picture will be larger.

projectors to fields in which their limited beam powers are wholly inadequate. The extreme facility with which material may be gathered by such cameras as Ansco Memo, Leica, and others of a similar nature, and the large field opened through the medium of Kodacolor would seem to merit the development of projection equipment having greater beam power. For, particularly if there is to be maintained an illumination level sufficiently high to permit taking notes, then certainly any screen image having a highlight brightness of less than 5 millilamberts may be considered to be inadequately lighted. Only the best 16-mm. projectors have beam powers of the order of 100 lumens, which for a flat white screen would limit the picture size to 3 by 4 feet. A more highly reflective screen would increase the permissible picture size, but such screens should be used with due caution at the short projection and viewing distances frequently encountered in practice, for reasons which will be dealt with later.

It is when we attempt to provide general illumination to enable the students to take notes and to relieve objectionable contrast that we meet with one of the most serious shortcomings of the great majority of classrooms for visual education. It is extremely difficult, and often impossible, to light the room properly without allowing a great deal of extraneous light to fall upon the screen. In many cases the only practical solution has been to increase the beam power, a procedure manifestly impossible with any but professional equipment; and this, of course, does not nullify the eye-strain resulting

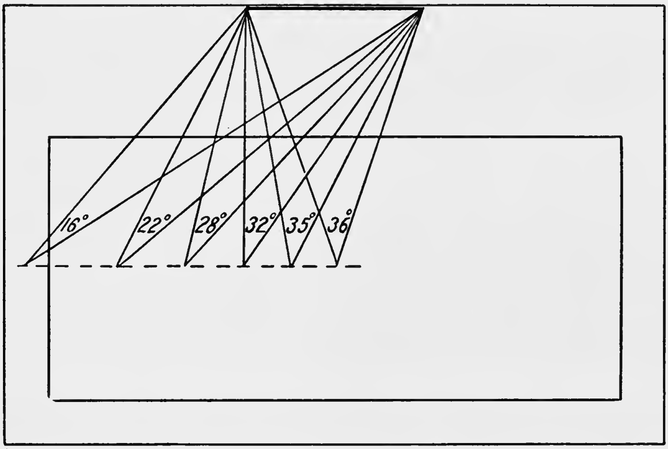

FIG. 2. Diagram showing variation of viewing angle in a typical classroom, the students being seated within the inner parallelogram.

from torn or misaligned window shades that let in streaks of sunlight; or from one, waving in the draft, that sets up a "flashing beacon" effect each time it flaps out of and back into its proper position.

Granting, however, that all other conditions have been fulfilled and that an acceptable screen image has been produced, it literally "must be seen to be appreciated;" in other words, the viewing angle now becomes a factor, and in this respect many classrooms are but poorly suited. Consider a typical classroom measuring 20 by 30 feet, with 6 feet of clear space in front and 2-foot aisles at the sides and rear (Fig. 2). For an observer viewing an 8-foot image projected on the center of the front wall, from various points along a line drawn across the center of the seating plan, the points being so chosen that he views the image at right angles to its plane and then at successive angles to the normal, the image would subtend angles as shown in Table I.

TABLE I

Viewing Angles and Per Cent of Normal Perspective

Viewing angle (degrees)	0	10	20	30	40	50
Angle subtended by the screen (degrees)	36	35	32	28	22	16
Per cent of normal perspective	100	97	89	78	62	44

Now, if we demand of the student that he assimilate correctly 70 per cent of what is presented to him, then certainly he has a right to demand that it be presented at least 70 per cent correctly. Plotting the values of Table I, Fig. 3 shows a rapidly drooping curve on which the angle for a 70 per cent correct view is 35 degrees. Drawing two lines from the center of the screen at an angle of 35 degrees from the normal (Fig. 4) an area is enclosed which in this case may be said to be the useful area from the standpoint of the viewing angle. Obviously it would be much better to arrange the seats as shown in Fig. 5 and obtain a useful area of 331 sq. ft. instead of the 193 sq. ft. provided for by the arrangement of Fig. 4. However, structural details do not always permit such an arrangement. In such cases the compromise arrangement of Fig. 6 possesses some advantages. The projector is located as in Fig. 4, necessitating no change in wiring. If the room is provided with movable seats or desk-arm chairs, not crowded too closely together, but a moment is required to turn the chairs to face the screen and to return them to their original positions after the visual presentation is ended. The useful area provided by the arrangement of Fig. 6 is 264 sq. ft., an increase of 37 per cent over that shown in Fig. 4.

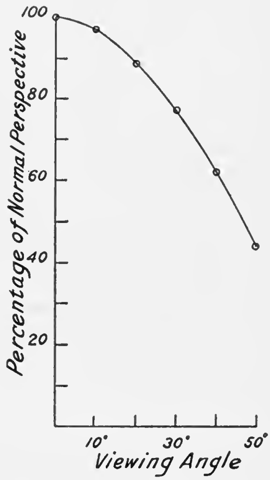

FIG. 3. A plot of the values given in Table I, relating the percentage of normal perspective to the viewing angle.

Anent the distribution characteristics of the screen there is considerable to be said. One broad statement already made applies to all of them, *viz.*, the texture of the surface should be finer than the image of the smallest particle in the object being projected. The projection microscope presents a special case, in which the fineness of the texture of the image is limited only by the resolving power of the lens system. The Mayo Foundation report that the most satisfactory screen that they have used is a steel plate coated with flat white enamel.

The more highly reflective opaque screens, and most of the translucent screens, present certain problems that are easily demonstrated by the translucent type. All but a small area in the center of certain translucent screens, one after the other, was masked off, and the brightness of the screen on the side facing the audience was measured from points in a horizontal plane passing through the optical axis of projection.

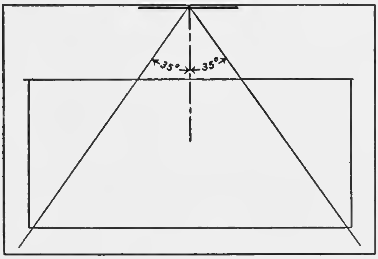

FIG. 4. Diagram showing the usable area of the classroom, for a viewing angle of 70 degrees.

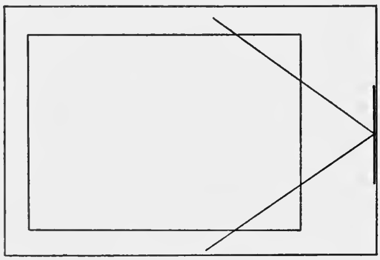

FIG. 5. A better arrangement of the room illustrated in Fig. 4.

Table II gives the brightness, as measured at intervals of 10 degrees along an arc in this plane, of ground glass, flashed opal glass, tracing cloth, and two commercial screens, *A* and *B*. All readings are referred to the brightness of a magnesium carbonate surface held against the projector side of the center of the screen, its brightness being assumed equal to 100.

Now, granting uniform illumination, it is reasonable to assume that if the mask opening had been moved to a point near the margin of the screen, and the readings had been referred to a line through the projection lens and the mask opening, the readings would have been quite similar to those in Table II. In other words, from any point in the audience, that part of a given translucent screen most nearly directly between the observer and the projection lens will appear brightest; and the brightness of any other observed point will

TABLE II

Relative Brightness of Various Screens Compared with Brightness of Magnesium Carbonate Surface

	Angle from the Normal (Degrees)						
	0	10	20	30	40	50	60
	Relative Brightness						
Magnesium Carbonate	100	99	96	94	92	89	84
A	207	115	86	60	32	18	15
Tracing Cloth	325	129	92	63	54	40	34
Ground Glass	2000	783	115	40	19	14	13
B	180	160	114	82	56	45	40
Flashed Opal Glass	58	57	55	53	49	45	45

be a function of the angle between the continuation of the line drawn from the optical center of the projection lens through this observed point on the screen, and the sight line from the observer to this

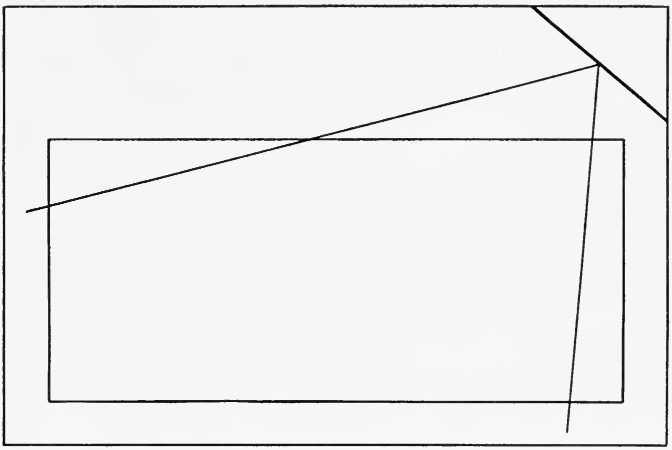

FIG. 6. A compromise arrangement of the classroom, providing greater seating area within the viewing angle of 70 degrees.

observed point. This angle is governed by the projection and viewing distance. Granting uniform illumination and normal projection, the point on the screen farthest from the observer will be the dimmest; and since we are concerned with the maximum contrast, if we adopt a maximum brightness ratio we can, by choice of projection distance, picture size, and screen material, control the shape of the useful audience area within certain limits. For example, take the case of an 8-foot picture projected a distance of 20 feet to have a maximum brightness ratio of 1 to 4. Along any sight line, s_1 s_2, *etc.* (Fig. 7), the brightest point will be where the sight line intersects the screen. The dimmest point will be at the margin P_1. The angle corresponding to one-fourth the maximum brightness is obtained from Fig. 8(*a*) and laid off on P_1s at P_1, giving the line A for screen material A and line B for material B. The portion beyond the line P_2s_5 is obtained in a similar manner, except that the maximum brightness is at P_2 and is obtained from Fig. 8 for the angle between P_2s_5 and the sight line in question. A shorter projection distance or a larger picture would alter the angles of lines A and B, and would

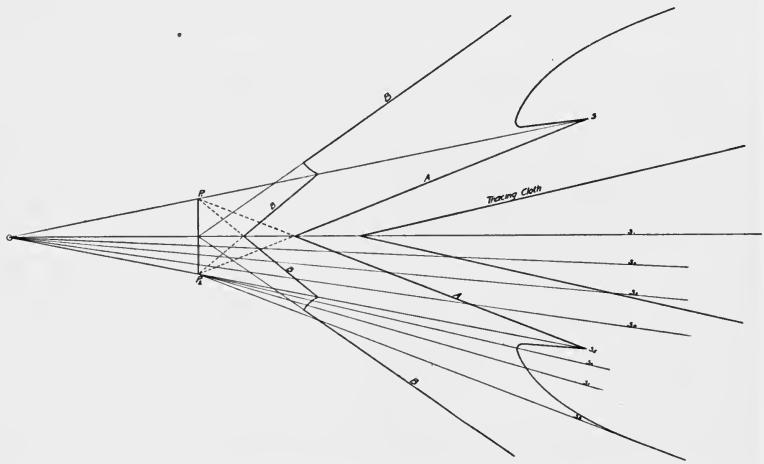

FIG. 7. Distribution diagrams for various types of screen, illustrating method of constructing the diagrams.

in general move them farther from the screen. A longer projection distance or a smaller picture would bring them closer to the screen and would alter their angles somewhat.

The same method is applicable to opaque screens, except that in the latter case the lines s_1, s_2, *etc.*, are drawn so that the angles of reflection and incidence are equal. Data are not quite as complete as is desirable for this class of screen. Table II is only approximate, as the figures for magnesium carbonate reveal. Illumination was furnished by a stereopticon, and there was some variation of line voltage.

With ample and accurate data a set of diagrams might be drawn on tracing paper or cloth and, by moving them about, superimposed upon the seating plans, the best combinations could easily and quickly be worked out.

A special and highly important phase of visual education is the projection of opaque objects. The system is admirably suited to those classes of work involving current material that is to be used only a few times or for those involving strong and brilliant coloring or fine shadings of color, as, for example, the color plates of dental and medical works. The projection of cardboard working models is often a powerful force in teaching. In fact, it is doubtful whether a more effective and versatile tool for visual education could be devised than a good opaque object projector in the hands of a resourceful teacher. But a *good* opaque object projector represents a problem, a problem that can be expressed in terms of "beam-power." Due to the way in which the image-carrying light must be

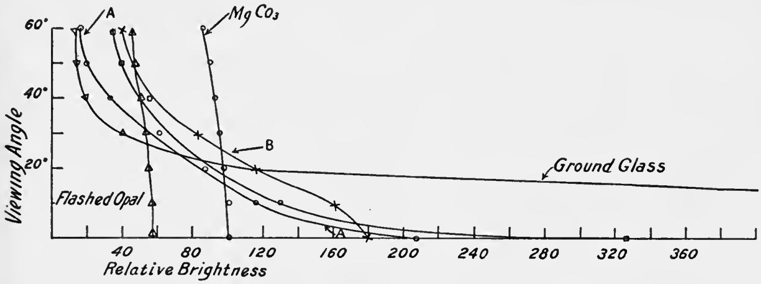

FIG. 8*a*. Curves showing the relation between the relative brightness of the screen, and the angle at which it is viewed, for various screen materials.

picked up by the lens, it is necessary to illuminate the object plane with approximately 27 times the number of lumens wanted in the screen image when plain white paper is being projected. This is the case for a lens of $f/5$. Now assume the case of an image 6 feet square projected before a small or moderately sized classroom, and demand an illumination of 5 foot-candles in the highlights, assuming the highlights to be the images of areas of flat white paper. The object plane must then receive approximately 4860 lumens, and if the area projected be 6 inches square, the illumination required is 19,440 foot-candles, which is probably somewhat more than any instrument now being manufactured will produce. Some instruments that could not illuminate the object plane with more than 3500 foot-candles have, in fact, been seriously offered for sale for use in large classrooms seating upward of 600 students. This is by no means intended as an arraignment of the equipment manufacturers. Thus far the educator demands the utmost simplicity in all projection apparatus because in most cases he must do the projection work or delegate it to a student, resulting in either case in the division of attention that professional apparatus will not tolerate. This demand for simplicity limits the choice of light source to the Mazda lamp, and unless special cooling devices are employed, 6000 or 7000 foot-candles is about the limit of intensity that can be used without scorching the paper. One or two forced-draft, air-cooled projectors have been introduced, and in 1929 the writer suggested the use of the water-cooled lamps demonstrated at the Toronto convention.

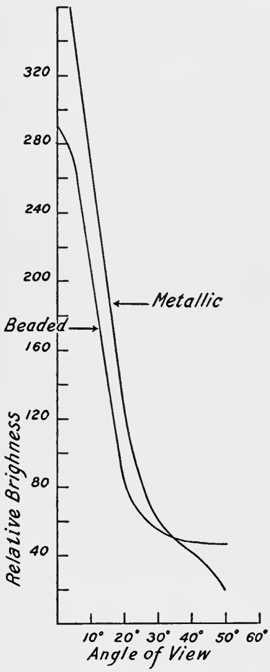

FIG. 8b. Curves showing the relation between the relative brightness of the screen and the angle at which it is viewed; for various screen materials.

Two models developed at the University of Minnesota are probably sufficiently unique to merit description. One was built by the physics department, and consists of a hollow sphere about a foot in diameter, nickel plated and highly polished on the inside and enameled black on the outside. The top is cut to fit the lens mount and the bottom is cut away to accommodate the object carrier. A first-surface mirror above the lens directs the beam horizontally and rectifies the image. Four 500-watt Mazda lamps grouped around the lens at the top of the sphere provide the illumination of 8000 foot-candles on the object plane. The heat promptly scorched every paper object placed into the projector until it was air-cooled by forced draft. Some consideration has been given to cooling by water and thus to permit increasing the illumination, which is still too weak, but conditions have not permitted further developments in this direction.

The other projector came as a result of a requisition by one of the departments for an opaque object projector that could be used with a 10-foot translucent screen in full daylight in a 700-seat lecture hall.

A preliminary survey indicated the need of about 60,000 foot-candles on an object six inches square, or 15,000 lumens. This would call for at least 10,000 watts in Mazda lamps. It would have been difficult to prevent the paper from scorching, whence it was decided to investigate the possibility of using a light source of higher temperature This proved more encouraging than we had dared to hope, for 63,000 foot-candles from a high-intensity arc had less scorching effect than 8000 foot-candles from Mazda lamps. No forced-draft cooling was necessary except for very long exposures of very dark objects.

Using lenses of about $f/5$ aperture, magnifications of 20 diameters were obtained, the screen image of plain white paper (reflection

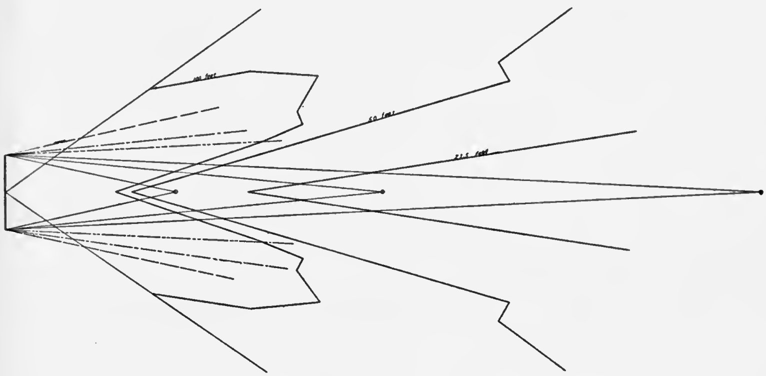

FIG. 9. Distribution diagram, for a 10-foot picture on a certain commercial metallic-surface screen, at projection distances of 100, 50, and 22.5 feet.

factor about 0.8) having an illumination of 6 foot-candles. With a plain white screen this would provide a highlight brightness of more than 5 millilamberts. Color plates were brilliantly and faithfully reproduced upon the screen.

Considering the requirements for good projection for visual education and the unsuitability of the average classroom for fulfilling these requirements, it would seem that further developments in this field ought to take the form of designing and constructing special rooms for the purpose. These might be of various sizes, to accommodate classes of all sizes, grouped around one central projection room. By means of interchangeable lenses and illuminants, together with sub-bases, intermediate bases, and registering pins, any type of projector might be used with any screen with assurance of perfect focus and registration and the proper intensity and balance of illumination. . Optimum service would be obtained for a given equipment investment, and changes from one form of projection to another might be made as frequently as desired without adverse effects upon the illumination.

These classrooms could be made optically and acoustically perfect. For instance, the screen might be cut to the exact size of the image and set out from the wall; and by illuminating the wall from

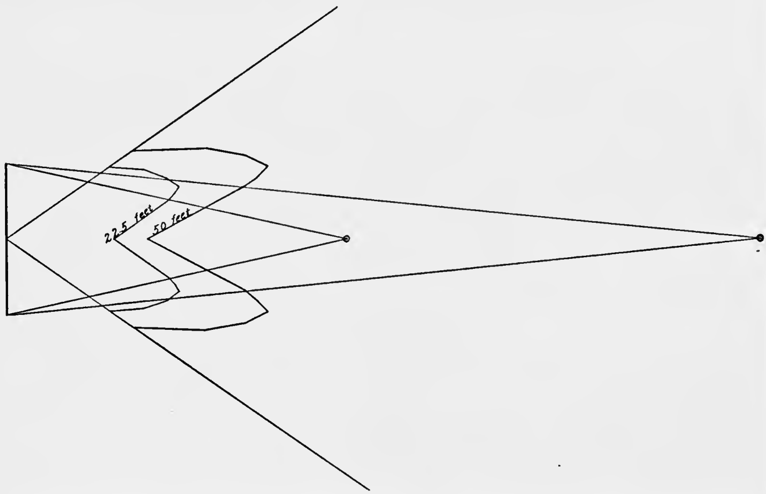

FIG. 10. Distribution diagram for a 10-foot picture on a certain commercial fine-beaded screen for projection distances of 50 feet and 22.5 feet.

behind the screen, a proper balance of brightness might be achieved and the perspective improved. Special attention could be given to sight lines and viewing angles. Perhaps a "reversed slope" floor might be indicated. The rooms might be equipped with loud speakers which, through a patch-cord panel in the central projection room, might be actuated by any desired source. Similar patch-cord panels at the input of the amplifiers would make the entire sound installation perfectly flexible. Lectures might be transmitted by wire from a distance, for the synchronization of projectors between distant points has long since been accomplished.

THE APPLICATION OF RECTIFIER POWER SUPPLY TO SOUND REPRODUCING EQUIPMENT*

B. F. W. HEYER**

Summary.—*The application of rectifier power supply units for furnishing the low voltage requirements of sound reproducing equipment demands careful consideration of the filter circuit characteristics as well as those of the sound reproducing equipment.*

Permissible ripple voltages are discussed in reference to the sound reproducing equipment in its present form. Consideration is also given to the possibility of future improvements of the sound equipment that might increase the effect on the system of the a-c. component from the rectifier filter sufficiently to interfere with sound reproduction. The factors governing load regulation of rectifiers and filters are treated with respect to allowable voltage variation under all operating conditions.

Output voltage characteristics are influenced by such variables as ambient and operating temperatures, manufacturing tolerances, and line resistance variations of each particular installation. This output voltage must be maintained within the range of the current regulating devices in the sound reproducing equipment. Description is given of a rectifier power supply unit, covering the electrical and mechanical design, shielding and installation problems.

In the design of sound reproducing equipment, the low voltage power supply is frequently the last matter to be given consideration. Nevertheless, proper power supply is essential to the efficient and continuous operation of the system. The power required will, of course, vary with the equipment design, but generally speaking, in a typical theater installation it is necessary to have a twelve-volt source supplying approximately eight amperes for the two exciter lamps, four and one-half to twelve amperes for the loud speaker fields, and in those systems having amplifiers using filamentary cathodes, filament current must be supplied. Some systems require, in addition, several amperes for the pilot lights, relays, and announcing system.

Thus, from ten to twenty-five amperes at approximately twelve volts represents the low voltage power demand of the usual sound

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* Presented at the Spring, 1932, Meeting at Washington, D. C.

** Heyer Products Co., Bloomfield, N. J. Credit is due to Mr. W. F. Bonner, of Electrical Research Products, Inc., for his assistance in preparing this paper.

system. In addition, there is required a high voltage power supply, which, however, will not be treated in this paper.

There are three general sources of supply for low voltage power for sound reproducing equipment: batteries, motor-generators, and rectifier power supply units. By far the largest proportion of sound reproducing equipment is operated by batteries. There are somewhat fewer installations equipped for motor-generator operation and comparatively few equipped for rectifier power supply. This paper will discuss, in a semi-technical manner, the application of rectifier power supply units as a source of low voltage power, both in connection with present installations designed and equipped for battery or motor-generator operation, and also for new installations.

RIPPLE VOLTAGE

The first major consideration in the design of a rectifier power supply unit is the suppression of the a-c. component of the rectified current. To arrive at the ripple voltage requirements, the following factors must be considered:

(1) The gain of the amplifiers.
(2) The size of the auditorium.
(3) The response of the system at 120 cycles.
(4) The effect of system noise introduced by the photoelectric cell and amplifier tubes.
(5) The cumulative effect of ripple voltage from the components of the system.

The gain of the amplifiers must be considered because the hum introduced in the photoelectric cell and amplifier from excessive ripple voltage in the exciter lamp will be increased in the same proportion as the reproduced speech. In making the tests to determine the allowable ripple voltage in the exciter lamp circuit, it will be noticed that the presence of film in the projector reduces the hum originating in the exciter lamp. However, the hum introduced from the exciter lamp will always be fixed with reference to the sound introduced by the sound track on the film, and for that reason it is preferable, when determining ripple voltage limits for the exciter lamp, to make these tests without film in the aperture.

In systems having amplifier tubes with filamentary cathodes that must be energized by the power unit, the hum introduced in the photoelectric cell amplifier will be constant but will be increased with the reproduced signal in direct proportion. In addition, where filament current is used for obtaining the *C* bias, the ripple voltage in the filament supply will directly excite the grids. This necessitates a filament current extremely free from ripple if annoying hum is to be kept out of the system.

The hum introduced in an amplifier* supplied with filament current from the power unit, where the amplifier is located in the system after the volume control, will be introduced into the system at a constant level for all gain settings.

In determining, therefore, whether a certain ripple voltage in the exciter lamp and the amplifier filament circuits is satisfactory, it is advisable to increase the gain of the system until the loud speaker is being energized at a maximum with no film in the aperture.

Having established a satisfactory ratio of hum to signal level by the original test on one loud speaker, this permissible voltage can then be applied to the system regardless of the number of speakers operating; and, although the volume of the sound will be increased to meet the requirements of a larger auditorium, the amplitude of the hum in the system will not increase appreciably with relation to the signal.

Should the sound system have a relatively low response at 120 cycles, it must be taken into consideration at the time the power unit is being designed, as otherwise future modifications, either in the amplifiers or loud speakers, that will improve the response may also raise the hum to an objectionable level.

The effect of system noise introduced by the photoelectric cell and amplifier tubes was very considerably masked in the earlier systems of recording, as the noise inherent in the recording itself was relatively high. This ground noise also has a masking effect on hum introduced into the system by the ripple voltage from a power supply unit. This must be considered at the time the tests are made to decide the ripple voltage limits, for, in the event that these amplifier and photoelectric cell noises are subsequently reduced by improving the system, a hum that was previously completely masked may become annoying during the quiet sequences of the film.

This will be particularly noticeable with films made by the "noiseless recording" process. With the introduction of films of this type, amplifier noises become conspicuous in the silent portion of the film and in the portions of the film reproducing speech at low level.

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* Referred to as *system amplifier* throughout this paper.

This necessitates improving the amplifier and photoelectric cell circuits and thus reducing the masking effect of these noises.

The cumulative effect of ripple voltage arising in the components of the system must also be considered in designing a power unit. For example, while a hum originating in the exciter lamp, amplifier, or loud speaker may be below audibility when considered by itself, the several hums may be additive, reaching an undesirable total value. This necessitates keeping the allowable ripple voltage of each circuit below that actually necessary so that the total hum in the system will still be within the ratio of noise to signal considered satisfactory for present-day sound systems.

Permissible ripple voltage for a loud speaker field will vary depending upon the particular type of loud speaker used and also upon the method of connecting units in the circuit. The hum introduced by excitation of the loud speaker fields will be constant for any particular method of connection, regardless of the gain of the system. The ripple current in the loud speakers may be affected by changing the field coil connections from parallel to series. It is desirable where possible to connect the fields in series, thus distributing the total ripple voltage of the power unit over two or more fields. This will reduce the ripple voltage on each loud speaker unit in proportion to the number connected in series.

Incorrectly poled speech coils may also cause an increase of hum. When correctly poled for speech, the speakers are correctly poled for minimum hum, as the ripple voltage in one speech coil opposes the ripple voltage in one of the other speech coils, and no current flows. When incorrectly poled, the voltages of the coils of one polarity add to those of opposite polarity, and 120-cycle current flows, resulting in motion of the loud speaker diaphragms.

The circuits operating the signal lights and relays in sound systems designed for battery operation are usually so wired that unfiltered direct current can not be applied to them without introducing hum into the system. For that reason it has been found necessary to filter this circuit not only to prevent inductive interference with the sound system but also to prevent chatter of relay armatures.

LOAD REGULATION

The second major consideration in design is that of load regulation. By load regulation of a rectifier power supply unit is meant the effect on voltage supplied to any part of the sound system of load changes made either purposely or accidentally on other parts of the system operated by the same source of power. This problem is practically non-existent with a lead storage battery, since the terminal voltage variation over the current range required in sound reproducing equipment is so slight that it can be neglected. However, both rectifier and filter circuits have certain regulation characteristics, giving rise to voltage variations under a changing load that must be given careful consideration. For example, in actual operation the exciter lamp is frequently turned on or off, thus changing the load borne by the system by approximately four amperes. When

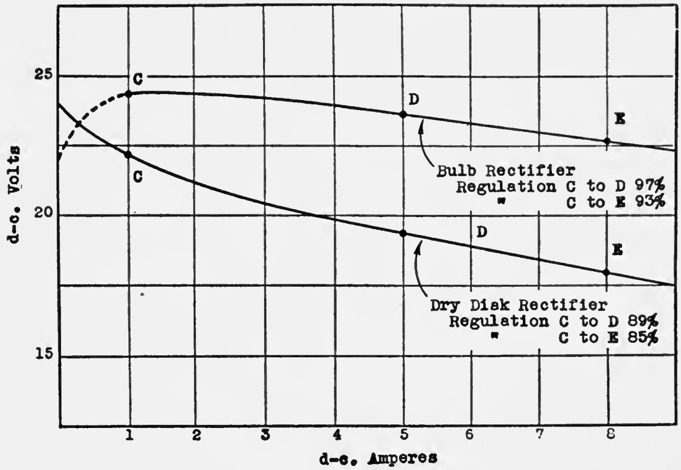

FIG. 1. Load regulation curves of rectifiers.

this occurs, it must not interfere with the satisfactory operation of the other parts of the system operated by the same power unit.

To determine the permissible limits of such load changes, it is necessary to consider the circuits of all the sound systems with which rectifier power supply is to be used. In some cases, minor changes in switching or circuits must be made to adapt the system to the load regulation characteristics of the power unit. Where such modifications are deemed inadvisable from an engineering, operating, or economic standpoint, the power unit must be designed to meet the requirements of the sound system. Unless a careful analysis is first made of all systems with which the power unit is to be used, it is impossible to design a unit that can safely be used in the field with the assurance that it will give the service expected.

To determine load regulation characteristics of a rectifier unit, it is necessary first to determine the load regulation of the rectifier, and then that of the filter required. Fig. 1 shows load regulation curves of the two principal types of rectifiers, bulb and dry disk. These curves were made with the rectifiers connected for full-wave rectification.

In this illustration it will be seen that the regulation of both the bulb and dry disk rectifier is shown at considerably higher voltages than required for operation of sound equipment. The reason is that this voltage is approximately that required in actual operation in order to allow for the voltage drop in the filter. The regulation

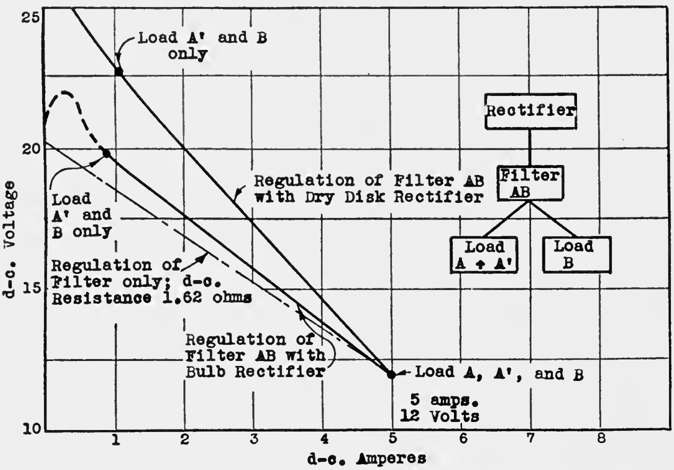

FIG. 2. Load regulation of parallel loads on the same filter.

curves, however, are almost identical in form over a voltage range of ten to thirty volts.

For comparison, the regulation is considered from one to five and from one to eight amperes, as these are the load ranges employed in the rectifier power supply units described later in this paper. As shown, the regulation of a standard dry disk rectifier that was tested is 89 per cent over the range of one to five amperes, and 85 per cent from one to eight amperes. This is to be expected, as the dry disk rectifier behaves practically as a simple ohmic resistance in the circuit.

The load regulation curve of the bulb rectifier is interesting, as it shows poor regulation and an unstable condition between zero and one ampere, but very good regulation from one ampere to practically full load. This curve was made using two standard 6-ampere, 125-volt, argon gas commercial rectifier bulbs connected for full-wave rectification, and shows a regulation of 97 per cent for 5 amperes and 93 per cent for 8 amperes' total d-c. load. Tests made on a large number of similar bulbs indicate that the load regulation characteristics of the commercial run of bulbs of this type are uniform within satisfactory limits. In making these curves, allowances were made for the regulation of the transformer, which, however, by proper design can be kept at approximately 99 per cent over the range of load required, and hence will not affect materially the figures given.

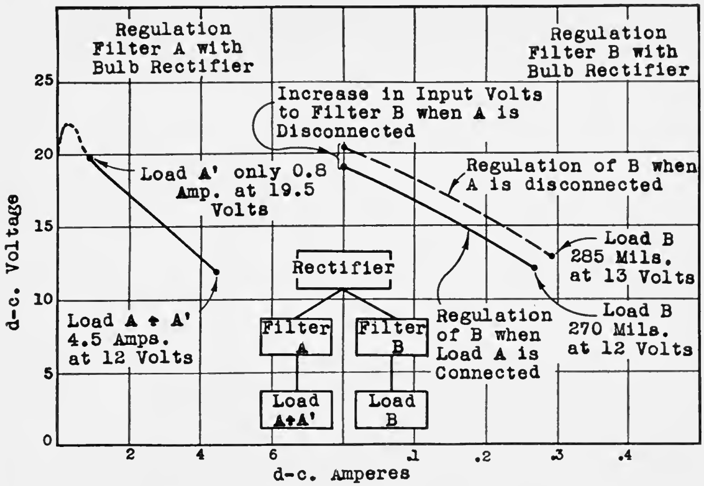

FIG. 3. Load regulation of parallel filters and loads on a bulb rectifier.

Fig. 2 shows the output characteristics of bulb and dry disk rectifiers used with a filter circuit. This filter is used in the exciter lamp circuit of the rectifier power supply unit later described. With this circuit arrangement, changes in one of the parallel loads will have a very great effect on the voltage applied to the other load as shown.

For the purpose of illustration, load *A* may be considered the exciter lamp, which draws about four amperes. Load *A′* is a fixed resistance, drawing approximately 0.5 ampere at 12 volts (the purpose of this fixed load will be explained later); and load *B* is the photoelectric cell amplifier filaments, drawing about 270 milliamperes. If these two circuits are connected in parallel with a bulb rectifier and filter, the operation will be satisfactory, provided there is no possibility of disconnecting load *A* without disconnecting load *B* at the same time. This can occur if the exciter lamp burns out, in which case the voltage on *B* will rise to 19.5 volts. This is beyond the safe voltage limits of the amplifier tubes. With a dry disk rectifier on the same filter, under these conditions a slightly higher voltage will be reached on load *B* as shown in the curves.

Variations Fixed over Operating Period, Adjustable at Time of Installation or Bulb Replacement

		Plus Variation (Volts)	Minus Variation (Volts)
(*a*)	Transformer voltage ratio (±2%)	0.6	0.6
(*b*)	Circuit resistance (±5%)	0.5	0.5
(*c*)	Rectifier characteristics	0.8	0.8
	Variation from average	+1.9	−1.9
	Total variation	3.8 volts	

Variations Changing during Operating Period, Adjustable by Equipment Rheostats

		Plus Variation (Volts)	Minus Variation (Volts)
(*a*)	Ambient temperature (32° F. to 110° F.)	0	1.6
(*b*)	Temperature rise	0	2.1
(*c*)	Line voltage variation (±5 volts)	1.3	1.3
	Variation from average	+1.3	−5.0
	Total variation		6.3 volts

FIG. 4. Causes of voltage variation in output of 4-ampere exciter lamp filter.

Because of the inherently poor load regulation characteristic of the filter, connecting various loads in parallel to the same filter must be avoided, unless the conditions are such that, should any one load be disconnected, the entire circuit will be opened or readjusted.

In Fig. 3 is shown another arrangement for parallel operation, but in this case separate filters are used to supply each part of the circuit operating from a bulb rectifier. This arrangement is advantageous, for in many cases load *A* will require a comparatively small amount of smoothing, while load *B* will require a large amount. It is considered impracticable to attempt to filter the four amperes required by the exciter lamp to the ripple voltage required by the photoelectric cell amplifier filaments. By using separate filters, the requirements of each circuit are more easily fulfilled.

With this circuit arrangement, changes in the load on one of the parallel filter circuits will affect the load on the other filter circuits only in proportion to the changes in the regulation of the rectifier unit itself. The regulation of two parallel filter circuits is shown in the illustration.

Load *A*, consisting of an exciter lamp and a fixed load resistance, *A'*, draws about $4^1/_2$ amperes, and *B* draws about 270 milliamperes.

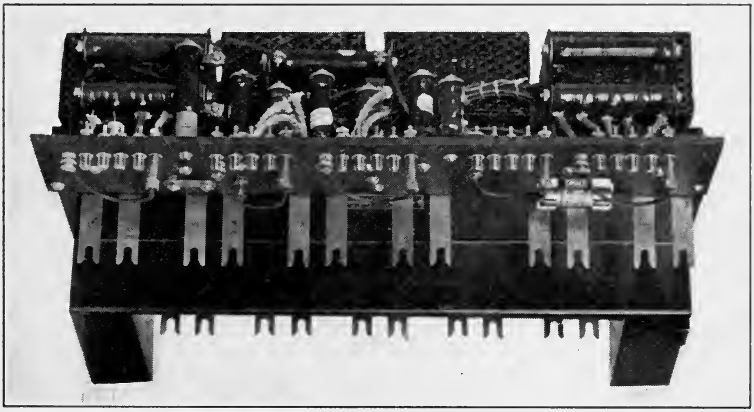

FIG. 5. Output voltage control resistances of a rectifier power supply unit.

If *A* be disconnected, the voltage output of the rectifier increases approximately 5 per cent, increasing the voltage of *B* to 13, and increasing the current in that circuit from 270 to 285 milliamperes. This variation is within safe limits for the amplifier tube filaments and is considered satisfactory. Because of the instability of the bulb rectifier at low loads, it has been found desirable to use a fixed resistance load across the output of the filter. This load should be such as to place a minimum load on the rectifier of one ampere (one-half ampere per rectifier bulb) under low load operating conditions.

A dry disk rectifier, due to its regulation characteristic, is not satisfactory for parallel operation of filters. Separate rectifiers and filters must be provided for each load circuit in order to maintain the required regulation. An alternative method can be employed, consisting in using relays and dummy resistances.

Due to the inherently good regulation of the bulb rectifier, in practically all cases it is not necessary to provide for the possibility of disconnecting certain portions of the load from the filters, although in a few instances it may be desirable to use a compensating relay, one example of which is described later.

OUTPUT VOLTAGE REQUIREMENTS

The third major design consideration concerns the output voltage. There are naturally many more factors influencing the output voltage of a rectifier power supply unit than of batteries. In sound equipment designed particularly for power unit operation it is pos-

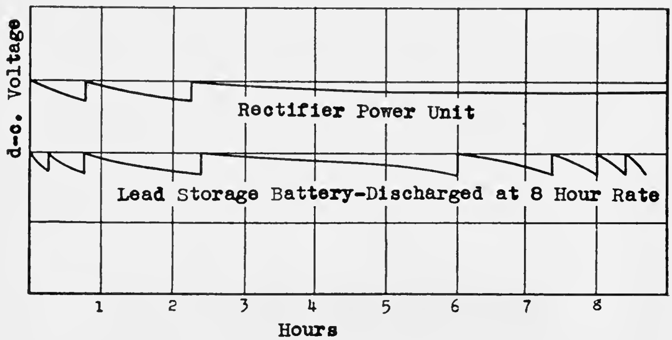

FIG. 6. Curves showing number of exciter lamp resistance readjustments necessary to maintain the exciter lamp current within satisfactory limits.

sible to incorporate rheostats having a sufficiently wide range to cover the possible voltage variations. In existing equipment, however, it is not always practicable to increase the range of the rheostats, and more attention must be given to the design of the power units as regards their output voltage limits.

Fig. 4 shows the factors influencing the voltage output of a rectifier power supply unit. As shown in the table, if the possible voltage variations add together they would total 8.8 volts as compared with a total variation of 3 volts in the terminal voltage of batteries. Of the total variation, that part due to the transformer, bulbs, and circuit resistance amounts to 3.8 volts. Correction for this can be made at the time of installation by incorporating adjustable resistances in the output circuits. The other variations must be covered by the equipment rheostats. In most cases the rheostats will have enough range to compensate for all possible fluctuations, provided that the power unit output circuits are adjusted at time of installation. The rheostats are adjusted to the predetermined value that experience has demonstrated will allow ample range of adjustment for both plus and minus variations.

Fig. 5 shows the output voltage control resistances of a rectifier power supply unit having five separate filter circuits with adjust-

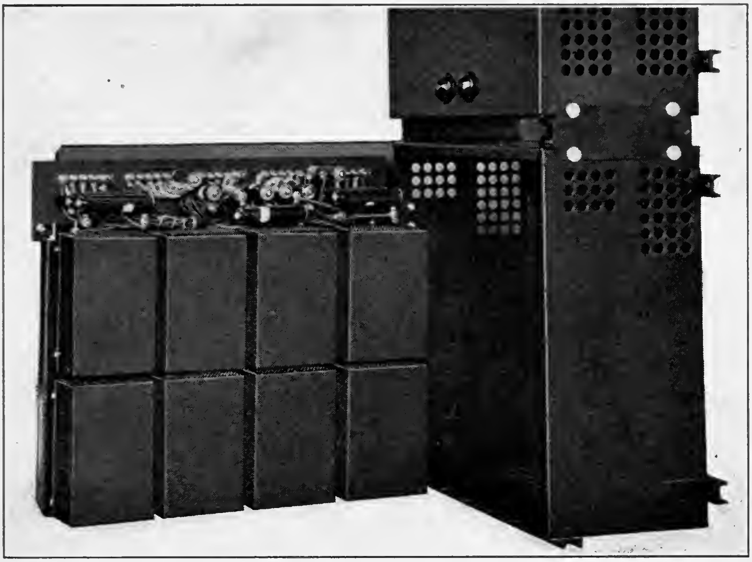

FIG. 7. View of lower section showing shielding.

ments. Tapped resistances are used rather than rheostats, as proper adjustment may be made at the time of installation.

Power supply units using a dry disk rectifier require adjusting resistances of somewhat larger range to compensate for aging. An alternative is to provide taps on the secondaries of the transformer that supplies the power for the rectifiers.

The resistance of the filter system should be made as low as possible, as otherwise the change in d-c. resistance of the filters, due to heating during operation, may be sufficient to cause a variation of output voltage beyond the range of the equipment rheostats, and thereby necessitate their constant readjustment while operating. If properly designed, they need be adjusted only once or twice during the first two hours of use, and perhaps once again when the temperature reaches a constant value. Fig. 6 shows the voltage output of a rectifier current supply unit, indicating the readjustment of the exciter lamp rheostat found to be necessary under average conditions during an eight-hour operating period.

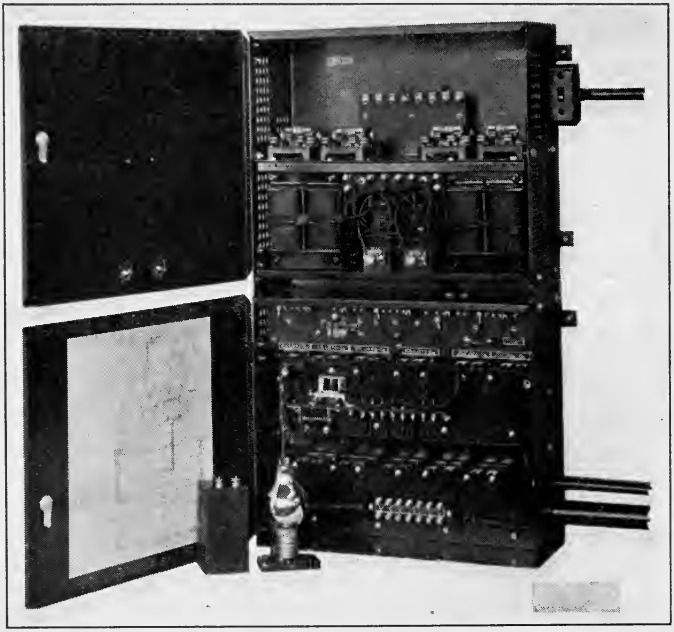

FIG. 8. Inside view of two-projector power unit showing reactances and relay.

LOAD REGULATION REQUIREMENTS OF A TYPICAL SOUND SYSTEM

The load voltage regulation must be good enough to permit the correct volume level to be maintained, to prevent burning out the vacuum tube filaments, and to avoid overloading or distortion in the amplifiers. The point in the circuit at which it is most important that proper voltage be maintained is at the exciter lamp. Any change of current in the lamp, however slight, is greatly amplified in its effect on the volume level of the system. The voltage applied to the amplifier filaments, while of less importance, must be maintained well within 5 per cent of normal voltage.

SHIELDING

In grouping rectifiers and filters in one compartment it is necessary to consider carefully the inductive effects of the reactances, both internal and external to the power unit. When a filter circuit in a power unit is connected or disconnected, a powerful magnetic field is set up about the reactances, which may cause a disturbance either in other filter circuits or directly in the sound system amplifier

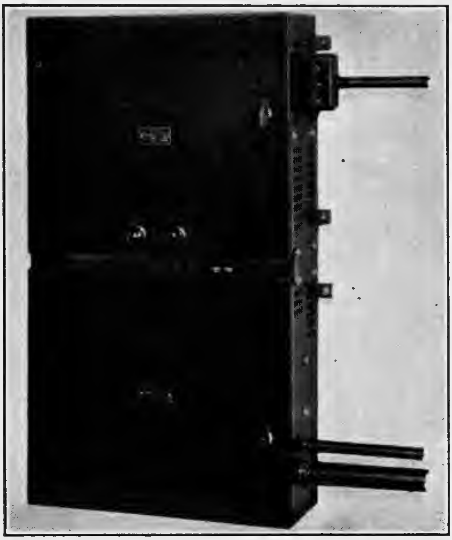

FIG. 9. Two-projector power unit mounted on wall.

circuits. To eliminate interference all reactances must be magnetically shielded. Fig. 7 shows the method used in mounting and shielding the reactances of the amplifier filament and signal current supply circuits, which eliminated all troublesome inductive effects. The sound system will also be completely free from clicks or disturbing noises when the output circuits of the filters are correctly wired for satisfactorily low rectifier hum.

INSTALLATION

The power unit shown has been designed to be mounted on the wall, and is of minimum practical width and depth to take best advantage of the space available in or near the projection room of the theater. The large unit is divided into upper and lower sections to facilitate mounting and handling in the theater. As it is desirable that the leads be as short as possible, it is best to locate the power units in the projection room. The rectifier tubes are carefully protected against damage, and the outside temperature of the cases is kept within the requirements of projection room equipment.

It is often possible and practicable when making replacement installations to locate the power units where the batteries were formerly located, using the existing wires of the charging panels and adding only such wires as the installation requires. By locating the equipment in the projection room, the equipment is centralized, and is under the constant observation of the operator, the space outside the booth being left available for other purposes.

To facilitate installation and to minimize wall space required, it is desirable to combine a number of the rectifier and filter circuits. To do this, a single unit was made, which includes circuits for two exciter lamps and associated amplifiers. An inside view of such a power unit is shown in Fig. 8. Fig. 9 is an outside view of this unit mounted on the wall.

THE LITERATURE OF THE MOTION PICTURE INDUSTRY*

G. E. MATTHEWS**

Summary.—*Information concerning the motion picture industry is published in a great many different journals issued by various societies and companies in this country and abroad. This information has been classified into two divisions, according as it pertains to the professional or to the amateur. Publications relating to the former group have been subdivided into four classes: (1) general technical publications, (2) publications related to motion picture production, (3) publications pertaining to exhibition of motion pictures, and (4) miscellaneous publications. Amateur publications have been further classified in relation to the dealer and to the customer or user. Publications in each of these groups are listed, giving a brief digest, when possible, of the nature of the issue, the frequency of its appearance, the address of the publisher, and the annual subscription. A classified bibliography of books on engineering and business aspects of the industry is included.*

Very few individuals have unlimited accessibility to the entire literature of an industry. The average person probably has access only to the trade journals, semi-technical publications, and books concerned with his own field. Much valuable information is gained from membership in various technical societies with the opportunity of examining regularly the publications of these organizations.

It would be folly to argue that every one engaged in an industry should read all the detailed published data concerned with his work. The tendency, unfortunately, lies in the other direction. Lack of knowledge of the nature of the literature, as well as a resulting inability to appraise the material and select the journals most pertinent to one's needs, may easily result in a failure to read enough of the literature to enable one to keep abreast of the times.

It is believed that an organized survey of the motion picture literature would be useful in that it would serve as a guide in selecting published information of interest to the reader. The writer has been in the favorable position for several years of having had, as part of his regular work, access to a large portion of the literature related to different branches of the motion picture industry. This article has

* Presented at the Spring, 1932, Meeting at Washington, D. C.

** Kodak Research Laboratories, Eastman Kodak Co., Rochester, N. Y.

been written in the hope that the digest may be of value to others.

CLASSIFICATION OF MOTION PICTURE PUBLICATIONS

The publications relating to the motion picture industry may be divided conveniently into two broad classes: namely, professional and amateur. The former class may be subdivided further but the latter, except for distinguishing dealers' journals from those pertaining to the customers, requires no further subdivision. A good many photographic publications of a general nature and a few professional publications include regularly a section devoted to the interests of the amateur. Examples are the *American Cinematographer* and the *British Journal of Photography.*

Perhaps the most effective classification of data related to the professional side of the industry is given in the semi-annual report of the Progress Committee of the Society of Motion Picture Engineers. This report divides the subject into three main divisions: namely, production, distribution, and exhibition. Besides these three divisions, the report also includes special divisions devoted to applied cinematography, color photography, amateur cinematography, and statistics. With the exception of amateur publications, there are no single journals devoted to these other classes and the information is recorded, as a rule, within other publications. Furthermore, distribution is so closely allied to exhibition that data on the former subject are usually found in publications devoted to the interests of the exhibitor. Broadly speaking, then, all professional trade literature may be said to consist of journals related to two fields, production and exhibition.

The strictly technical publications contain papers devoted to all branches of the field, including the amateur, but the number of such publications is limited. For purposes of discussion, the material will be presented under four headings: namely, I. General Technical Publications and Reference Works; II. Publications Related to Production; III. Publications Related to Exhibition; and IV. Miscellaneous Journals. The list is restricted to the technical, semi-technical, and industrial publications and does not include the popular or so-called "fan" publications. Few compilations of photographic periodicals are known, but the paper by Cummins* published in 1931 includes several motion picture publications and provides a useful source of reference.

* *Phot. J.*, **71** (NS), **55** (Apr., 1931). Sci. & Tech. Supp., p. 53.

Professional Motion Picture Publications

I. GENERAL TECHNICAL PUBLICATIONS AND REFERENCE WORKS

There is no single periodical devoted exclusively to abstracts of motion picture publications. There are, however, three publications issued at the present time that are devoted to abstracts dealing with photography, and many motion picture publications are covered by these journals. Patents related to cinematography are well covered in these journals. In a search of the literature, much time will be saved if reference is made first to these abstract journals. Reference to material published before 1915 will have to be made directly in the journals or in books issued before that date, as the abstracts do not date back earlier than 1915.

Monthly Abstract Bulletin.—Issued since 1915 by the Kodak Research Laboratories, Rochester, N. Y. Contains sections on photography, physics, chemistry, technology, and patents (including U. S., British, French, German, Canadian, and Australian). Distributed by Eastman Kodak Co., Rochester, N. Y.

Photographic Abstracts.—Issued quarterly since 1921 by the Royal Photographic Society, 35 Russell Square, London, England. All abstracts, including patent abstracts, are classified according to the Decimal Bibliographical Classification of the Institut International de Bibliographie (Brussels). For convenience of reference several general subheadings are included. 10s. per year, or sent free to members of the Scientific and Technical Group, Royal Photographic Society, 35 Russell Square, London, W. C. 1.

Science et Industries Photographiques.—Issued 1921–29 by P. Montel, 35 Blvd. S. Jacques, Paris; 1930—by Editions de la "Revue d'Optique Théorique et Instrumentale." In addition to the comprehensive classified abstract section (Decimal Bibliographical System, Brussels) this publication also contains original papers on photography and cinematography as well as trade notes and minutes of the meetings of the Société Française de Photographie et de Cinématographie. 60 fr. yr. (other countries 75–85 fr. yr.). 165 Rue de Sevres, 3 and 5 Blvd. Pasteur, Paris (15e), France.

Abstract sections containing papers referring to motion pictures may also be found in the following publications: *Journal of the Society of Motion Picture Engineers, Abstract Bulletin* (issued since April, 1930, by the Bausch & Lomb Optical Co., Rochester, N. Y.), *La Technique Cinématographique, Kinotechnik, Filmtechnik, Photo-*

graphische Industrie, Il Progresso Fotografico, El Progresso Fotografico.

A section of the American Chemical Society's abstract journal is devoted to photography. This section has been included since 1907 when the first volume appeared and motion picture references are given. Abstracts of papers on chemical aspects of photography may be found in this publication as well as in *British Chemical Abstracts, "A" Pure Chemistry* (issued by the Bureau of Chemical Abstracts) 3£ yr., 46 Finsbury Square, London, E. C. 2, *Transactions and Abstracts of the Journal of the Society of Chemical Industry* (*British*), 4£. 4s. yr., 46 Finsbury Square, London, E. C. 2, *Chemisches Centralblatt* (German), 200 R. M., Sigismundstr. 4, Berlin W. 10. Abstracts of papers on physical aspects of photography may be found in *Physikalische Berichte* (German), 100 R. M., F. Vieweg & Sohn, Akt.-Ges. in Braunschweig, and *Science Abstracts,* Sections A and B (British), 35s. yr. (U. S. A. $9 yr.). Spon & Chamberlin, 120 Liberty St., New York.

General technical publications devoted exclusively to motion pictures, arranged according to countries, are:

France

*La Technique Cinématographique.**—Technical articles, trade notes, and technical abstracts. Monthly. 40 francs yr. ($3 in U. S. A.). 24 Rue Petrelle, Paris (9e).

Germany

Die Kinotechnik.—Official publication of the Deutsche Kinotechnische Gesellschaft. Issued twice a month. Technical reports on original research and new equipment; society notes; abstracts of papers and patents. 16.2 R. M. yr. (18.6 R. M. in U. S. A.). G. Hackebeil, A.-G., Stahlschreiberstr. 33, Berlin S.14.

Italy

Revista Italiana di Cinetecnica.—Monthly. Technical papers related to production and exhibition; practical articles; news notes; short amateur cine section. 20 lira yr. via Viminale, 38, Rome.

United States

Journal of the Society of Motion Picture Engineers.—Official publication of the Society of Motion Picture Engineers. Monthly. Previous to 1930, issued as Transactions of the Society of Motion Picture Engineers, first annually, then semi-annually, then quarterly since 1916. Technical reports and abstracts on

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* Abbreviations are not included for the various publications, since there is no official standard for cinematographic periodicals. Each abstract journal publishes annually its own list of abbreviations, which should be consulted by any one planning a search of the literature.

research and new apparatus related to motion picture engineering in all branches of the industry. $12.00 annually to non-members: $9.00 to members (included in yearly dues). Editorial office: 33 West 42nd St., New York, N. Y.

The following publications occasionally contain technical articles of cinematographic interest:

France

Bulletin de la Société Française de Photographie et Cinématographie.—Official publication of the Société Française de Photographie, 51, Rue de Clichy, Paris (9e). Monthly. Technical articles; minutes of meetings; brief abstracts; new apparatus. 20 fr. yr. (U. S. A. 40 fr. yr). Gauthier-Villars et Cie. Quai des Grande Augustins 55, Paris (6e).

Revue Française de Photographie et de Cinématographie.—Twice monthly. Practical and technical articles; minutes of meetings; new apparatus; brief abstracts. 20 fr. yr. (U. S. A. 50 fr. yr.). 189 Rue S. Jacques, Paris (5e).

Science et Industries Photographiques.—Monthly. Technical papers related to photography and cinematography; technical notes and news; large abstract section covering articles and patents. 60 fr. yr. (other countries 75–85 fr. yr.). 165 Rue de Sevres, 3 and 5 Boulevard Pasteur, Paris (15e).

Germany

Photographische Industrie.—Weekly. Technical papers, notes, and news of general photographic and cinematographic interest; abstracts of articles and patents; minutes of meetings; tests reported on new apparatus and sensitive materials. 14 R. M. yr. (other countries 20 R. M. yr.). Union Deutsche Verlags Ges., Krausenstr. 35–36, Berlin, S. W. 19.

Physikalische Zeitschrift.—Twice monthly. Technical reports and original papers on research in physics, radio activity, and electronics; reports of German technical societies; abstracts and book reviews. 16.2 R. M. yr. (other countries 17 R. M. yr.). S. Hirzel, Leipzig.

Zeitschrift für Instrumentenkunde.—Monthly. Original papers on design and use of physical instruments; abstracts. 14 R. M. yr. Linkstr. 23–24, Berlin, W. 9.

Great Britain

British Journal of Photography.—Weekly since 1854. Practical and technical articles; new apparatus and patents; book reviews. Issue of first week of each month contains Color Photography Supplement. 17s. 4d. yr. United Kingdom and Canada (U. S. A. 19s. 6d. yr.). H. W. Greenwood & Co., 24 Wellington St., Strand, London, W. C. 2.

Journal of Scientific Instruments.—Monthly. Papers dealing with the science and manufacture of instruments for accurate measurement. 30s. yr. Cambridge University Press, Fetter Lane, London, E. C. 4.

The Photographic Journal.—Official publication of the Royal Photographic Society. Monthly. Articles devoted to all branches of photography; new apparatus; book reviews. 35s. yr. (free to members). 35 Russell Square, London, W. C. 1.

Transactions of the Optical Society.—Quarterly. Technical papers dealing with the theory and practice of optical science; new apparatus; book reviews. 1 Guinea. 1 Lowther Gardens, Exhibition Road, South Kensington, London, S. W. 7.

The following publications are not of direct motion picture interest but deserve mention:

Illuminating Engineer.—Monthly. Technical papers and trade notes on applications of various types of lighting; book reviews. 10s. 6d. yr. (foreign 15s. yr.). 32 Victoria St., London, S. W. 1.

Proceedings of the Physical Society.—Bi-monthly. Papers on aspects of fundamental physics. Reviews of books. 35s. yr. 1 Lowther Gardens, Exhibition Road, London, S. W. 7.

Television.—Monthly. Technical papers and trade news dealing with television; minutes of the Television Society (British); workshop hints; correspondence section; notes on new apparatus. 13s. 6d. yr. (U. S. A. $4.50 yr.). Benn Bros., Ltd., London, E. C. 4.

The Wireless Engineer and Experimental Wireless.—Monthly. Technical papers related to radio and wireless equipment; descriptions of new apparatus; abstracts and book reviews. 32s. yr. United Kingdom and abroad. 116–117 Fleet St., London, E. C. 4.

United States

None of the following publications are related directly to photography but each occasionally contains articles of interest in some phase of motion picture engineering.

Bell Laboratories Record.—Monthly. Official publication of Bell Laboratories. Abridgments of technical papers; business developments; news notes. Gratis. 463 West St., New York.

Bell System Technical Journal.—Quarterly. Official technical publication of the American Telephone and Telegraph Co. Technical papers dealing with the scientific and engineering aspects of electrical communication. $1.50 yr. 195 Broadway, New York.

Electronics.—Monthly. Radio, sound, and industrial application of electron tubes; their design and manufacture; new products and patents. $3.00 yr. 330 West 42nd St., New York.

Journal of the Acoustical Society of America.—Quarterly. Official publication of the Acoustical Society of America. Technical papers on all phases of acoustical problems; news and notes. $6.00 yr. (members $4.00 yr.). 919 N. Michigan Ave., Chicago, Ill.

Journal of the Franklin Institute.—Monthly. Official publication of the Franklin Institute. Technical papers on physics, engineering, and related sciences; abstracts; news and notes. $6.00 yr. (foreign postage additional). Franklin Institute, Philadelphia, Pa.

Journal of the Optical Society of America.—Monthly. Official publication of the Optical Society of America. Vols. 6 to 19, incl. (1922–29) combined with

Review of Scientific Instruments. Technical papers related to all branches of optics. Review of Scientific Instruments included as part of this journal until 1930. $4.00 yr. or $5.00 yr. including Review of Scientific Instruments. 450 Ahnaip St., Menasha, Wis.

Proceedings of the Institute of Radio Engineers.—Monthly. Official publication of the Institute of Radio Engineers. Technical papers and news notes related to radio engineering; patents and book reviews. $10.00 yr. to non-members. 33 West 39th St., New York.

Radio Engineering.—Monthly. Technical and practical articles; news notes; new equipment. $2.00 yr. ($3 in Canada and foreign countries). 19 East 47th St., New York.

The Review of Scientific Instruments.—Monthly since 1930. Previous to 1930 combined with Journal of the Optical Society of America. Papers on instruments of all kinds for research, instruction, and industrial purposes; abstracts. $4.00 yr. or $5.00, including Journal of the Optical Society of America. 450 Ahnaip St., Menasha, Wis.

Scientific American.—Monthly. Technical and practical articles on new developments in all branches of science and engineering; occasional notes relating to motion pictures. $4.00 yr. ($5.00 foreign). 24 West 40th St., New York.

Transactions of the Illuminating Engineering Society.—Monthly, except August and October. Technical papers and news notes; descriptions of new installations. $7.50 yr. 29 West 39th St., New York.

II. PUBLICATIONS RELATED TO PRODUCTION

There are only a limited number of publications devoted exclusively to production, although several exhibitors' journals are obviously of interest to the motion picture producer, the cameraman, and others in the production field.

Czechoslovakia

Studio.—Monthly. 6 Purkynlova ul. Prague. II.

France

Hebdo.—Production review of French studios. 50 fr. yr. (other countries 100 fr. yr.). 28 Boulevard St. Denis, Paris.

Germany

Filmtechnik.—Twice monthly. Official publication of several German and Austrian cameramen's and sound technicians' societies. Every other issue devoted to art in set design and pictorial composition. Remaining issues contain technical articles, descriptions of new apparatus, book reviews, and patent abstracts. 21 R. M. yr. Mühlweg 19, Halle.

United States

American Cinematographer.—Monthly. Official publication of the American Society of Cinematographers. Articles of technical and tutorial interest; new apparatus; amateur cine section. $3.00 yr. ($3.50 Canada, $4.00 abroad.) Suite 1222, Guaranty Bldg., Hollywood, Calif.

Bulletin of the Academy of Motion Picture Arts and Sciences.—Several issues a year. News notes on work of general and special committees of Academy. Distributed free to Academy members. 7046 Hollywood Blvd., Hollywood, Calif.

Cinema Crafts.—Monthly. Official publication of Local 666 of the International Photographers of the Motion Picture Industries. News notes related to cameramen and their work; brief technical section; special technical edition in May of each year. $1.50 yr. U. S. and Canada; $2.25 yr. abroad. Suite 306, 1029 S. Wabash Ave., Chicago, Ill.

International Photographer.—Monthly. Official bulletin of the International Photographers of the Motion Picture Industries, Local No. 659 of the International Alliance of Theatrical Stage Employees and Moving Picture Operators of the United States and Canada. Articles of technical and practical interest; accounts of cameramen's experiences in the field; reviews of current pictures and descriptions of new apparatus. $3.00 yr. 1605 N. Cahuenga Ave., Hollywood, Calif.

III. PUBLICATIONS RELATED TO EXHIBITION

More publications are devoted to motion picture exhibition than to any other phase of the industry. Two very comprehensive lists of these publications have been compiled: one dealing with American journals is included annually in the Year Book of Motion Pictures;* the other, covering European periodicals, was assembled by the Motion Picture Division of the U. S. Department of Commerce.** Many of the journals given below were selected from these lists. Details of composition were not available in many cases, but the publications are included for reference purposes. A comprehensive list of French motion picture trade publications is included in the *Annuaire Général de la Cinématographie.*† References are incomplete on motion picture publications in the Orient, South America, and Australia.

Argentina

Excelsior.—Weekly. Producers', distributors', and exhibitors' trade journal. Lavalle 921, Capital, Buenos Aires.

La Película.—Weekly. Producers', distributors', and exhibitors' trade publication. Lavalle 754, Capital, Buenos Aires.

Revista de Exhibidor.—Weekly. Producers', distributors', and exhibitors' trade periodical. Florida 32, Capital, Buenos Aires.

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* *Film Daily*, 1650 Broadway, New York, N. Y.

** Motion Picture Division, U. S. Department of Commerce, Paper No. 36-T, Nov. 7, 1930.

† Published by *Ciné Magazine*, 3 Rue Rossini, Paris (9e), 1930–31.

Australia

Everyone's.—Weekly. A periodical devoted to the interests of the motion picture and theatrical industries. 102 Sussex St., Sydney.

The Film Weekly.—Trade news relating to exhibition. 198 Pitt St., Sydney.

Austria

Das Kinojournal.—Neubaugasse 25, Vienna VII.

Die Lichtspielbühne.—Official organ of the Society of German Theaters in C. S. R. Teichgasse 11, Aussig am Elbe.

Mein Film.—Canisiusgasse 8, Vienna VII.

Österreichischen Filmzeitung.—Neugbaugasse 36, Vienna VII.

Belgium

Bulletin de l'Association Cinématographique de Belgique.—Monthly. 109 Rue Verte, Brussels

Bulletin Belge Cinémat.—Fortnightly. 10 Place Rogier, Brussels.

Cinema.—16 Courte Rue de l'Hopital, Antwerp.

Cinema.—Weekly. 34 Rue de Marche aux Poulets, Brussels.

Film Revue.—Weekly. 16 Courte Rue de l'Hopital, Antwerp.

Revue Belge du Cinema.—Weekly. 64 Boulevard Emile Jacqmaine, Brussels.

Canada

Canadian Motion Picture Digest.—Weekly. News notes; reviews of current pictures. $5.00 yr. 259 Spadina Ave., Toronto.

Czechoslovakia

Cesky Filmovy Epravodaj (Czech Film Bulletin).—Weekly. Maceskuv Palac, Fochova tr., Prague XII.

Filmovy Kuryr (Film Courier).—Weekly. Palac Olympic Spalena ulice, Prague II.

Filmovy oficielne Organ Svazu Filmoveho obchodu a Prumyslu.—Monthly. Official film journal of the Association of the Motion Picture Trade and Industry. 31 Vodickova ul, Prague II.

Internationale Filmschau (International Film Review).—Monthly. Palais Lucerna, Vodickova ul, Prague II.

Die Lichtspielbühne (Motion Picture Theater).—Monthly. 11 Teichgasse Usti, N. 1.

Zpravodej Zemskeho Svzu Kinomajitelu v Cechach (Bulletin of the Association of Motion Picture Theater Owners of the Province of Bohemia).—Monthly. Palac Feniz, Vaclavske nam, Prague II.

Denmark

Biograf-Bladet.—Issued by the Joint Association of Danish Exhibitors. Twice monthly. Nygade 3, Copenhagen.

Estonia

Filmilcht.—Juninga 1, Tallin.

Film, Mood, Tauts.—Aia 19, Tartu.

France

Bulletin de la Chambre Syndicate Française de la Cinématographie.—Monthly. Official organ of the Film Board of Trade. 13 bis, Rue des Mathurins, Paris.

Ciné Export Journal.—Monthly. 66 Rue Caumartin, Paris.

Ciné Journal.—70 fr. yr. (other countries 100 fr. yr.). 30 Rue Bergere, Paris (9e).

Cinématographie Française.—Weekly. Trade news and notes; technical résumés; reviews of new pictures. 70 fr. yr. (U. S. A. 140 fr.). 19 Rue de la Cour-de-Noues, Paris (20e).

Ciné Magazine.—70 fr. yr. (other countries 100 fr. yr.). 3 Rue Rossini, Paris (9e).

Le Cineopse.—Monthly. Trade news and notes on studios, theaters, and educational uses of pictures. 30 fr. yr. (U. S. A. 55 fr.). 73 Boulevard de Grenelle, Paris (15e).

Ciné-Phono-Magazine.—Bi-monthly. 6 Rue Guenegand, Paris (6e).

Comedia.—Daily. 51 Rue St. Georges, Paris.

Le Courrier Cinématographique.—Weekly. 70 fr. yr. (other countries 100 fr. yr.). 28 Boulevard St. Denis, Paris.

L'Écran (Organ of French Exhibitors' Syndicate).—Weekly. 17 Rue Etienne Marcel, Paris.

Revue de L'Écran.—Monthly. 10 Cours du Vieux Port, Marseille.

La Semaine Cinématographique.—Weekly. 48 Boulevard Beaumarchais, Paris.

Finland

Elokuva.—21 issues per year. Hakasalmenkatu 1, Helsingfors.

Fama-Lattia.—Monthly. Sanduddsgatan 18, Helsingfors.

Filmiatta-Filmrevyd V.—Twice monthly. Henriksgatan 20, Helsingfors.

Germany

Der Film.—Weekly. 21 R. M. yr. (24 R. M. yr. foreign). Ritterstr. 71, Berlin.

Film Kurier.—Official organ of German Exhibitors' Association. Daily. $12.00 yr. Kothenerstr. 37, Berlin W. 9.

Kinematograph.—Issued since 1906. One of oldest periodicals devoted to cinematography. Daily and weekly. Ximmerstr. 35/41, Berlin, S. W. 68.

Die Linse.—Monthly. Review of photography and cinematography. Ximmerstr. 94, Berlin, S. W. 68.

Lichtbildbühne.—Daily and weekly. Trade notes; reviews of pictures. Friedrichstr. 225, Berlin, S. W. 48.

Reichsfilmblatt.—Stallschreiberstr. 34, Berlin, S. 14.

Suddettsche Filmzeitung.—Weekly. Pestalozzistr. 1, Munich 28.

Great Britain

Bioscope.—Weekly. News notes of studios and theaters; trade news; reviews of current pictures; brief technical section. 10s. 6d. (U. S. A. 30s.). Faraday House, 8–10 Charing Cross Road, London, W. C. 2.

Cinema News and Property Gazette.—Daily. 80–82 Wardour St., London, W. 1.

Cinematograph Times.—Official organ Cinematograph Exhibition Association of Great Britain. Weekly. Broadmead House, Panton St., London, S. W. 1.

Close Up.—Quarterly. Reviews chiefly pictures of high artistic merit. Contains articles by cameramen and directors. 26 Lichfield St., Charing Cross Road, London, W. C. 2.

Daily Film Renter & Moving Picture News.—Daily. 58 Marlborough St., London, W. 1.

Film Review.—Weekly. 72 Oxford St., London, W. 1.

Kinematograph Weekly.—News items of studios, theaters, and trade; reviews of current pictures and a short technical section; monthly supplement on theater design and construction. 30s. yr. (U. S. A., $12.00). 93 Long Acre, London, W. C. 2.

Today's Cinema.—Daily. 80–82 Wardour St., London, W. C. 1.

Hungary

Mozihet.—Weekly. (The Film Week.) Pannonia utca 9, Budapest V.

Italy

Il Cinematografico.—Fortnightly. Via Lazio 9, Rome.

Cinema Teatro.—Via in Arcione 71, Rome.

Cine Mondo.—Fortnightly. Via Principe Oddone 20, Turin.

Il Corriere Cinematografico.—Weekly. Via Pio Quinto, Turin.

L'Eco del Cinema.—Monthly. Via S. Antonio 8, Florence.

Kinema.—Weekly. Via Fratelli Bronzetti 1, Milan.

Kines.—Via Aurelians 39, Rome.

La Rivista Cinematografica.—Fortnightly. Via Ospedale 4 bix, Turin.

La Vita Cinematografica.—Monthly. Via Pio Quinto 17, Turin.

Japan

Kinema Jumpo.—Every 10 days. Taihei Bldg., Uchisaiwai-cho, Kojimachiku, Tokyo.

Kinema News.—Monthly. Takimichi Bldg., 611 Kanocho, Kobe.

Naigwai Eigwa Tsushin.—Daily. Exhibitors' publication. 26 Kitanoshiraume-cho, Kamikyo-ku, Kyoto.

Nippon Kogyo Tsushin.—Daily. Trade news of interest to exhibitors. 11 Shinsakana-machi, Kyobashiku, Tokyo.

Teikoku Eigwa Tsushin.—Daily. Trade periodical for exhibitors. 10 1-chome, Minaminabe-cho, Kyobashiku, Tokyo.

Netherlands

Cinema en Theater.—Douzastraat 1, Leiden.

Nieuw Weekblad voor de Cinematografie.—Weekly. Nieuwe Mostraat 24, The Hague.

New Zealand

New Zealand Theatre and Motion Picture Magazine.—Monthly. 98 Waipapa Rd., Hataitai, Wellington.

Norway

Film.—Oslo.
Filmen og Vi.—Oslo.
Vilmrevy.—Oslo.

Poland

Fino dla Wszystkich.—Twice monthly. Wierzbowa 7, Warsaw.
Kino i Teatre.—Twice monthly. Wspolna 54, Warsaw.

Portugal

Cinefilo.—Weekly. Trade news. Rua do Seculo, Lisbon.

Rumania

Cinema.—Twice monthly. Boulevard-dul Elisabeta 14, Bucharest.

Spain

Arte y Cinematografía.—Monthly. Trade news; reviews of pictures. 10 pesetas yr. (foreign 15 pesetas). Aragon 235, 3 Barcelona.
Biblioteca Films.—Valencia 234, Barcelona.
El Cine.—Seneca 9 y 11, Barcelona.
El Mundo Cinematografía.—Valencia 200, Barcelona.

Sweden

Biografbladet.—Monthly. Ostermalsgatan 23, Stockholm.
Film Journalen.—Monthly and quarterly. Ahlen Akerlunds Forlag, Stockholm.
Svensk Filmtidning.—Twice monthly. Jutas Backe 1, Stockholm.

Switzerland

Cinema Suisse.—Organ of the Swiss film renters. Twice monthly. Rue du Theatre, Montreaux.

Turkey

Sinema Gazetesi.—Weekly. Resimli Ay, Constantinople.

Union of Soviet Socialist Republics

Kino.—Weekly. Strastnaya Place 2/42, Moscow.

United States of America

For convenience in reference, the American publications are grouped according to their frequency of issue: daily, weekly, fortnightly, and monthly.

Daily Publications

Daily Screen World.—West Coast trade. Daily except Sunday and Monday. 6715 Sunset Blvd., Hollywood, Calif.

Film Daily.—Trade news of studios and theaters; reviews of current pictures; special Sunday issue containing brief technical section; foreign news notes;

descriptions of new apparatus. $10 yr. ($15 foreign) both including copy of Year Book. 1650 Broadway, New York.

Hollywood Reporter.—Daily except Sunday. Trade news; business notes; reviews of pictures. 1606 N. Highland Ave., Hollywood, Calif.

Motion Picture Daily.—Business transactions; news of studios and theaters; reviews of current pictures; short technical notes on new apparatus. $6 yr. 25 West 43rd St., New York.

Weekly Publications

Associated Publications.—This company publishes ten different weekly regional trade periodicals. Main office: Glover Bldg., Kansas City, Mo. Names of publications are: Exhibitors' Forum, Weekly Film Review, Film Trade Topics, Michigan Film Review, Motion Picture Digest, Motion Picture Times, Movie Age, New England Film News, Ohio Showman, Reel Journal.

Extra.—Trade notes of West Coast production and exhibition. 224 Guaranty Bldg., Hollywood, Calif.

Film Curb.—Regional trade notes. 309 West 49th St., New York.

Film Mercury.—National trade news of studios and laboratories. 6362 Hollywood Blvd., Hollywood, Calif.

Greater Amusements.—Regional trade news. Lumber Exchange Bldg., Minneapolis, Minn.

Here's How.—National trade news. 7046 Hollywood Blvd., Hollywood, Calif.

Harrison's Reports.—National trade news. 1440 Broadway, New York.

Hollywood Filmograph.—National trade news. Warner Theater Bldg., Hollywood, Calif.

Hollywood Herald.—Studio and exhibitors' trade news; reviews of pictures. $3 yr. Hollywood Herald, Ltd., 6305 Yucca St., Hollywood, Calif.

Inside Facts.—West Coast trade news. 800 Warner Bros.' Downtown Bldg., Los Angeles, Calif.

Motion Picture Herald.—News notes of all branches of the industry; market reports; box-office returns; brief technical notes, particularly on projection; reviews of current pictures; suggestions on picture exploitation. Special section issued monthly on theater construction and maintenance. $3 yr. 407 S. Dearborn St., Chicago, Ill.

Motion Picture Journal.—Regional trade news. $312^1/_2$ S. Harwood St., Dallas, Tex.

Motion Picture Record.—Regional trade news. 2319 Second Ave., Seattle, Wash.

Screen Press.—Semi-weekly national trade news. 156 East 42nd St., New York.

Monthly Publications (also Fortnightly)

Allied Exhibitor.—Trade news on theater business. 525 Union Trust Bldg., Washington, D. C.

Emanuel-Goodwin Publications.—This company publishes three trade periodicals bi-weekly. Main address: 219 N. Broad St., Philadelphia, Pa. The publications are: The Exhibitor, The National Exhibitor, The New York State Exhibitor.

International Projectionist.—Technical and practical articles on all aspects of projection; trade news; apparatus notes. $2 yr. 1 West 47th St., New York.

Motion Picture Projectionist.—Technical and practical articles on all aspects of projection; notes on new equipment and recent patents. $2 yr. 7 West 44th St., New York.

Ondas Sonoras.—Spanish edition of Sound Waves. (See below.)

Pacific Coast Independent Exhibitor Bulletin.—Twice monthly. Regional trade news. 622 Golden Gate Theater Bldg., San Francisco, Calif.

Sound Waves.—Semi-monthly. Technical and semi-technical articles and news notes. $2 yr. (foreign $2.50 yr.). 1040 N. Las Palmas Ave., Hollywood, Calif.

Projection Engineering.—Technical and practical articles on details of theater design and maintenance with particular emphasis on projection; notes on new equipment, including 16 mm. apparatus. $2 yr. ($3 foreign, including Canada). 52 Vanderbilt Ave., New York.

Theater Management.—Articles on engineering aspects of theaters; news notes, and descriptions of new equipment. $2 yr. ($2.50 Canada; $3 foreign). 7 West 44th St., New York.

Publications Not Directly Related to Motion Pictures but Containing Some Trade News of Motion Picture Interest

The Billboard.—Weekly. News notes on vaudeville, drama, and motion pictures. 25 Opera Place. Cincinnati, O.

Variety.—Weekly. National trade news related to vaudeville, motion pictures, and drama. 154 West 46th St., New York.

Zit's Theatrical Newspaper.—Weekly. Semi-trade news about films, vaudeville, and drama. 755 Seventh Ave., New York.

Wid's Trade Weekly.—News notes on drama, vaudeville, and motion pictures. 420 Lexington Ave., New York.

IV. MISCELLANEOUS PUBLICATIONS

Most of the miscellaneous publications are devoted to uses of motion pictures in education. This program embraces not only the uses in schools but also in general education of the masses, as regards health, law, and government, *etc.*

France

Le Cineopse.—Monthly. Trade news and notes on studios, theaters, and educational uses of pictures. 30 fr. yr. (U. S. A., 55 fr.). 73 Boulevard de Grenelle, Paris (15e).

Germany

Der Bildwart.—Monthly. Data on school uses of films, slides, and pictures; reviews new films for educational purposes. Bochumerstr. 8a, Berlin N. W. 21.

Die Schulephotographie.—Monthly. Review for students and teachers using films for visual instruction. Zehlendorf, Weidmanusche Buchhandlung, Berlin, S. W. 68.

Italy

International Review of Educational Cinematography.—Monthly. Issued in five different languages. Official motion picture publication of the League of Nations' International Educational Cinematographic Institute. Articles on all phases of educational cinematography. 20 gold francs (Swiss), (U. S. A. $4). via Lazzaro, Spallanzani 1, Rome.

Japan

Ciné-Education.—Monthly. Papers on educational applications of motion pictures; reviews of new films. Osaka Mainichi Publishing Co., Ltd., Osaka and Tokyo.

Union of Soviet Socialist Republics

Proletarskaye Kine (Proletarian Cinema).—A review of the social, political, and scientific progress made by the Russian workers in the cinema industry. Tverskaya 35, Moscow 9.

United States of America

Educational Screen.—Monthly, except July and August. Reports on the uses of different visual aids in schools and colleges; news and notes on the cinema in education; appraisals of current pictures. $2 yr. (Canada $2.75; foreign $3). 64 East Lake St., Chicago.

The Motion Picture.—Monthly publication of the Motion Picture Producers and Distributors of America, Inc. Short articles and news on picture production and exhibition of interest to community clubs, schools, and other non-theatrical groups. Gratis. 28 W. 44th St., New York.

Amateur Motion Picture Publications

As previously noted, amateur ciné publications may be classified as to whether they are of interest to a dealer or to a customer.

I. AMATEUR CINÉ PUBLICATIONS FOR DEALERS

Only one publication is known which is devoted exclusively to the ciné amateur trade, namely:

The Ciné Kodak Salesman.—Published monthly by the Eastman Kodak Co., Rochester, N. Y.

The following publications contain items on amateur ciné equipment:

Agfa Ansco News.—Published monthly by the Agfa Ansco Corporation, Binghamton, N. Y. Also contains items on new professional motion picture products.

De Fotohandel.—Twice monthly. Issued by publishers of *Focus*. Deals chiefly with photographic and ciné apparatus. 2.5 florins N. V. Focus, Bloemendaal N. Holland.

The Photographic Dealer.—Monthly. 5s. yr. (U. S. A. $1.20 yr.). Sicilian House, Southampton Row, London, W. C. 1.

II. AMATEUR CINÉ PUBLICATIONS FOR CUSTOMERS

A. Publications Devoted Wholly to Amateur Cinematography

The Ciné Kodak News.—Bi-monthly, by Eastman Kodak Co., Rochester, N. Y.

Der Film-Amateur.—Organ of the Society of Film Amateurs. 4 R. M. yr. Krausenstr. 35–36, Berlin 809.

Film für Alle.—Monthly. Technical notes and hints on making better pictures. 2.25 R. M. yr. Friedrichstr. 46, Berlin S.W. 68.

Filmo Topics.—Monthly, by Bell & Howell Co., Chicago, Ill.

Home Movies and Home Talkies.—Monthly. Practical articles; new apparatus, news notes. 7s. 6d. yr. Geo. Newnes, Ltd., Southampton St., Strand, London, W.C. 2.

Kinoamateur.—Twice monthly. Organ of the Ciné Amateur clubs of Austria. 6 R. M. yr. Stallschreiberstr. 34–35, Berlin S.14.

Movie Makers.—Official organ of the Amateur Cinema League, Inc New York. Monthly. Practical and semitechnical articles; new apparatus book and picture reviews. $3 yr. (Canada $4; foreign $3.50, to members of League $2, in Canada $3). 105 West 40th St., New York.

The Screen.—Monthly. Society news; hints on play production; reviews of current pictures. 7s. yr. 37 Furnival St., London, E. C. 4.

B. Publications Containing a Section or Occasional Articles Related to Amateur Cinematography

France

Bulletin de la Société Française de Photographie et Cinématographie.—Monthly. 20 fr. yr. (U. S. A. 40 fr. yr.). Quai des Grande Augustins 55, Paris (6e).

La Photo pour tous.—Monthly. 40 fr. yr. (U. S. A. 60 fr. yr.). 39 Rue Lafayette, Paris (9e).

Photo Revue.—Twice monthly. 18 fr. yr. (U. S. A. 40 fr. yr.). 118 Rue d'Assas, Paris (6e).

Revue Française de Photographie et de Cinématographie.—Twice monthly. 20 fr. yr. (U. S. A. 50 fr. yr.). 189 Rue S. Jacques, Paris (5e).

Germany

Filmtechnik.—Twice monthly. 21 R. M. yr. Mühlweg 19, Halle.

Photographische Rundschau.—Twice monthly. 0.70 R. M. per issue. Mühlweg 19, Halle (S).

Great Britain

Amateur Photographer and Cinematographer.—Weekly. 17s. 4d. yr. United Kingdom and Canada (other countries 19s. 6d. yr.). Dorset House, Tudor St., London, E. C. 4.

British Journal of Photography.—Weekly. 17s. 4d. yr. United Kingdom and Canada (other countries 19s. 6d. yr.). H. Greenwood & Co., 24 Wellington St., Strand, London, W. C. 2.

Photographic Journal.—Monthly. 35 s. yr. (free to members of R. P. S.). 35 Russell Square, London, W. C. 1.

Ireland

The Camera.—Monthly. 7s. 6d. yr. Brit. Empire (U. S. A. $2). 2 Crow St., Dublin.

Italy

Il Corriere Fotografico.—Monthly. 30 L. (60 L. U. S. A.). via Stampatori N. 6, Turin.

Il Progresso Fotografico.—Monthly. 30 L. (60 L. U. S. A.). via Tullo Morgagni N. 2, Milan.

Netherlands

Focus.—Fortnightly. 10 florins yr. Bloemendaal N. Holland.

Lux de Camera.—Fortnightly. 10 florins yr. (other countries 12 florins). Warmoesstraat 147–151, Amsterdam.

Spain

El Progresso Fotografico.—Monthly. 15 pesetas Spain and America (other countries 25 pesetas). Apartado 678, Barcelona.

United States

American Cinematographer.—Monthly. \$3 yr. (\$3.50 in Canada; \$4 abroad). Suite 1222 Guaranty Bldg., Hollywood, Calif.

American Photography.—Monthly. With this is combined *Photo Era Magazine.* \$2.50 yr. (foreign \$3.50 yr.). 428 Newbury St., Boston, Mass.

Camera.—Monthly. \$2.50 U. S. A. and possessions (Canada \$3.25; countries in Pan-American Postal Union \$3.00; all other countries \$3.50). 636 Franklin Square, Philadelphia, Pa.

Camera Craft.—Monthly. \$2 yr. (Canada \$2.60; foreign \$2.50). Claus Spreckels Bldg., San Francisco, Calif.

Journal of the Society of Motion Picture Engineers.—Monthly. Occasional technical articles on amateur apparatus and applications of amateur ciné equipment. \$12 annually to non-members; \$9 to members. Editorial Office: 33 West 42nd St., New York, N. Y.

Photo Era. (See *American Photography.*)

Classified Bibliography of Books on Motion Pictures

Reviews of progress in the motion picture industry are published semi-annually by the Progress Committee of the Society of Motion Picture Engineers. These contain references to the major portion of the technical papers and patents issued relating to all branches of the industry. The annual review of photographic progress published by the Society of Chemical Industry (British) in their volume, *Reports of the Progress of Applied Chemistry,* contains many references to cinematography.

Abstracts of all papers published in the *Transactions* and in the JOURNAL OF THE SOCIETY OF MOTION PICTURE ENGINEERS from 1916 to June, 1930, are given in a volume entitled *Aims and Accomplishments of the Society of Motion Picture Engineers.*

The bibliography that follows is probably somewhat incomplete, but it represents a fairly comprehensive list of all books on cinematography. Books on television are not included, as it is not considered that this subject is a branch of cinematography.

HISTORICAL

Story of the Motion Picture by B. J. Lubschez. Short treatise. Reeland Publishing Co., New York, 1920.

Histoire du Cinématographe by M. Coissac. Gauthier-Villars, Paris, 1925.

Geschichte der Kinematographie by W. Dost. Short treatise. W. Knapp, Halle, 1925.

A Million and One Nights—The History of the Motion Picture, 2 Vols., by T. Ramsaye. Simon and Schuster, New York, 1926.

Illustrated Catalog of the Will Day Historical Collection of Cinematograph and Moving Picture Equipment by W. E. I. Day. London, 1930.

A History of the Movies by B. B. Hampton. Covici-Friede, New York, 1931.

Geschichte der Photographie (2 Parts). This is Vol. 1 of *Ausführliches Handbuch der Photographie,* edited by J. M. Eder. Several sections deal with cinematography. W. Knappe, Halle (S), 1932.

ANNUALS, GENERAL TEXTS, AND COMPILATIONS

Jahrbuch für Photographie by J. M. Eder. W. Knappe, Halle. Issued since 1887. Recent volumes include data on motion pictures.

Handbuch der Praktischen Kinematographie. Edited by F. P. Liesegang and G. Seeber. 4 Vols. Vol. 3, Pt. 1, has appeared. This volume is entitled *Die kinematographische Projektion* by H. Joachim. W. Knappe, Halle, 1928.

British Journal Photographic Almanac. Yearly since 1861. Contains data related to motion pictures, particularly amateur cinematography. H. Greenwood & Co., London.

American Annual of Photography. Yearly since 1887. American Photographic Publishing Co., Boston, Mass.

Kinematograph Year Book. Yearly since 1913. Kinematograph Publications, Ltd., London.

Year Book of Motion Pictures. Yearly since 1918. Film Daily, New York, N. Y.

Film Daily Directors' Annual and Production Guide. Issued since 1920. Film Daily, New York, N. Y.

Annuaire Général de la Cinematographie. Founded in 1922. Ciné Magazine, Paris (9e).

Motion Picture Almanac. Quigley Publications, Inc., Chicago, Ill.

American Cinematographic Annual. Yearly since 1930. American Cinematographer, Hollywood, Calif.

L'Annuario Generale della Cinematografia. A. C. I. E. P., Rome.

Soviet Photo Almanac. Edited by Soviet Photo, Ogonyok, Ltd., Moscow. Usually contains several technical articles of interest to motion picture technicians.

Proceedings of the International Congress of Photography. Issued about one year after the meeting. Usually contains several papers dealing with motion pictures. Information on the Congress may be obtained by addressing the Secretary, Royal Photographic Society, 35 Russell Square, London, W. C. 1.

Abridged Scientific Publications from the Kodak Research Laboratories. Issued annually. Each volume contains several papers on motion picture technology. 14 volumes published to 1931. Eastman Kodak Co., Rochester, N. Y.

Veröffentlichungen des Wissentschaftlichen Zentral-Laboratoriums der Photographischen Abteilung Agfa. Original papers from the Agfa Research Laboratory. Vol. 1 appeared in 1930. S. Hirzel, Leipzig.

Picture Ribbons by C. F. Jenkins, Washington, D. C., 1897.

Animated Pictures by C. F. Jenkins. H. L. McQueen, Washington, 1898.

La Photographie Animée by B. Matuszewski. Imprimerie Moizette & Co., Paris, 1898.

La Chronophotographie by L. Gastine. Gauthier-Villars, Paris, 1898.

La Photographie Animée by E. Trurat. Gauthier-Villars, Paris, 1899.

La Chronophotographie by J. Marey. Gauthier-Villars, Paris, 1899.

Animated Photography by C. M. Hepworth. 2nd Edit. Hazel, Watson & Viney, Ltd., London, 1900.

Le Cinématographie-Scientifique et Industriel, J. Ducom. Librairie des Sciences, Paris, 1911.

Kinematographie by H. Lehmann. Teubner, Leipzig, 1911.

Die Kinematographie by K. W. Wolf-Czapek. Union Deutsche Verlags, Berlin, 1908. 2nd Edit., 1911.

Der Kinematograph by C. Forch. Hartlebens Verlag, Leipzig, 1913.

Making the Movies by E. A. Dench. Macmillan Co., New York, 1915.

The Guide to Kinematography by C. N. Bennett. Heron & Co., London, 1918. Revision of *Handbook of Photography* published in 1911.

Handbuch der praktisches Kinematographie by F. P. Liesegang. E. Liesegang, Düsseldorf, 1912.

Conferences sur la Cinématographie by E. Kress. Comptoir d'Edition de "Cinema-Revue," Paris, 1912.

Practical Cinematography and Its Applications by F. A. Talbot. J. B. Lippincott Co., Philadelphia, Pa., 1913.

Motion Picture Work by D. S. Hulfish. Amer. Tech. Soc., Chicago, Ill., 1913.

Traite Practique de Cinematographie by E. Coustet. 2 Pts. Charles-Mendel, Paris, 1914.

Living Pictures by Henry V. Hopwood. Optician & Phot. Trades Review, London, 1899. 2nd Edit., The Hatton Press, London, 1915.

A-B-C of Motion Pictures by R. E. Welsh. Harper & Bros., New York, 1916.

How Motion Pictures Are Made by H. Croy. Harper & Bros., New York, 1916.

Wissenschaftliche Kinematographie by F. P. Liesegang. E. Liesegang, Düsseldorf, 1920.

The Film Industry by D. Boughley. I. Pitman & Sons, London, 1921.

The Cinema Handbook by A. C. Lescarboura. Scientific American Publishing Co., New York, 1921. Sampson, Low London, 1922.

Behind the Motion Picture Screen by A. C. Lescarboura. Scientific American Publishing Co., New York, 1919. 2nd Edit., 1921.

Moving Pictures—How They Are Made and Worked by F. A. Talbot. Lippincott Co., Philadelphia, Pa., 1912. 2nd Edit., rewritten 1923.

Der Film in der Technik by R. Thun. V. D. Verlag, G. m. b. h., Berlin, 1925.

The Public and the Motion Picture Industry by W. M. Seabury. Macmillan Co., New York, 1926.

Motion Picture Photography by C. L. Gregory, 1920. 2nd Edit. edited by H. C. McKay. Falk Publishing Co., New York, 1927.

The Story of the Films, edited by J. P. Kennedy. A. W. Shaw Co., New York, 1927. A series of lectures given by leaders of the film industry before students of the Harvard School of Business Administration.

La Technique Cinématographique by L. Lobel. Dunod et Pinat, Paris, 1912; Dunod, Paris, 2nd Edit., 1922; 3rd Edit., 1927.

The Handbook of Motion Picture Photography by H. C. McKay. Falk Publishing Co., New York, 1927.

Kine Handbook—Four Parts. Agfa, Berlin, 1929.

See and Hear by W. Hays. Motion Picture Producers & Distributors of America, Inc., New York, 1929.

La Cinematografia per Tutti by E. Cauda. A. C. I. E. P., Rome, 1931.

Bild und Film im Dienst der Technik by A. Kassally. W. Knapp, Halle, 1931.

Die Technologie des Films by D. M. Zolonitsky. Ukrtechstaatsverlag, Kharkov, 1931. (Printed in Russian.)

CAMERA WORK AND STUDIO TECHNIC

The Camera Man by F. A. Collins. Century Co., New York, 1916.

Animated Cartoons by E. G. Lutz. Chas. Scribner's Sons, New York, 1920.

Kinematograph Studio Technique by L. C. Macbean. I. Pitman, London, 1922.

Hilfsbuch für den Kameraman. W. Knappe, Halle, 1926.

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REPORT OF THE COMMITTEE ON STANDARDS AND NOMENCLATURE*

16-MM. SOUND FILM

In pursuing its work devoted to the recommendation of 16-mm. sound film dimensional standards, a sub-committee appointed for the purpose communicated with all of the manufacturers and individual research workers who were thought to be interested in the subject. Specifically, these persons were requested to submit their recommendations as regards the dimensions of the film and the location of the sound track. The recommendations thus received from those who were not officially represented on the sub-committee were included among the data that were considered at the several meetings.

In order to arrive at a decision in regard to a suitable layout, the following factors were considered:

(*a*) Ample tolerances between the sound track and the picture, and between the sound track and the sprocket holes, must be provided; (*b*) the film must have satisfactory life characteristics under operating conditions; (*c*) the quality of the picture must not suffer by reason of the addition of a sound track to the film; and (*d*) the dimensions should provide for the best possible sound reproduction, taking into consideration cost and production problems.

Discussion of these factors led to the conclusion that widths other than 16 millimeters should not be considered. The 16-mm. layout with one row of sprocket holes, as shown in Fig. 1, provides what are considered to be adequate margins on both sides of the sound track. The sound track scanning beam is 65 mils wide, affording what is considered to be an advantage over proposals requiring narrower tracks. The 16-mm. picture is not reduced in size but retains its standard frame dimensions, thus allowing film made according to this layout to be interchangeable with existing silent film, without requiring modification of projector and printing apertures.

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* Presented at the Spring, 1932, Meeting at Washington, D. C.

N. B.—Readers of the JOURNAL are invited to submit comments on this report to the General Office of the Society.

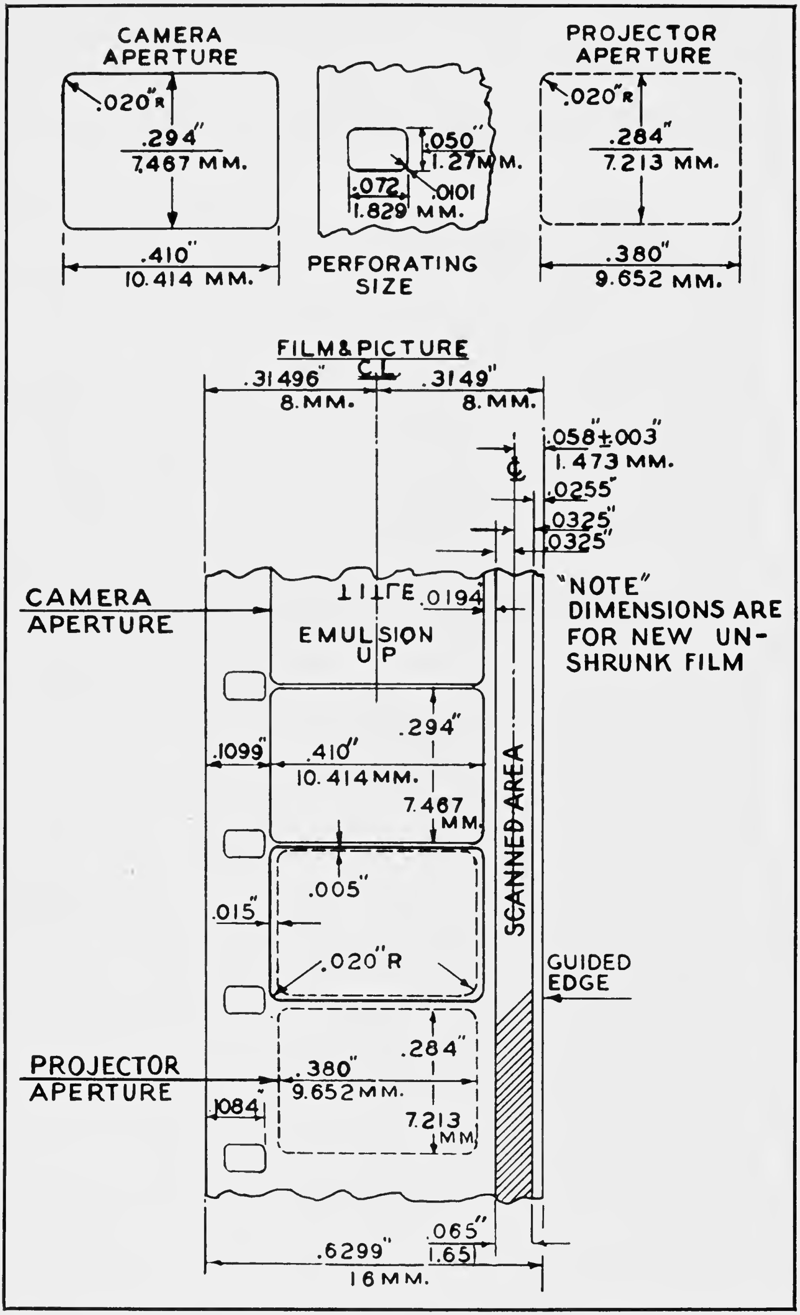

FIG. 1. Recommended standard, 16-mm. sound film.

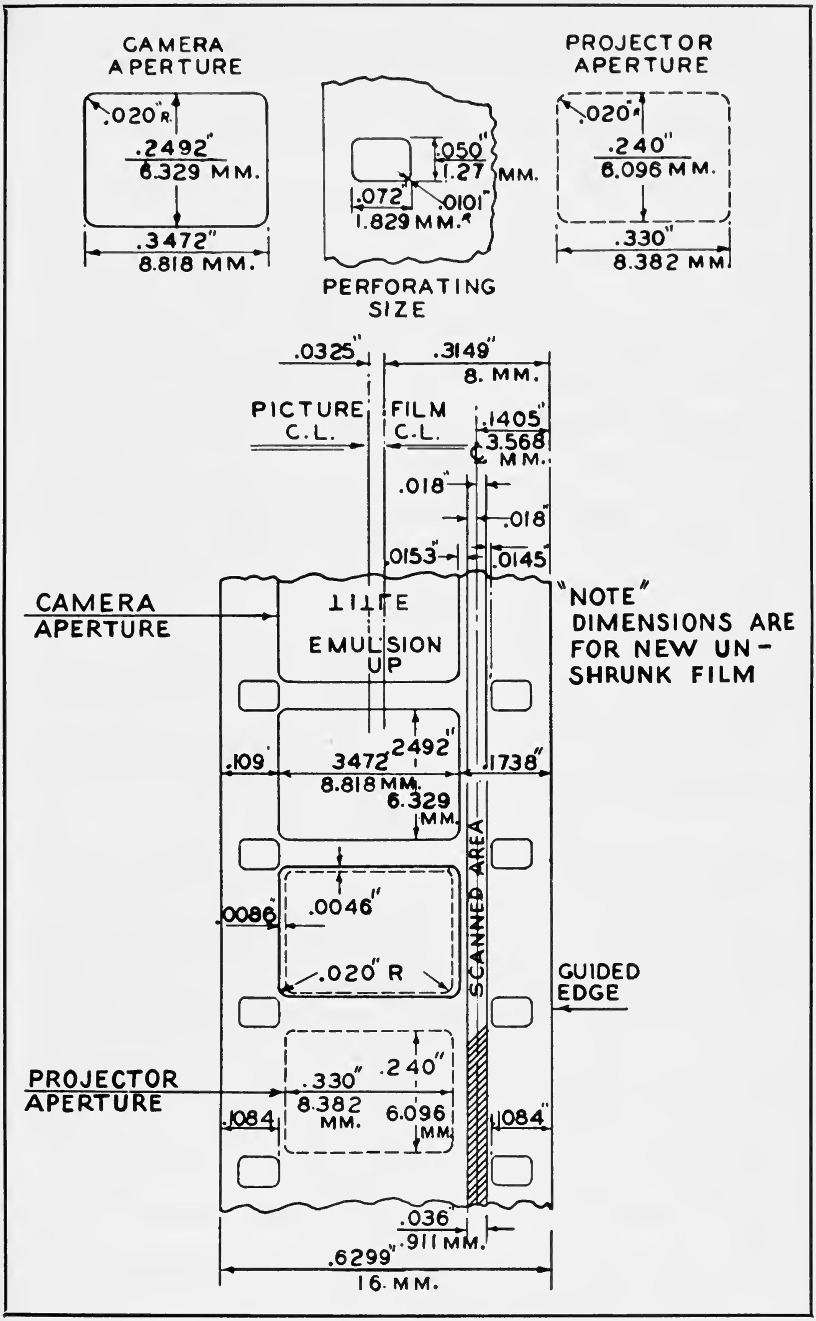

FIG. 2. Non-recommended specification, 16-mm. sound film.

The sub-committee concluded that the life of the 16-mm. film was not materially affected by using one row of sprocket holes instead of two. The use of one row of sprocket holes demands no sacrifice as regards the picture, does not shorten the useful life of the film, and provides the maximum possible space for the sound track. Sufficient experimental work has been done by several concerns to show that the problem of maintaining a uniform speed of the film during the reproduction of sound is not sensibly affected by using one row of sprocket perforations. After devising the two layouts shown in Fig. 1 and Fig. 2, the sub-committee on 16-mm. standardization passed the following motion, *viz.*,

That the plan involving one row of perforations be adopted as a recommended standard for 16-mm. sound on film, and that the plan involving two rows of perforations be published as a non-recommended specification.

The Standards Committee later reviewed in meeting the work of the sub-committee. At this meeting the importance of arriving at a definite standard was stressed by several members of the Committee. It was pointed out that in connection with 16-mm. sound on film, great consideration should be given to the matter of cost; and that one very important factor is the cost of sound prints. The Committee recommends the adoption of a 16-mm. layout as defined in the following motion:

That, in general characteristics, the plan (*as noted above*) recommended by the sub-committee involving a single row of perforations, as described in the minutes of the meeting of the sub-committee of February 8, 1932, be accepted; and that the recommendation of the sub-committee, described in the same minutes, of a film layout involving two rows of perforations, be accepted in its general characteristics as a non-recommended specification.

A discussion of the speed at which the sound film is to be run led to the adoption of the following motion:

That a speed of 24 frames per second be adopted as the standard speed of projection of 16-mm. sound film.

As regards the lead of the sound, the Committee felt that, while it is desirable to make it not less than 25 frames, disadvantages will arise from having too great a lead because of the increased length of time required to regain synchronism, when cut-outs are made in the film. A lead smaller than 25 frames would greatly limit the possibilities of designing suitable projection equipment. The following motion was passed:

That the lead of the sound gate in 16-mm. equipment be 25 frames.

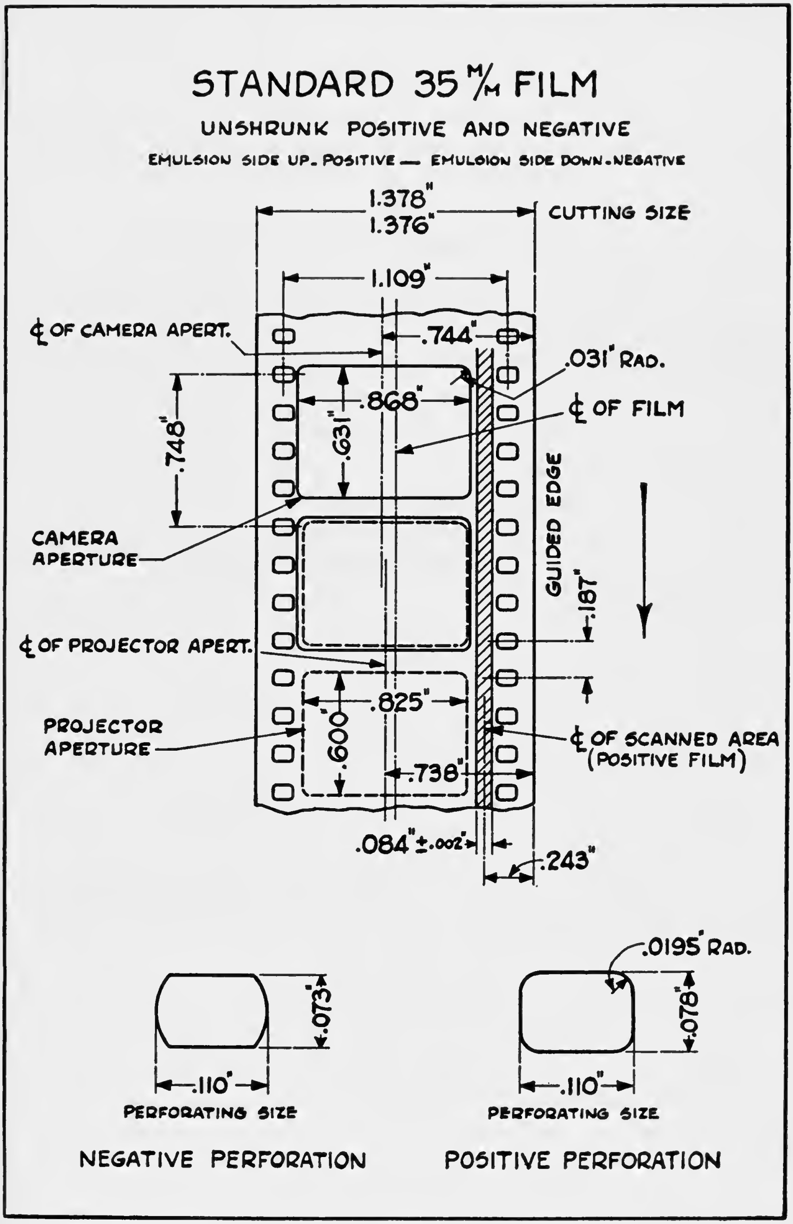

FIG. 3. Layout of 35-mm. sound film and apertures.

STANDARD APERTURES

The general circumstances attending the discussion on the dimensional apertures of projectors and cameras by the Academy of Motion Picture Arts and Sciences resulted in the following action by the S. M. P. E. Standards Committee:

That the dimensions 0.600 by 0.825 inch be recommended as dimensional standards for 35-mm. projector apertures; and that the dimensions 0.631 by 0.868 inch be recommended as dimensional standards for 35-mm. camera apertures.

The locations of these apertures with respect to the film are to be in accordance with Fig. 3.

SOUND SCREENS

By formal action the Standards Committee agreed that the data described on pages 445 to 447 of the September, 1931, JOURNAL relating to test procedure and tolerances of acoustical performance of screens be recommended as representing good practice in the specification and acceptance of screens. For convenience, this material is reprinted here, as follows:

Test.—It is the present practice to measure the sound transmission characteristics or response characteristics of each type of screen before approving it for use with sound projecting equipment. Although there are various methods by which these acoustical measurements may be made, the commonly used method involves response-frequency measurements of the output of a loud speaker with the screen placed before the speaker in its normal position, and with the screen removed. In order to adhere as closely as possible to actual field conditions in making these measurements, a loud speaker of the type used in the field should be employed. Since this method of test approximates closely the theater conditions and since it includes the effect of the diaphragm action of the screen, if present, it is probably the most desirable method of making the measurements. The response-measuring technic should conform to accepted loud speaker response-measuring methods.

Tolerances.—There are three factors which must be determined before a proper judgment of screen performance may be made. The general loudness attenuation effect, the frequency range for sound transmission, and the regularity of frequency response all enter into the determination of the suitability of a screen from the acoustical standpoint. In general, little trouble is experienced in obtaining efficient low-frequency response. Usually, however, screens exhibit a drooping characteristic at high frequencies. Since the droop at high frequencies is usually rather gradual, no definite frequency range may be assigned to the screen response; the allowable loss at certain high-frequency points relative to the 1000-cycle response should be specified. On the whole, it must be observed that it is difficult to set absolute limits for screen response, covering all possibilities. The following have been applied successfully to the great majority of cases by the two largest manufacturers of sound equipment:

A loss of 2.5 decibels, as given by the average response curve, at 6000 cycles, relative to the 1000-cycle response, is considered a desirable limiting value for existing types of sound equipment. Screens that meet this requirement are usually found to attenuate less than 4 decibels at 10,000 cycles. As to regularity of response, variations greater than ±2 decibels would not be tolerable. Because of standing wave effects in the measuring room, inaccuracies of measurement may occur, causing variations somewhat greater than this below 300 cycles. It is felt that no limits for regularity should apply below this frequency. The interpretation of measurements must be left to the discretion of one closely acquainted with the measuring conditions. A general attenuation in loudness, as judged from the measured screen transmission characteristic, greater than 1 decibel, is not considered tolerable. Although this limit may appear rather stringent, there are many screens available which meet this requirement. It seems advisable to maintain this high standard for sound transmission.

M. C. BATSEL, *Chairman*

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L. DE FOREST	R. C. HUBBARD	W. B. RAYTON
J. A. DUBRAY	L. A. JONES	C. N. REIFSTECK
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R. E. FARNHAM	D. MACKENZIE	T. E. SHEA
C. L. FARRAND	G. A. MITCHELL	J. W. SPENCE
H. GRIFFIN		E. I. SPONABLE

DISCUSSION

MR. PALMER: The most important feature in this report relates to 16-mm. sound film. The great majority of subjects are, of course, made on 35-mm. film, and the 16-mm. film must always look to the 35-mm. field for a large part of its supply of subjects. A standard that does not allow direct reduction from 35-mm. film to 16-mm. film seems very undesirable for that reason.

In connection with the 35-mm. film, we are all familiar with the various proposals that were made to change the standards when sound came in. We talked about a wider film, we talked about film with the sound track outside the sprocket holes, we talked about various changes in the perforations; but finally, after considering all these, we finally adhered to the old standard. It seems to me to be very wise to make the dimensions of 16-mm. sound film such that a direct optical reduction can be made from 35-mm. film.

Since the problem of providing a sound track on 35-mm. film was solved without changing the dimensional standard or the sprockets, there seems to me to be no good reason why the 16-mm. problem can not be solved in the same manner.

MR. BATSEL: All those points were discussed by the Standards Committee. So far as optical reduction is concerned, I believe it is agreed that the layout chosen by the Committee offers no greater handicap than the other. The suggestion that two rows of sprocket holes would be better required that the picture and sound track be both exposed through the same aperture simultaneously, and that was not considered practicable. Many persons felt that the proposal to omit one row of perforations involved fewer changes in existing equipment than any other proposal, inasmuch as it has been shown commercially that one row of perforations is adequate for pull-down. The change of aperture is avoided, as well as the confusion that arose in the 35-mm. field. Any existing film having two rows of perforations can be used in the machines, using one side for the sprockets.

MR. PALMER: I understand that the dimensions of the proposed sound track are such that it could not be printed by optical reduction from the standard 35-mm. sound track. In other words, its width is not in proportion to the reduction.

MR. EVANS: The 35-mm. sound track can not be printed optically on 16-mm. film having one row of sprocket holes unless a special lens system is used, having a cylindrical element, as different optical reductions are required in the horizontal and the vertical axes.

In the case of film having two rows of sprocket holes, a 16-mm. picture print can be made directly from a 35-mm. picture negative with a continuous printer. If the one row of sprocket holes is employed, this can not be done. It is necessary to make a dupe negative first. In a 35-mm. negative, due to the inclusion of the sound track, it was necessary to reduce the size of the picture on the negative, and consequently it does not fill the entire space on the film. In the case of the 16-mm. prints having a single row of sprocket holes, it is proposed to have a picture that will fill the entire space. Therefore, the 35-mm. picture must be "blown up" to fill the entire available space. If continuous printing is to be used, it is absolutely essential that a dupe negative be made of the picture before the 16-mm. print of the picture can be made. On the other hand, this is not necessary with the arrangement having two rows of sprocket holes. The original negative can be used directly in making the print. The use of dupe negatives is to be avoided wherever possible.

MR. KELLOGG: In the proposed alternative standard, in which the sound track is inside the sprocket holes, were the clearances, as used in 35-mm., reduced in a four-tenths to one ratio, as the picture and sound track?

MR. TASKER: They are not in exact proportions, as the Standards Committee adopted them. Sound and picture are normally printed separately. In consideration of this fact and the relatively greater width of 16-mm. film between sprocket holes, the diagram presented by the Standards Committee provides slightly larger clearance between sound track and picture than four-tenths of the 35-mm. clearance. The proposed clearance for 16-mm. film is 0.015 inch between scanning line and sprocket hole, and 0.015 inch between sprocket hole and picture frame.

DR. GOLDSMITH: If one be given a 35-mm. combined picture-and-sound negative, and have a printer that will print picture and sound in two successive steps (with a suitable optical system at each step) could combined prints be made of the dimensions of the recommended standard with single sprocket perforations without any further equipment?

MR. EVANS: Not if a continuous printer is to be used. If it is to be used, a dupe negative must first be made. This report of the Standards Committee carries in it the adoption of a new camera aperture of 0.631 by 0.868 inch. The available space on the film is 0.748 by 0.999. This explains why the picture must be "blown up" before a continuous optical printer can be used. In Fig. 2 there is a 60 per cent reduction of all dimensions; that is, the picture is 40 per cent of the 35-mm. dimensions. The border of 0.177 mil between frames is also reduced in the same proportion. The proportion is very close to four to three.

MR. CRABTREE: In Fig. 1 it is four to three also.

MR. EVANS: But the space has been changed; there is no separating space between frames. In 90 per cent of the cases, we have a separate negative for picture and sound track. The important thing here in this standard is the picture, not the sound track. The only way one can get Fig. 1 is by step printing, unless you first make a dupe negative by a step printer, and "blow up" the size of the frames.

MR. DEPUE: You speak of the negative. There is only one negative to be used at one time. What difference does it make whether you enlarge or reduce it? How do you make a reduction print from an original negative?

MR. EVANS: By continuous reduction printing—Fig. 2.

MR. TASKER: In making a combination reduction print of the type having two rows of sprocket holes, it is possible to print directly on a continuous printer from the original sound and picture negatives of a 35-mm. sound subject. Printing in this manner is similar to 35-mm. contact printing, in that sound and picture negatives may be successively used in the same printing head to print sound and picture tracks, respectively. The reduction printer, however, carries the 16-mm. raw stock in spaced relation to the negative with simple optical means between negative and positive films to produce a reduced image on the latter. Under these circumstances, every point in the 16-mm. image corresponds exactly in position within the frame to the corresponding point in the 35-mm. image. Accordingly, there will be a space between sucessive images in the 16-mm. print which corresponds to the space between images in the 35-mm. negative except that it is reduced four-tenths to one. Since the camera aperture just adopted by the Society provides a space of about 0.177 inch between images in the 35-mm. negative, proportionately wide spaces will appear in the 16-mm. negative when printed in this manner.

The only way to obtain a 16-mm. picture print in which minimum spaces appear between images is to make use of step printing, either by using of a step reduction printer from the 35-mm. negative to the 16-mm. positive, in which the reduction ratio is greater than four-tenths to one, or by obtaining a dupe negative by step printing, using an optical ratio greater than unity so that the images are blown up to fill the entire frame. Obviously, step printers are not adaptable to the printing of sound track, so that separate machines must be provided for this purpose. On the other hand, the making of a print such as that shown in Fig. 2, requires nothing more than the original negative and a single continuous reduction printing head.

DR. GOLDSMITH: There appear to be two ways of making single-sprocket-perforation prints of the recommended standard dimensions shown in Fig. 1. If the original negative is available, the picture can be produced by optical reduction step printing, and the sound can be produced by continuous reduction in printing through a suitable cylindrico-spherical lens system. If the original negative is not available, a duplicate negative can be made by similar processes (or by electrical re-recording of the sound) and thereafter the 16-mm. positive prints could be made with a single continuous contact printing operation. These appear to be the two ways of making prints corresponding to Fig. 1.

Mr. Evans: It is possible to use the original negative and print according to Fig. 1, by step printing.

Mr. Kellogg: As regards the unequal reduction of the sound track in the two directions, I am sure it is not difficult. It involves a different optical system with more lenses than would be used if the reductions were equal. As regards the picture, the whole question reduces to the merits of continuous printing *vs.* step printing. The reason why we have adhered to the re-recording plan is that it permits compensation for high-frequency losses, which always occur. I feel that it is the right way to get the best records, although a usable record undoubtedly may be made by direct optical reduction. Referring again to Fig. 2, it seems to me that the spaces between the pictures are considerably larger than in the 35-mm. film.

Mr. Carpenter: Fig. 2 is a direct reduction from the existing negative.

Mr. Kellogg: Is the picture proportion the same as it is in the 35-mm. film? Are not the clearances somewhat greater in proportion?

Mr. Tasker: In Fig. 2 the picture proportion is identical to that of the 35-mm. film, but in view of the fact that the two rows of sprocket holes in 16-mm. film are spaced relatively farther apart than in 35-mm. film, it has been proposed, as shown in Fig. 2, to use clearances between picture and sound track, and between sound track and sprocket holes, which are relatively greater than in 35-mm., and to use a scanning line slightly longer than four-tenths of the 35-mm. scanning line. The slight increase in scanning line length is intended to favor variable width recording, which, of course, suffers in quality if scanned with a light beam that is too short. With the dimensions shown in Fig. 2, the scanning line exceeds the width of the fully modulated variable width track by 8 mils, assuming a four-tenths to one reduction from the present standard 35-mm. track. This compares rather well with the 14-mil tolerance allowed in 35-mm. practice. At the same time, the position and length of the scanning line are such that satisfactory results would be obtained from the direct reduction printing of a combination negative made in the single film type of newsreel camera.

It should be pointed out that any of the production methods applicable to Fig. 1 may also be used in preparing film of the type shown in Fig. 2, while there are several special requirements for Fig. 1 which are by no means necessary for Fig. 2. It is impossible to produce a print of the form shown in Fig. 1 by printing in a single continuous reduction printer from the original 35-mm. sound and picture negatives of S. M. P. E. standard form. On the other hand, re-recording is just as feasible in preparing film of the type shown in Fig. 2 as in the case of Fig. 1, and we have prepared a number of film records by this process. It is likewise equally possible to apply contact printing from a master 16-mm. negative to either type of film, although there seems to be very little merit in such a procedure.

Dr. Goldsmith: It is of interest to compare the areas of the pictures in Fig. 1 and Fig. 2. In the case of the recommended standard (Fig. 1) the area of the picture is 0.380 by 0.284 inch, or approximately 0.108 square inch. In the case of the non-recommended specification (Fig. 2) the picture is considerably smaller and has an area corresponding to 0.330 by 0.240 inch, or 0.079 square inch. The area of the non-recommended standard is accordingly 27 per cent less than that of the recommended standard.

MR. JONES: It seems to me that in deciding what is to be done in the establishment of 16-mm. sound-on-film dimensional standards, we should consider present conditions and the dimensional characteristics of the 16-mm. silent film now in existence. Of course, this problem can be regarded from two distinct points of view: namely, that of the strictly home entertainment or amateur field, and that of the semi-commercial field. I shall speak largely from the standpoint of the purely amateur point of view.

There are in existence at the present time millions of feet of silent 16-mm. film. This has been accumulated by amateur cinematographers during the past ten years, and many individual or home libraries are in existence containing films of great value to the individuals. We must not penalize the owners of this 16-mm. silent film in putting out and offering for their purchase 16-mm. sound-on-film equipment that will not with perfect satisfaction be capable of projecting this silent film that they have accumulated and will continue to cherish for many years. It is highly desirable that we do not change the present dimensional characteristics of the 16-mm. picture and the proposal presented in Fig. 1 was formulated with this idea in mind.

In the amateur field, the first and most probable market for 16-mm. sound film projectors will be among those individuals who have become interested in amateur cinematography and who are at the present time owners of 16-mm. cameras, projectors, and individual film libraries of their own making. If we are to appeal to these individuals with a 16-mm. sound projector, it is absolutely essential that it shall be of such nature that the present 16-mm. silent film may be run thereon with a maximum of convenience and efficiency. Doubtless eventually equipment will be offered to the amateur cinematographer such that he can do sound recording simultaneously with the taking of pictures. At the present time, however, he has available of his own manufacture only silent film, and for many years this silent film will be of great interest to the amateur and a large percentage of home projection will be of silent film. For the present, at least, he will have to depend upon sources other than himself, for instance, film libraries, for sound film. It is inconceivable to me that he will not on almost all occasions when he wants to run sound film wish to run some of his own silent film. The sound-on-film positive should therefore be completely interchangeable with his present silent film, and the equipment that is offered to him should be capable of running with absolute interchangeability. The film shown in Fig. 1 meets these requirements. That shown in Fig. 2 meets these requirements only partially.

In Fig. 2 the picture area is about 35 per cent less than the area in Fig. 1. In order to obtain the same picture size with Fig. 2 it is necessary to use appreciably higher magnifications. This is undesirable. Even now the demand in the amateur field is for screens of larger size than those used in the past. This, coupled with a smaller picture area as shown in Fig. 2, means much greater magnification. Greater magnification means increased graininess in the projected picture with attendant loss in quality of the projected image. It means also that the film during projection is subjected to an appreciably increased amount of heat since, in order to obtain satisfactory screen illumination, the same amount of radiant flux must be forced through a smaller area of film, thus giving increased radiant flux density at the projector aperture.

In making release prints, according to the dimensions of Fig. 1, it is necessary only to work through a duplicate negative made from the 35-mm. standard picture negative. Results of perfectly satisfactory photographic quality can be obtained in this manner according to the well developed technics already being used for the reduction of 35-mm. to 16-mm. silent film. In my opinion the production of release prints according to the dimensions shown in Fig. 2 will also have to be made through duplicate negatives. It is inconceivable to me that the owners of valuable 35-mm. original negatives will permit them to be used for printing hundreds of copies of 16-mm. sound-on-film release print positives.

I think it is quite generally agreed among sound engineers that it is undesirable to use a sound track very much narrower than that used in the present 35-mm. film. It is well known that, as the sound track is made narrower, necessitating the use of a shorter scanning line, the ratio of ground noise to signal increases. In the amateur field the quality of the projection technic can not be expected to be as good as that existing in the theatrical projection room. We should therefore avoid anything that even tends toward higher ground noise levels. The projection equipment and the film itself should be designed to give the best possible quality. I personally feel very sure that it would be a serious mistake to standardize a film layout calling for a sound track as narrow as that shown in Fig. 2.

It seems to be the general opinion that a single row of perforations on 16-mm. film is not adequate for the mechanical handling of the film through the projector. We feel that this impression is entirely unfounded. In our laboratory we have been carrying on experiments for the last four years on 16-mm. film, using one row of perforations. We have made tens of thousands of feet of 16-mm. positive with perforations on one edge only and have run it hundreds of times through projectors designed to use this product. Our experience has been entirely satisfactory. We have never encountered trouble due to breakdown or imperfections in the perforations. With film 16 millimeters wide and of its present thickness and quality of base, there is no necessity of having more than one row of perforations. The life characteristics of this product are as good as those of similar products with two rows of perforations. It is probable that even with the two-row product the actual pull-down is accomplished by the action of the claw or tooth on one row of perforations only. In our experience the effective life of a 16-mm. positive is determined by factors other than the physical breakdown of the film band.

It is well known in the 35-mm. field, and this applies with equal force to the 16-mm. field, that sound-on-film positives become unusable, not through breakdown of the perforations, but by the building up of ground noise due to surface conditions, such as the accumulation of dust, finger prints, abrasions, and scratches on the surface of the film. We have perfect confidence, therefore, that a 16-mm. film band with one row of perforations is entirely satisfactory. I can assure you that there will be no difficulty or shortening of the life of the film when handled by one row of perforations.

I am thoroughly convinced that it is utter folly to change the dimensions of the present 16-mm. picture size or to change the projector aperture size and its relation to the film band and other parts of the projector mechanism.

MR. TASKER: With respect to ground noise, it should be pointed out that a two to one change in scanning line length will make only three db. difference in ground noise. In the examples at hand, we are comparing a scanning beam of 36 mils with one of 65 mils, which will result in a difference of slightly less than three db. in ground noise, assuming, of course, that all other conditions remain unchanged. On the other hand, an improvement of much more than three db. in ground noise to signal ratio may result from improvements in film emulsion and in recording technic.

With respect to the interchangeability of the film, I should like to ask Mr. Jones whether he means to give the impression that it is impossible to run silent film on a projector adapted to accommodate the layout of Fig. 2.

MR. JONES: Not without modification. It would require a change of projector aperture plate, and in order to obtain the same picture size without changing the distance between projector and screen, it would be necessary to use a shorter focal length projection lens. Since Fig. 2 is asymmetrical with respect to the film, the optical axis of the projector, as set for the center line of the picture, would not pass through the center line of the silent film picture area. Hence, when running existing silent film in the projector designed to accommodate the layout of Fig. 2, the projection lens, that is, the optical axis, would be off center with respect to the center line of the silent picture, unless arrangements were made to re-center when changing from present silent film to that made according to Fig. 2.

MR. TASKER: It seems to me that the matter of a different picture size on the screen is not of such tremendous importance as has been indicated. In the machine used to demonstrate to this Society, film of the type shown in Fig. 2, the only effort required to change from sound to silent film is the moving of a single lever that changes the aperture size. Optical elements are already properly aligned for the projection of the larger silent film frame.

MR. EVANS: I move that we accept the Report of the Standards Committee, with the exception of the 16-mm. standards.

MR. JONES: It is desirable that some agreement be reached. The S. M. P. E. should formulate something in the way of 16-mm. sound-on-film standards. The report should be submitted to the membership.

MR. GLUNT: The standardization of dimensions for film should be most carefully considered, and should be based upon practical experience. It seems to me that the proposal before us is based largely upon theoretical consideration. I recommend, then, that we follow the suggestion that has been made, namely, that the proposals of the committee either be accepted and tabled, or that the whole matter be held over for further consideration at the next meeting. The Committee could be asked to give the subject further consideration and study and to render a supplementary report at that time

MR. SHEA: The Standards Committee provides an opportunity to standardize. It is no reflection on the Committee as to what action is taken. The Standards Committee has done valuable work in reducing the standards to not more than two. We find two strongly divergent points of view on these, and the reason for this is probably that, whereas standardization usually follows the fact, here we are expediting things for strong commercial reasons.

DR. GOLDSMITH: Standards should be adopted at a time when they will be of substantial importance in the formation of current practice. There is little use in adopting standards that have already been universally accepted by an industry, because this merely constitutes a confirmation of an existing state of affairs and is not a constructive contribution. Standards in many cases should be adopted at a time when practice has not completely crystallized, in order that we may avoid the confusion which results from the simultaneous existence of several competing standards in the field, and may guide the industry constructively along practicable lines. It is my understanding that the American Standards Association does not regard it as suitable for standardizing groups to await the "complete acceptance of a standard by an industry prior to its adoption." In the particular case of 16-mm. sound-on-film standards, it is likely that if the Society waits for a considerable period of time before adopting standards, the industry will have solved the problem in its own way, the action of the Society will be of comparatively little help, and the role of the Society in the matter of relative unimportance.

Those in favor of returning the material on the 16-mm. proposed standards to the Committee for further consideration: 29; those opposed: 14.

The remainder of the report is accepted.

SOCIETY OF MOTION PICTURE ENGINEERS

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1932-1933

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SOCIETY ANNOUNCEMENTS

ANNUAL FALL BANQUET, HOTEL PENNSYLVANIA, NEW YORK, N. Y., OCTOBER 5, 1932

As previously announced in the JOURNAL, owing to prevailing conditions, the annual fall meeting of the Society, usually lasting four or five days, was this fall restricted to the single evening of October 5, at which time the annual fall banquet was held and the newly elected officers for 1933 were installed. The banquet was held at the Hotel Pennsylvania in the Salle Moderne. The voting ballots, recently returned by the Active membership of the Society, were counted by a committee of tellers appointed by the president, and the newly elected officers were introduced. The list follows:

A. N. Goldsmith	*President*
W. C. Kunzmann	*Vice-President*
J. H. Kurlander	*Secretary*
H. T. Cowling	*Treasurer*
W. C. Hubbard	*Governor*
R. E. Farnham	*Governor*

After the introductions, which were followed by the presidential address, an interesting address was made by Mr. Terry Ramsaye on the subject "Where Is the Motion Picture Going?"

The remainder of the evening was devoted to the showing of recently released motion pictures: *Wild Girl*, courtesy of Fox Film Corp.; *Once in a Lifetime*, courtesy of Universal Pictures; *Flowers and Trees*, a Silly Symphony in color, courtesy of United Artists Corp.; *Feathered Follies*, a Van Beuren Fable, courtesy of RKO Radio Pictures, Inc.; and a picture illustrating recent work in color by the Brewster Color Film Corp. Acknowledgment is due to Mr. H. Griffin of the International Projector Corp. for his assistance in arranging the projection facilities.

BOARD OF GOVERNORS

A meeting of the Board of Governors was held on the afternoon of October 5, preceding the annual fall banquet held that evening. The greater part of the meeting was taken up with fiscal matters, relative to the drafting of the 1933 budget. The annual report of the treasurer was presented, in the form of the audit reproduced on page 496 of this issue of the JOURNAL.

In view of the existing conditions, it was felt advisable again to limit, in 1933, the number of conventions to one, and to hold this convention at New York during the latter part of April.

In the preceding issue of the JOURNAL, announcement was made of the request of the S. M. P. E., addressed to the American Standards Association, to form a sectional committee on motion picture standardization, to operate under the rules of the American Standards Association. Invitations have been addressed to the various organizations of the motion picture industry that are interested in standardization projects to become members of this sectional committee. All those organizations, whose replies to the invitation have been received, have replied in the affirmative. It is to be hoped, therefore, that the formation of the sectional committee will be completed in the near future.

The following method of acting upon recommendations for standardization by the Standards Committee of the S. M. P. E. was adopted by the Board: "That a majority affirmative vote of letter ballots received within thirty days, on specifically stated recommendations of the Standards Committee, shall be authorization of early publication in the JOURNAL of the corresponding material, and an adjoined request for comments from all those interested. It shall be the duty of the office of the Society to bring any communications relative to the published recommendations to the attention of the Board at its earliest meeting. Such recommendations, if later approved by the Board, shall be republished as S. M. P. E. recommended practice."

EASTERN MOTION PICTURE EXHIBIT

Arrangements have been completed for establishing an exhibit of historical motion picture equipment in the New York Museum of Science and Industry, located in the News Building at New York, N. Y., similar to the S. M. P. E. exhibit in the Los Angeles Museum, so ably collected by the Museum Committee, under the leadership of Mr. W. E. Theisen. The first piece of equipment to be placed on exhibit will be the Edison spool-bank projector, obtained from its original owner, Mr. A. H. Cobb, Jr., of Asheville, N. C., by Mr. F. H. Richardson, and presented to the Society at the Washington, D. C., convention in May, 1932.

NEW YORK SECTION

The first meeting of the 1933 season was held in the Electrical Institute at the Grand Central Palace in New York, N. Y., on October 19th. An interesting paper entitled "Practical Problems in Recording and Reproducing Music for Audible Pictures" was presented by Mr. David Mendoza, muscial director of Warner Brothers Eastern Vitaphone Studio. This was followed by a paper on the "Engineering of a Picture," by Mr. Joseph Henabery, motion picture director, Warner Brothers Eastern Vitaphone Studio.

The newly elected officers of the New York Section for 1933, as announced at the close of the meeting, are as follows:

P. H. Evans	*Chairman*
D. E. Hyndman	*Secretary-Treasurer*
M. C. Batsel	*Manager*
J. L. Spence	*Manager*

PACIFIC COAST SECTION

At a meeting held at the Norman Bridge Laboratory of the California Institute of Technology at Pasadena, on October 12th, Dr. W. V. Houston, professor of physics, spoke on "Color," using an elaborate apparatus for demonstration purposes.

Another meeting is scheduled for October 26, at which time papers or demonstration films will be presented by Technicolor, Morgana Color, Cinecolor, Magnacolor, and Dunning Color, in both 35-mm. and 16-mm. widths.

SUSTAINING MEMBERS

Agfa Ansco Corp.
Bausch & Lomb Optical Co.
Bell & Howell Co.
Bell Telephone Laboratories, Inc.
Case Research Laboratory
Du Pont Film Manufacturing Co.
Eastman Kodak Co.
Electrical Research Products, Inc.
Mole-Richardson, Inc.
National Carbon Co.
RCA Photophone, Inc.
Technicolor Motion Picture Corp.

HONOR ROLL

OF THE

SOCIETY OF MOTION PICTURE ENGINEERS

By action of the Board of Governors, October 4, 1931, this Honor Roll was established for the purpose of perpetuating the names of distinguished pioneers who are now deceased:

LOUIS AIMÉ AUGUSTIN LE PRINCE
WILLIAM FRIESE-GREENE
THOMAS ALVA EDISON
GEORGE EASTMAN
JEAN ACME LE ROY

SOCIETY OF MOTION PICTURE ENGINEERS, INC.

REPORT OF THE TREASURER FOR THE PERIOD SEPTEMBER 16, 1931, TO SEPTEMBER 30, 1932

Balance, September 16, 1931			$24,566.36
Receipts during Period			
Dues and Fees			
Dues of active members	$6,099.51		
Dues of associate members	3,533.57		
Dues of sustaining members	4,850.00		
Admission and transfer fees	1,193.25	$15,676.33	
Publication Income			
Journal sales and subscriptions	3,089.81		
Reprints revenue	2,654.30		
Advertising revenue	346.40	6,090.51	
Other Income			
Interest on bank balances	814.70		
Certificates, badges, and binders	74.13		
Convention receipts	1,863.31		
Miscellaneous receipts	12.70		
S. M. P. E. Fellowship fund	1,500.00	4,264.84	26,031.68
			$50,598.04
Disbursements during Period			
General Expenses			
Convention expenses	2,259.34		
Office rent and expenses	4,349.46		
Salaries, management	5,725.00		
Salaries, clerical	3,165.67		
Officers' and Governors' expenses	388.69		
Committee and Section expenses	1,040.51		
Refunds and adjustments	75.42		
Contingency account	129.55		
General Society expenses	326.63		
Univ. of Rochester Fellowship	1,500.00	18,960.27	
Publication Expenses			
Journal	11,426.89		
Reprints	2,010.02	13,436.91	32,397.18
Balance, September 30, 1932			$18,200.86

Manufacturers Trust Co.—Current account	992.51	
Genesee Valley Trust Co.—Savings account	5,145.15	
Rochester Savings Bank—Savings account	7,307.05	
Bowery Savings Bank—Savings account	4,756.15	$18,200.86

(Audited by Robt. W. Sparrow and Co., New York, N. Y., Sept. 30, 1932.)

PAMPHLETS, BOOKLETS, AND CATALOGUES RECEIVED

Copies of the publications listed here may be obtained free of charge by addressing a request to the manufacturer named. Manufacturers are requested to send new publications to the General Office of the Society immediately upon issue.

General Radio Co.: The *Experimenter*, Aug., 1932; telephone transmission measurements, and frequency stability with the screen grid tube; description of measuring technics and instruments used for measuring; a portable heterodyne frequency meter, employing a voltage-stabilized circuit. Address: 30 State St., Cambridge A, Mass.

Hewes-Gotham Co.: Circular describing film cement, and film cleaning and renovating liquid; literature describing method of cleaning projection screens of various types with Hewes' *Screen Nu Clean.* Address: 520 W. 47th St., New York, N. Y.

Howell Electric Motors Co.: Circular describing new built-in capacitor motor of fractional horsepower; adapted to various styles of mounting and cushioning; h. p., $\frac{1}{3}$ to $\frac{1}{8}$. Address: Howell, Mich.

Jenkins & Adair, Inc.: Bulletins 26, 28, and 6*F*, describing, respectively, type *F* plugs and receptacles, the Jenkins & Adair new 35-mm. recorder for use in any glow tube double recording system, and the type *E* condenser transmitter. Address: 3333 Belmont Ave., Chicago, Ill.

Silver-Marshall, Inc.: Leaflet describing *SM* series 60 volume (power level) indicators, used in sound systems for monitoring, control of modulation, and for line equalizing. Address: 6401 W. 65th St., Chicago, Ill.

Telephoto & Television Corp.: A leaflet describing Telephoto photoelectric cells designed for use with various makes of reproducing equipment, giving some of their operating characteristics. Address: 133 West 19th St., New York, N. Y.

Victor Animatograph Corp.: Circular announcing new line of improved projectors: models *10*, *10FH*, and *10RH;* prices and brief descriptions of these models are given. Address: Davenport, Iowa.

Weber Machine Corp.: Leaflet describing a portable sound and picture *Synchrofilm* projector for 35-mm. film, complete with amplifier and loud speaker, designed for both professional and nonprofessional use. Address: 59 Rutter St., Rochester, N. Y.

Wood-Watson Printer: Circular describing a 16-mm. sound-on-film printer designed to compensate automatically for shrinkage by bending the shrunken negative so that its emulsion surface temporarily regains the exact length that matches the positive. Address: H. T. Cowling, 6 Sibley Place, Rochester, N. Y.

JOURNAL

OF THE SOCIETY OF

MOTION PICTURE ENGINEERS

Volume XIX **DECEMBER, 1932** **Number 6**

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JOURNAL
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MOTION PICTURE ENGINEERS

SYLVAN HARRIS, EDITOR

Published monthly at Easton, Pa., by the Society of Motion Picture Engineers.

Publication Office, 20th & Northampton Sts., Easton, Pa.
General and Editorial Office, 33 West 42nd St., New York, N. Y.

Subscription to non-members, $12.00 per annum; to members, $9.00 per annum, included in their annual membership dues; single copies, $1.50. A discount on subscriptions 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 33 W. 42nd St., New York, N. Y.

Entered as second class matter January 15, 1930, at the Post Office at Easton, Pa., under the Act of March 3, 1879.

THEATER NOISE PROBLEMS*

S. K. WOLF AND J. E. TWEEDDALE**

Summary.—*Incident to the many advances in recording and reproducing sound motion pictures, greater attention has been drawn to the necessity of reducing the noise from various sources integral to the theater. Analysis of the various sources, the factors influencing noise transmission, and the general structural limitations indicate that no general solutions of specific noise problems may be readily expressed except that of the reduction of noise directly at its source. In existing theaters many noise problems may be overcome by employing sound insulating and vibration isolating constructions adapted to the particular circumstances. Analysis of a large number of theater noise problems has indicated that attention to detail and to the proper use of materials has resulted in satisfactory solutions where other trial or temporary expedients have failed. In contemplated theater projects all aspects of the noise problem should be carefully considered, and every effort should be made to provide minimum noise conditions. It is anticipated that future designs will incorporate not only specifications for and requirements of necessary sound insulative construction, but also the maximum permissible noise level that may be created by any part of the theater equipment.*

From the inception of sound motion pictures, the necessity has been recognized of providing good acoustical conditions in the theater in order that the theater patron might obtain the maximum enjoyment from the program. To this end the theater owner has considered the correction of excessive reverberation time to acceptable limits, the reduction of the more obnoxious noise sources, and more careful monitoring of the loudness level of the reproduced sound, all these tending toward better listening conditions and a resultant lessening of the aural discomfort and strain under adverse acoustical conditions. Incident to the many recent advances in recording and reproducing sound motion pictures, even greater attention has been drawn to the necessity of providing the most acceptable acoustical conditions in the theater if the maximum benefits are to be gained from the refinements in the art. The correction of reverberation time to provide these optimal conditions has been adequately discussed in the past, but it has been found that the

* Presented at the Spring, 1932, Meeting at Washington, D. C.

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

noise problem has proved most difficult to solve because of the failure to realize its effect and, in many cases, the failure of trial expedients due to the lack of properly appreciating the particular factors influencing the reduction of noise.

In the theatrical sense, noise refers to unwanted sound. It may produce two general effects: it may annoy the patron and, under certain conditions, it may impair his aural sense, particularly in interfering with sounds that the listener desires to hear. The annoyance caused by noise does not lend itself to objective study.

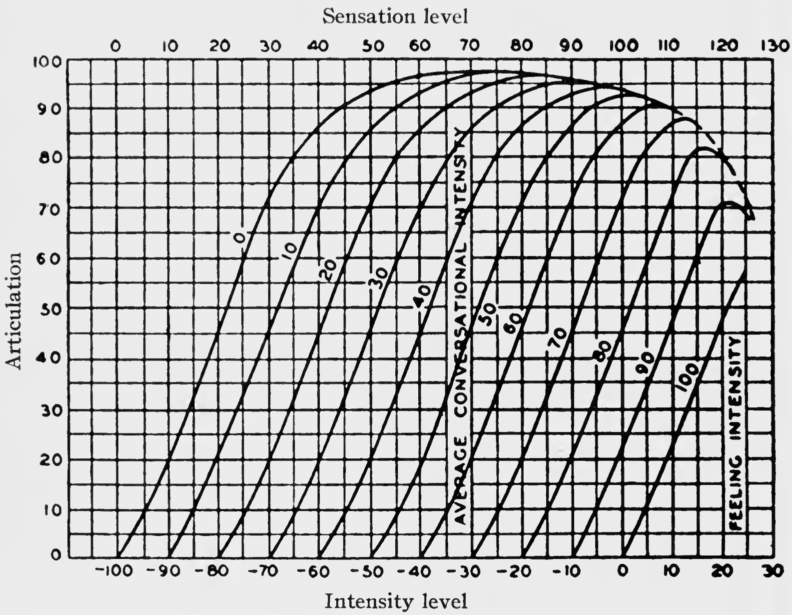

FIG. 1. Articulation *vs.* intensity of received speech in the presence of noise.

It is a function of the emotional state of the individual at the particular moment. The effect of noise in interfering with aural discrimination can be readily measured objectively and, in the case of speech sounds, is rated in terms of articulation percentages. Studies by Fletcher[1] and Knudsen[2] have shown conclusively the effect of noise on the impairment of the interpretation of speech. Some of the results of Fletcher's studies on the effect of noise on speech articulation are shown in Fig. 1. In the case of reproduced music, the effects of noise can not be readily expressed, except in terms of frequency masking, this being a function of the frequency composition of noise and the frequency range of the reproduced music.

Relative to the recent advances made in recording sound, involving in particular an extension of the range of volume, the influence of extraneous noise in the theater where the recording is reproduced must be carefully considered. To avoid misconceptions, the noise referred to is the noise that is residual or ambient in the theater, and not the noise that may arise in the reproducing system. In the extended volume range recordings, the major difference from the old style recordings lies at present in making it possible to utilize the low intensity range by eliminating the surface and background noise in the recording and reproducing systems. The upper intensity level is at present limited by the capacity of the reproducing amplifier. Thus it is apparent that residual or ambient theater noises should be reduced concurrently with the surface or background noises of the reproducing systems in order to make available this band of low intensity sounds.

The effect of noise in reducing the benefits of wide volume range recording is shown in Fig. 2 (*a*) and (*b*), which were taken with an automatic level recorder developed by the Bell Telephone Laboratories, a picture of which is shown in Fig. 3. In Fig. 2 (*a*) is shown the intensity level chart of a recording having a wide volume range, no noise being present. It will be seen that all low intensity sounds are clearly defined, and that the full volume range could be enjoyed by an auditor without requiring close aural attention. In Fig. 2 (*b*) is shown the chart of the same recording under exactly the same conditions, having the same upper intensity level but reproduced in the presence of noise. It will be seen from this chart that the effectiveness of the low intensity range has been seriously impaired by the noise, resulting in a consequent loss of intelligibility and enjoyment. It is to be appreciated, of course, that even in the presence of this noise, the average auditor could distinguish and interpret speech and music, but his interpretation would be attended with difficulty and the necessity of paying close attention. It is for reasons of this nature that it is as much the duty of the exhibitor to provide good aural conditions and freedom from noise as it is to provide good ventilation and comfortable seats for his patrons.

The maximum permissible limit of noise in the theater is determined by the noise produced by the audience. It is possible to control other sources of noise, but the audience is one source over which our control is meager. From a series of observations made in a number of theaters, it has been found that the noise level that may be considered to be representative of a comparatively quiet audience is approximately 25 to 30 decibels above the threshold of audibility. It is to be appreciated that greater levels may momentarily occur, and that during very dramatic scenes much lower noise levels may exist. It is apparent then that the audience noise is the controlling factor influencing the maximum level of permissible noise, and that every effort should be made to reduce all theater noise sources to levels lower than it. This does not imply that the

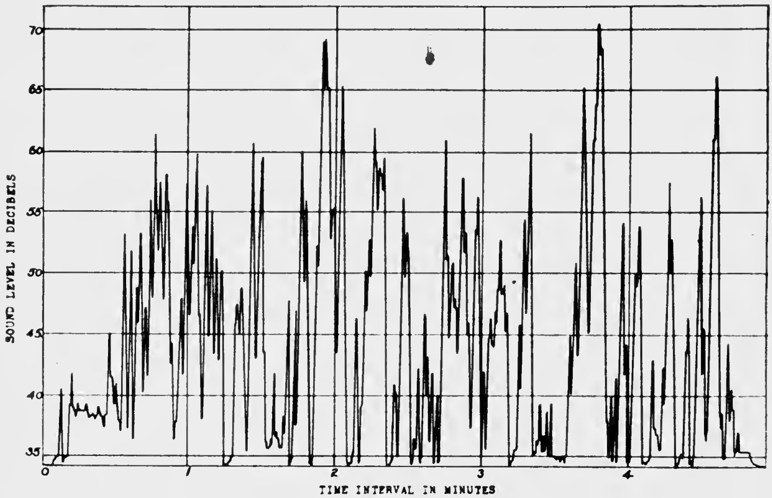

Fig. 2 (*a*). Chart of variation of reproduced sound level of a wide range recording under quiet acoustical conditions.

noises will not be audible, but rather that their effect on the acoustical conditions will have been overcome from a practical standpoint.

Theater noise sources may be divided into two general classes: those external to the theater, and those within the theater and incidental to its operation. Primary among noises produced external to a theater are those of street traffic, industrial establishments, and railway or other forms of transportation. Observations conducted in New York City have shown that the average level of street noise due to traffic is approximately 60 to 70 decibels, depending upon the nature and density of the traffic and its proximity to the theater. Momentary peaks, of varying duration, of 80 to 85 decibels may be encountered and in a few instances levels of street noise as high as 95 decibels have been measured. It is apparent, therefore, that in order to keep the level of noise coming from the streets below the maximum level of internal noise, the theater structure should have transmission reduction factors varying from 35 to 40 decibels to overcome average traffic noise for satisfactory conditions, and for very severe situations 60 to 70 decibels. In suburban locations the average level of street noise may be considerably less than the values here presented, but the momentary peak values stated will probably be still representative of conditions in such locations.

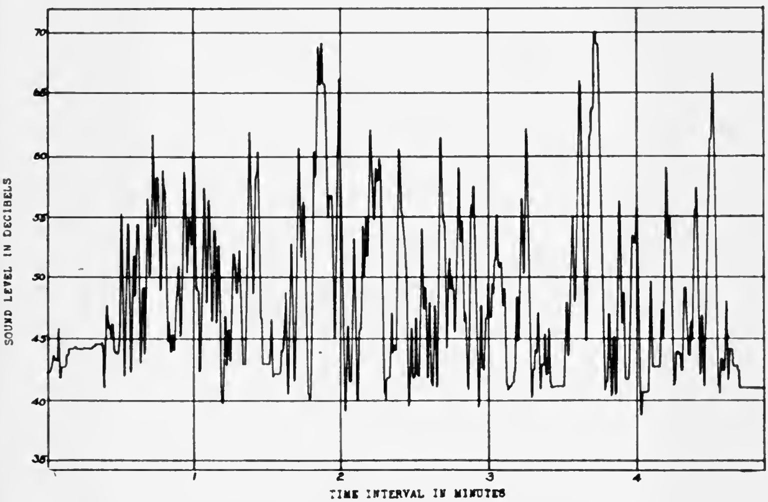

FIG. 2 (*b*). Same as Fig. 2 (*a*) but reproduced in the presence of noise of 41.5 db.

It has been found that not many urban theaters can fulfill these stringent sound reduction requirements except for average street noise conditions. However, it has been found that in the theater of average construction, by attending to details and by modifying some parts of the building structure, reasonable reductions can be made in the amount of noise admitted into the theater. In particular, it has been found that in many theaters fire exit doors are frequently the paths by which external noise enters the theater. By using better fitting doors of heavier construction, this cause of annoyance has been materially reduced in many cases. Likewise, it has been found that by using additional sets of doors and by applying suitable acoustic treatment in shallow entrances leading directly from the street the transmission of street noise into the theater will be greatly reduced. For theaters of light construction, located in noisy areas, but little hope can be held out, for undoubtedly the cost of modifying the structure so as to fulfill the indicated requirements would be prohibitive.

In new theater projects, the problem of external noise can be handled more satisfactorily. By making a comprehensive survey of noise

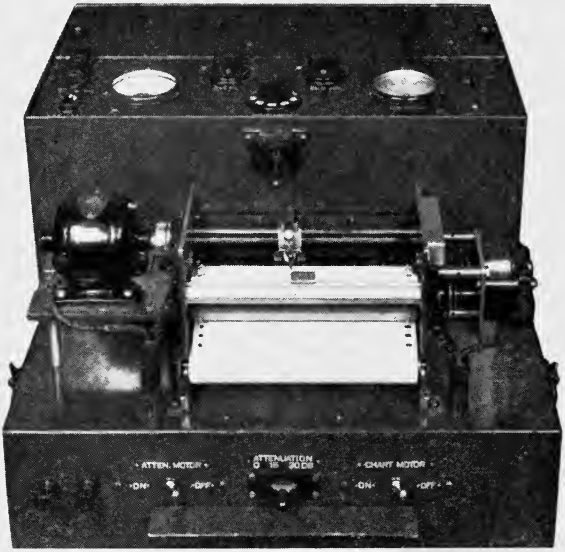

FIG. 3. The automatic level recorder.

levels about sites selected as being suitable for a theater, information can be obtained that can be used for determining the exact sound reduction requirements of the structure. The importance of such information in determining the economic balance between the cost of construction and the probable revenue at different locations, but having the same essential requirements, can not be overestimated.

For general information, the range of levels of various street and theater noises is shown in Fig. 4. These values of noise level may

Outdoor Noises in New York City		Db. above Zero Noise Level	*Other Noises*
Dist. from Source in Feet	Source or Description of Noise		Source or Description of Noise
35	Riveter	100	Subway—Local Station with Express Passing
15–20	Elevated Electric Train	90	
15–75	Very Heavy Street Traffic	80	
15–75	Busy Street Traffic Passenger Automobiles	70	Reproduced Sound in Theaters
		60	Projector Noise in Booth
15–300	Rather Quiet Residential Street, Afternoon		Large Hall with Audience Talking
		50	
	Minimum Noise Levels		
15–500	in Entire City Daytime — 10–20 Min Av. 5 Sec. Av.	40	
15–500	In Mid-City Night — 5 Sec. Av.		
		30	
			Audience Noise during Performance in Large Auditorium
		20	Maximum Total Noise Level for Optimal Conditions
		10	Obtainable in Sound-Proofed Rooms
Above Data from Report by New York City Noise Abatement Commission			Above Data Obtained by Electrical Research Products, Inc.

LEVELS OF NOISES

FIG. 4

be accepted as representative of average conditions, and will serve to indicate the requirements for insulating the external and internal structural surfaces to fulfill the indicated optimal acoustical conditions. These noise levels were measured with the sound meter shown in Fig. 5, which was described in a recent paper.[3]

In addition to the problem of insulating against external noises, the theater owner and prospective builder may under some conditions be confronted by the problem of preventing the transmission of vibrations from the street, adjacent railways, or from industrial establishments. On the occurrence of such a condition competent acoustical authorities should be consulted, since unsuccessful trial

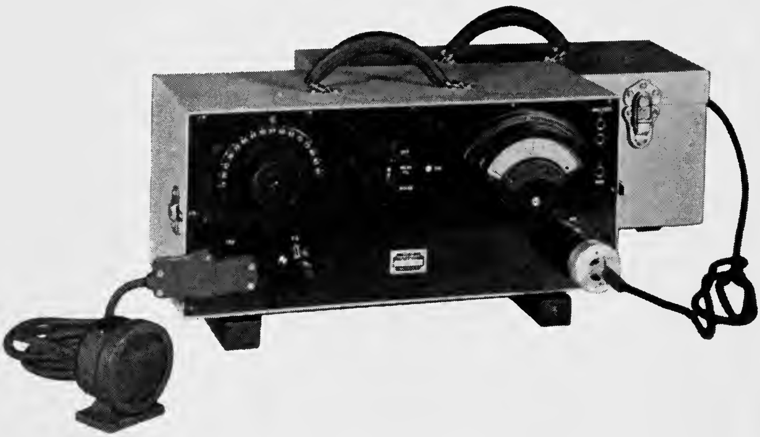

FIG. 5. The sound meter.

expedients based on an indefinite knowledge of the factors involved generally prove far more expensive in the end.

Noises of internal origin arise from projection machines, ventilating or air conditioning apparatus, and from house service or other operating equipment. The noise from such sources may be transmitted through the air directly, or through the structure that houses the apparatus. In addition, vibrations from such sources may be transmitted directly into the structure of the building, and may be transformed into noise at points remote from the apparatus causing it. Both air-borne noise and vibrations can be minimized by applying correct precautionary measures.

The noise created by projection equipment is of most immediate interest, due to the great frequency with which noise problems involving it have been encountered. The term "projection equipment" is meant to include the projectors, generators, monitors, rewinds, and such other devices that are part of or accessory to the projection of motion pictures and the reproduction of sound. The noise created by the projectors is of the most immediate interest. The method of reducing noise is either to select quiet equipment or to construct projection rooms that will confine both the air-borne noise and the vibrations to the area immediately surrounding the source. This necessarily implies that the projection room be adequately insulated. Measurements of noise level in representative projection rooms have indicated that the noise level varies between 55 and 65 decibels, or even higher when the equipment is badly worn. It has been found that projection room structures should be capable of attenuating the sound to the extent of 45 or 50 decibels if an appreciable disturbance is not to be created. This is particularly true of projection rooms that are located immediately adjacent to choice seating areas in the theater.

The success attained in so constructing walls as to be effective acoustical insulators depends not only upon the selection of materials and the design, but also upon paying meticulous attention to such details as projection ports and doors. The glazing of the projection ports and the construction of the door should be such as to provide insulation equivalent to that of the wall structure in which they are used. Apparently minor, direct openings that permit the transmission of air-borne noise will vitiate an entire sound insulative wall construction. To illustrate, consider an exposed wall surface, 10 by 20 feet, constructed of six inches of clay tile, plastered on both sides. From laboratory data, this structure should reduce the transmission of sound by approximately 44 decibels. Suppose that ports totaling eight square feet in area, glazed with a single thickness of $^1/_4$-inch plate glass, were placed in this wall so that no direct leakage occurred around the glass; the sound transmission of the structure would in such a case be reduced to approximately 41.5 decibels. To carry the illustration one step further, suppose that lack of attention to port and door details in this last wall resulted in a total area of one square foot of direct air leakage. The apparent transmission reduction would now be only about 23 decibels, 18.5 decibels less than previously. The importance of paying attention to details is therefore obvious.

As regards the construction of booths in new theaters, or their modification in existing theaters to fulfill noise reduction requirements, a number of factors are involved. Whereas a heavy masonry construction, which would provide adequate sound insulation, could be specified, it is frequently found that either the weight of such a structure is excessive or the cost is prohibitive. However, where the allowable weight is limited, there are a variety of nonhomogeneous materials that may be used in the construction that will provide adequate sound insulation, and will be generally satisfactory as regards the structural requirements involved. Experience has shown that special composite sound insulating structures will, under certain circumstances, provide sound insulation equivalent to that of the usual homogeneous masonry structures. However, the advantages that may be gained by using such structures are contingent upon the circumstances under which the structures are to be used. No specific recommendations on the use of such structures can be provided without exact knowledge of all the influencing factors.

Relative to the problem of isolating vibration that may be created by any part of the projection equipment, certain fundamental factors must be carefully considered. In general, the isolation of vibration consists in providing a supporting structure that is capable either of dissipating the vibration energy transmitted into it, or of otherwise effectively acting as a barrier to its transmission. Such a supporting structure must be designed for each individual vibrating source, if the vibrations are to be successfully isolated. In designing isolating structures of simple form, it has been found desirable to make the natural frequency of the mounting, as loaded by the vibrating source, at least one-fifth the lowest frequency of vibration to be eliminated. The proper combination of mass, stiffness, and resistance may be determined for which the transmission of vibration will be reduced to any desired degree, and at the same time fulfill such other special requirements as may be involved. In general, the design of a satisfactory vibration isolating system to be placed beneath a projection machine requires knowledge of the distribution of mass, the frequencies of vibration, the available floor area, and the types of material that will satisfactorily fulfill the particular requirements.

In new theaters, or in existing theaters where extensive modifications of the floor structure of the booth can be made, a highly satisfactory solution of the vibration problem is to mount all projection equipment on large concrete bases, which in turn are isolated from the building structure in accordance with the usual basic principles of isolation. By so doing, the mass of the concrete base adds stability, and reduces the likelihood of fluttering of the picture during projection, as might occur with a more lightly loaded elastic support. Such precautions are particularly advisable for avoiding the effects of shock sustained by the equipment while it is being handled or adjusted during projection.

Similar principles should be applied in isolating other pieces of projection equipment, particularly motor-generator sets. By properly isolating the various vibrating elements, many noise problems common to theaters can be solved without difficulty. However, it should be remembered that an isolating material does not of itself make an isolation foundation; proper consideration must be given to all the factors involved in the problem, and a design must be evolved that will satisfactorily fulfill the particular requirements indicated.

In the case of ventilating or air conditioning equipment, the noise and vibration problems are solved similarly, except in respect to certain items. The ventilating ducts complicate the noise problem. Noise can be transmitted by, or can be created in, the ducts supplying air to the various parts of the theater. For this reason it has been found necessary to select in so far as possible very quiet operating equipment. To this end the leading manufacturers have been developing equipment that will operate at lower noise levels. However, in spite of the development of quieter equipment, noise will still be created by the motion of the air through the ducts. It has been found that if the air velocity within the ducts be kept below 500 feet per minute, no appreciable noise will be created, and if the exit velocity of the air from the ducts into the theater or in the reverse direction be kept at substantially lower values, the characteristic sound of moving air will be avoided.

However, in spite of these precautions it has frequently been found necessary to use acoustical baffles within the duct system for further reducing such noise as may be propagated through the duct. Experience has shown that baffles composed of highly efficient sound absorbing materials concentrated at the theater end of a duct system provide the most satisfactory means of reducing the transmission of the noise into the theater. In these baffles the material should be so arranged as not to restrict the flow of air or otherwise to lower the efficiency of the ventilating system. An additional precaution that should be taken is to make sure that none of the ducts are rigidly connected to pieces of equipment that are capable of vibrating. Failure to consider this item may result in the transmission of vibration into the duct system, where appreciable disturbing noise may be created and transmitted into the theater. It has been found that by using canvas sleeves and joints at all connections between blowers and ducts, such conditions will materially, if not entirely, be overcome.

In connection with ventilating or air conditioning systems, it has been frequently found that the ducts of such systems may be the medium of transfer of excessive noise from locations external to the theater. Such noise may come from the street or from sources integral to the theater building but not an immediate part of the theater. In such cases, it has been found necessary to provide insulation around the ducts or to relocate them in quieter places. Ducts supplying air to the theater should be carefully separated from ducts that supply air to other possible noisy locations, otherwise acoustical coupling between the ducts may take place.

In connection with other house service equipment, similar precautions should be taken. The location of plumbing and steam lines with respect to the theater auditorium should be carefully considered, as these are frequently sources of annoyance. Likewise all other potential noise sources should be examined; and every effort should be made to prevent them from creating noise, or to prevent the transmission into the theater of any noise that they may create. Under all circumstances the noise emanating from these sources should be reduced to a level below the average noise level of the audience; and if possible, to a limit sufficiently low that the source will not be distinctly recognized.

Although it may appear that theater noise problems are difficult to overcome, it has been found that by paying attention to details and by applying the basic acoustical principles, satisfactory reductions of the theater noise level can be achieved. In the case of new theaters, fewer difficulties are involved, as the necessary modifications in design can be readily made in order to fulfill the indicated requirements. However, it is apparent that the real solution of the theater noise problem lies in the development of much quieter equipment. It is anticipated that in the very near future, specifications for the purchase and installation of theater equipment will include a clause on the maximum permissible noise level that may be created under certain specified conditions. To this end, the further development of quieter theater equipment by the manufacturer is determined by the interest of the exhibitor and the demands of the public for better acoustical conditions in the theater.

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SHORT FOCUS LENSES FOR PROJECTION WITH TRANSLUCENT SCREENS*

WILBUR B. RAYTON**

Summary.—*Projection from behind a translucent screen appears to have advantages in small theaters designed to be operated in low-rental space and with a minimum of operating staff. In large theaters this type of projection permits stage effects not so easily produced, perhaps, by any other means.*

All advantage, however, is lost, unless the projection distance can be made very small for a given size of picture compared with the usual projection distance. For this purpose lenses have been developed with a focal length as short as one inch that will project 35-mm. film. Patents have been granted disclosing that all these make use of the diverging power of a negative lens in order to cover a large field of view. Such use of negative lenses was applied in submarine periscope construction at least as early as 1915.

In projection lens practice, simple meniscus, compound meniscus, and negative lenses with compound curves have been disclosed in the patents issued. Another construction will be shown in which the distortion introduced by the usual negative element is compensated by an additional positive element, the two elements being used in conjunction with any standard projection lens to give the effect of a lens of shorter equivalent focal length, high aperture, and freedom from distortion.

Projection from behind a translucent screen appears to have advantages in small theaters designed to be operated in low-rental premises and with a minimum of operating staff; and also in larger theaters, where it permits stage effects that are impossible by any other means.

To realize these advantages, however, the projection distance must be much smaller than is common in the conventional type of projection for a picture of the same size. For this purpose lenses have been developed, with a focal length as short as one inch, that project 35-mm. film with satisfactory image quality. The optical requirements are rather difficult to meet. For a projector aperture of 0.600 × 0.825 inch, the field of view amounts to about 54 degrees, four times as much field as is required of a 4-inch focus projection lens. At the same time, the relative aperture customary in projection lenses must

* Presented at the Spring, 1932, Meeting at Washington, D. C.

** Bausch & Lomb Optical Co., Rochester, N. Y.

be maintained in the interest of attaining a sufficiently bright picture. Furthermore, in view of the large angular field, it is necessary to avoid the considerable reduction of diameter of the light concerned with imaging the margin of the field, common in photographic lenses, an expedient that makes the problem of the designer of photographic lenses somewhat easier.

The projection screen is probably no less tolerant of a variation of illumination from center to edge than the photographic film, but other factors contribute to cause so great a reduction of marginal illumination when using lenses of this kind that the reduction due to the projection lens must be held to a minimum.

These requirements make the problem of design one of unusual

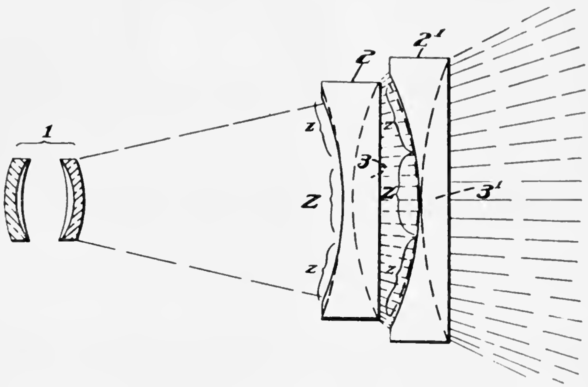

FIG. 1. From U. S. patent 1,802,099, granted April 21, 1931, to W. G. Wolfe.

difficulty if approached in the usual way. It has been generally understood throughout the motion picture industry that the problem has been solved, but it has not been known just how it has been accomplished. There has been, in fact, a vague impression of mystery about it, and a mild curiosity as to wherein these lenses differ, if at all, from ordinary types of projection lenses. Patents granted in this country and in England during the past year disclose a method of attack that seems to have engaged the attention of several people simultaneously.

Some of the drawings of the patents referred to are shown in Figs. 1 to 4, inclusive.

All these have one feature in common, *viz.*, the use of a divergent or negative lens in front of, and separated by some considerable distance from, a converging rear component which is generally a projection or a photographic lens of some well-known type. In general, the whole construction resembles, in some degree, an inverted telephoto combination.

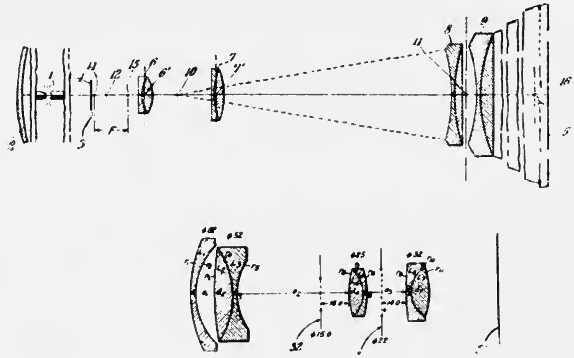

FIG. 2. From British patent 348,123, granted May 1, 1931, to Translux Daylight Picture Screen Corp.

The optical advantage of such a combination is twofold. In the first place, it leads to a longer back focus than is obtainable in a single lens or a conventional type of projection lens of the same equivalent focal length. The second advantage is significant only to

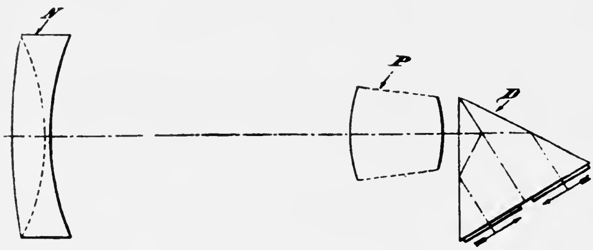

FIG. 3. From British patent 347,946, granted May 7, 1931, to Technicolor Motion Picture Corp.

the lens designer and, briefly stated, lies in the fact that such a combination permits the attainment of satisfactory image quality over a larger angular field of view than appears to be attainable with ordinary constructions when, at the same time, a high relative aperture must be maintained.

The optical principles involved are immediately apparent to the optical expert, but since only relatively few persons have occasion to study optics intensively, it may not be amiss to outline briefly the theory involved so that it may be comprehended how these advantages are realized.

Assuming a combination of two simple lenses, one a negative and

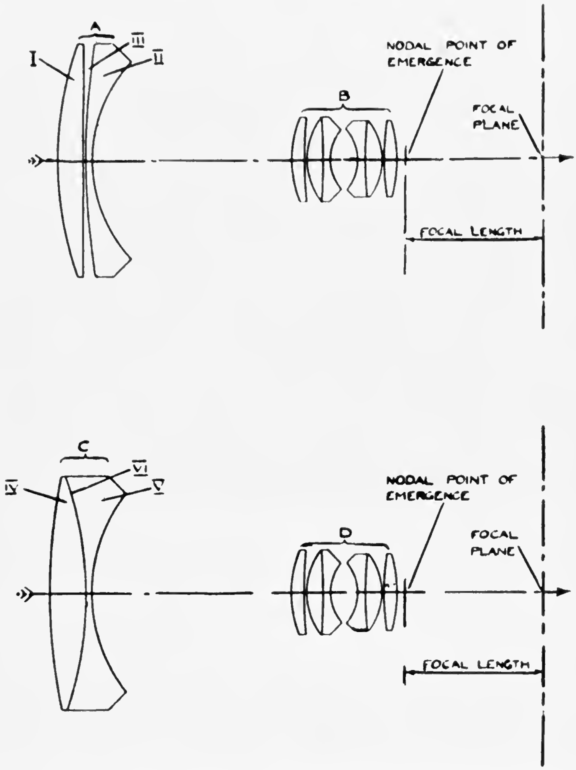

FIG. 4. From British patent 355,452, granted August 27, 1931, to H. W. Lee.

the other a positive lens with the negative lens lying between the object and the positive lens, we may distinguish three cases of interest. These are represented in Fig. 5. In Fig. 5 (*a*), the negative lens lies between the positive lens and its first principal focus. In this case the equivalent focal length of the combination is greater than that of the positive lens, and the back focus of the combination (distance from lens to image) is greater than that of the positive element.

In Fig. 5 (*b*), the negative element lies in the first principal focus of the positive lens. Here, the equivalent focal length of the combination is exactly equal to the focal length of the positive element. The negative lens has no effect, therefore, on the ultimate size of the image. The back focus of the combination is shorter than in Fig. 5 (*a*), but is still longer than that of the positive lens alone.

In Fig. 5 (*c*), the negative lens is separated from the positive by a distance greater than the focal length of the latter, and this is the case in which we are interested, for here the equivalent focal length

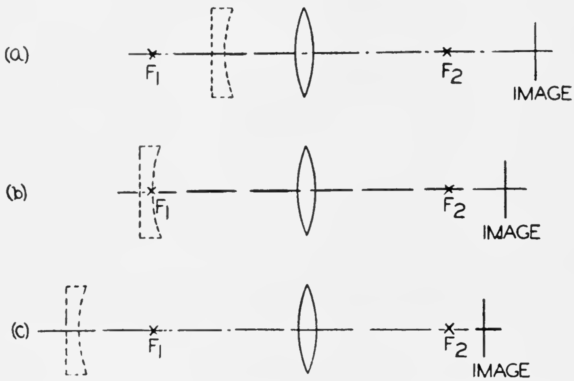

FIG. 5. (*a*) Combination of positive and negative elements separated by a distance shorter than the focal length of the positive lens; equivalent focal length of combination greater than focal length of positive. (*b*) Separation equal to focal length of positive; equivalent focal length equal to focal length of positive. (*c*) Separation greater than focal length of positive; equivalent focal length less than focal length of positive. (In all cases, the back focus is greater than the back focus of the positive lens.)

of the combination is less than that of the positive lens. The back focus, on the other hand, is still greater than that of the positive lens, although shorter than in either Fig. 5 (*a*) or Fig. 5 (*b*). The first of the two advantages claimed for the combination is here apparent.

Fig. 6 is designed to show in a crude way how the second advantage is realized. The simple positive lens of Fig. 5 has been replaced by a lens of the Petzval type. At the left is represented a motion picture aperture, the edges of which are connected by lines representing the principal rays of the pencils to the second nodal point, H_2, of the lens. The enclosed angle, $2w_1$, is the angular field of view. These principal rays leave the lens as though they diverge from the first nodal point, H_1, and proceed toward the screen within the same angle, $2w_1$. Falling on the negative lens, however, they are further diverged so that they enclose the larger angle, $2w_2$. It is obvious, therefore, that the projected picture is enlarged by the introduction of the negative lens.

It is realized that this is utterly inadequate as an exposition of the optical principles involved, and yet no more is needed to establish a basis on which to call attention to the one interesting feature. If we have at our disposal a lens whose maximum useful field of view is of some finite value such as $2w_1$ in Fig. 6, a combination whose covering power is appreciably greater can be obtained by adding a negative element in the manner we have been discussing.

Now, in spite of the fact that the elementary theory indicates that this system would perform as indicated, there is no reason to

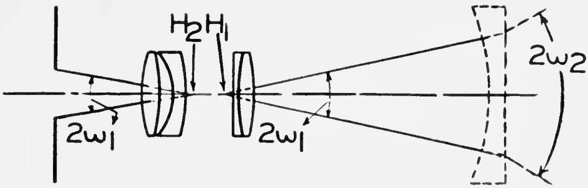

FIG. 6. Showing how a negative lens element operates to increase angular field of view.

assume that the quality of the image would be satisfactory. Fortunately, if one is content with a reasonable increase in size of field, a negative lens of relatively low power suffices, and many of the aberrations of even a simple negative lens are of such a sign as to compensate for the inevitable residual aberrations of a high-speed positive projection or photographic objective. It can not be said, however, that the final result is entirely satisfactory if a simple negative lens is used when the increase in field sought is great enough to make it of interest. As a matter of fact, a simple negative lens used in this manner will inevitably introduce cushion-shaped distortion when the combination is used for projection and barrel-shaped distortion when it is used for photography. For this reason all the constructions shown in Figs. 1 to 4 disclose more or less complex negative elements; and many of the specifications, as well as most of the claims, are concerned with specific constructions proposed as means for overcoming distortion and other aberrations. Claim (1) of the

British patent 347,946 issued to Technicolor Motion Picture Corp., and claim (1) of the British patent 348,123 issued to Translux Daylight Picture Screen Corp., as assignees of Lester W. Bowen, cover rather broadly the basic combination for a photographic and a projection lens, respectively. They were granted just a week apart. In addition to these patents another was granted to Wolfe, U. S. patent 1,802,100, on the same day as patent 1,802,099 (Fig. 1), disclosing another form of the negative element.

These various solutions of the problem employ in some cases aspheric surfaces; in others, compound constructions in which aberrations are eliminated in the customary way by suitable choice of glasses and shapes of lenses; and in still others, aberrations are purposely introduced into the positive lens of such a character as to compensate for those of the negative element.

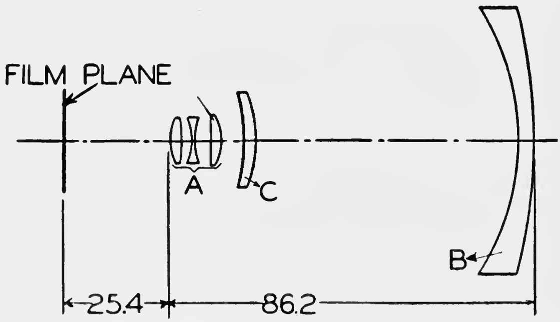

FIG. 7. Construction of a new form of lens of 1-inch focal length giving excellent definition on 35-mm. film.

The writer has found another method of attacking the problem that gives very satisfactory correction of distortion as well as of the other aberrations with very small optical effort. The method is based upon a consideration of the elementary laws governing distortion in lenses. Any simple lens working in combination with a diaphragm at some distance from it will exhibit distortion. Examples of such combinations are the simple meniscus lenses with the diaphragm in front of them, as used in cheap hand cameras. The magnitude of the distortion depends on many factors, such as the distance from the diaphragm to the lens, the focal length of the lens and its shape. The sign of the distortion depends upon the nature of the lens, whether convergent or divergent, and on the position of the diaphragm relative to the object and the lens. In hand camera practice, if the diaphragm is in front of the lens the photograph will exhibit barrel-shaped distortion, while if the diaphragm is placed behind the lens, the distortion will be cushion-shaped.

In view of these facts, it seemed possible that the distortion introduced by the negative element, which, in such a combination as is under discussion, must operate in effect as though with a diaphragm between itself and the film, could be compensated for by adding a positive element between the negative lens and the diaphragm, without losing all the advantages inherent in the application of the negative lens. The experiment was successful, and Fig. 7 discloses one

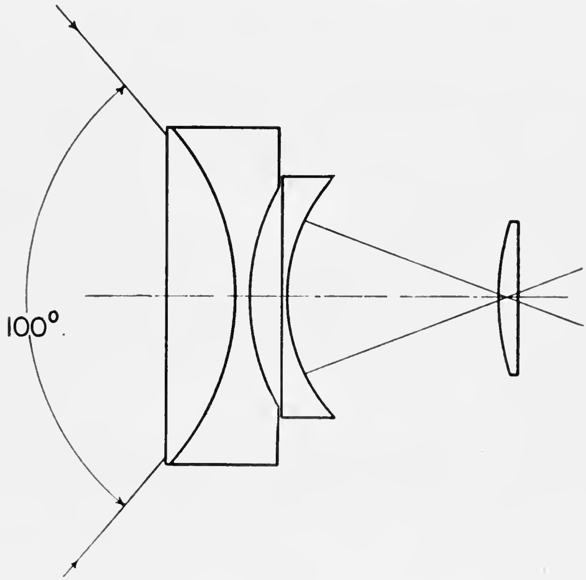

FIG. 8. Negative element used as the first lens of a submarine periscope in 1915 to cover a field of 100°.

form of construction to which this method leads. In this construction *A* represents a completely corrected self-contained lens, in this case a triplet; *B* is a simple negative lens, and *C* is an additional simple positive lens. Since both *B* and *C* lie on the same side of the diaphragm plane or crossing point of the principal rays, the distortion due to each is opposite in sign; and since, by appropriate selection of focal lengths and separation, the amount of distortion due to each may be made identical, the combination can be made completely orthoscopic. Other aberrations also tend to compensate, so that by an appropriate choice of shapes for *B* and *C*, astigmatism and coma can be disposed of. The lenses are nearly of the same focal length, and therefore the Petzval condition for flatness of field is reasonably fulfilled and a proper choice of glasses leads easily to chromatic correction. The lens illustrated in Fig. 7 has an equivalent focal length of 25.6 mm. and a relative aperture of *f*/2.8. This lens will therefore produce nearly as bright an image for a picture of given size as the average projection lens, as it has a relative aperture nearly as great as the latter. The speed of the combination can easily be increased by beginning with a positive lens of higher speed. This particular construction, however, has the merit that it contains no cemented surfaces and a number of air-glass surfaces that are reasonably small in view of the requirements to be met.

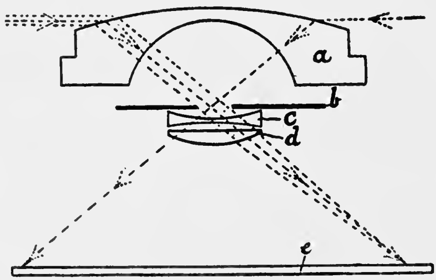

FIG. 9. From drawings of British patent 225,398 granted December 4, 1924, to Robin Hill. Photographic lens to cover 180° of field.

It should be evident that there are limits to the increase of field of view that can be expected from efforts so slight. The same fundamental principle can be employed, however, in more elaborate constructions, wherein both the added negative and positive elements may be made compound.

It is interesting to note that the application of a negative lens as the first element of a system of which a large field of view is required has been well known to optical designers for a long time. Without having made any effort to trace its history, I can mention the fact that I employed the device in submarine periscope design in 1915, using a form shown in Fig. 8. Kollmorgen and Jenkins disclose a similar application in patents granted in 1919, nos. 1,309,639 and 1,309,478, respectively; and an application to photographic lens design is found in a British patent 225,398 granted in 1924 to Robin Hill on a lens intended to cover a field of 180 degrees. This construction is shown in Fig. 9. Many will recognize it, for it was given considerable publicity at the time. In this combination, the distortion due to the negative lens is welcomed; it would be impossible, of course, to cover the 180-degree field without it. In motion picture lenses, on the other hand, whether applied to photography or to projection, the amount of permissible distortion does not much exceed 0.5 per cent.

Finally, it is not to be understood that this is the only way in which it is possible to design a lens of one-inch focal length with enough speed and covering power to be satisfactory for 35-mm. film. It is merely the most successful method yet tried.

MEMORANDUM ON WIDENING THE FIELD OF CAMERA LENSES AND ON THE USE OF NORMAL FILMS FOR THE PANORAMIC SCREEN*

HENRY DAIN**

The following article was transmitted to the Projection Theory Committee subsequently to the appearance of the report of that Committee in the Journal of July, 1931. It is to be understood that publication of this article does not carry with it the implication that the Committee is in entire accord with the argument contained in it. The paper deals with several questions that have been raised concerning the properties and characteristics of anamorphosing optical systems.

The report of the Projection Theory Committee published in the JOURNAL of July, 1931, indicates (p. 131) that the Committee is impressed with the idea that it is desirable to increase the horizontal angle of taking views in cinema practice. Two methods have been recommended for this purpose: namely, wide film and anamorphotic systems. The Committee holds, however, against the latter method, some objections that would be very serious if they were justified.

At the very start, I may be permitted to recall that it was Mr. Henry Chrétien, Professor at the University and at the Institut d'Optique of Paris, who first showed, in a communication presented to the Academy of Sciences on May 30, 1927, by Mr. Louis Lumière, the advantage that one can derive from the application of anamorphosis properly applied to the images, in the extension of the field of the cinematographic apparatus. His works have resulted in the construction of an optical apparatus completely reduced to industrial practice, and which the Société Technique d'Optique et de Photographie (S. T. O. P.), that I founded in 1927, is exploiting under the name of "Hypergonar."

This apparatus solved, in an entirely satisfactory manner, the problem of increasing the angular field, the very great importance of which the Committee has so well made evident.

The Hypergonar doubles the field of an ordinary objective in one

* Posthumous; received July 25, 1932.

** Consulting engineer, Paris, France.

sense only; it consequently permits, in the space of 18 by 21 mm. actually reserved on the standard film (35 mm.) the taking of a view which, restored to its normal proportions on the screen, gives an image of which the size is in the relation of 18 to 42, or 3 to 7 (assuming the doubling in width of the actual size).

This apparatus, turned through 90 degrees, permits the presentation on the screen of views having a proportion of 36 to 21, or 6 to 3.5. This presents a considerable artistic interest, for the elongation on the screen, in the horizontal sense only, limits the possibilities of the producers. The elongated format makes the presentation of certain scenes ridiculous.

The Hypergonar was presented to the Optical Society of America in November, 1928. It has just come into industrial practice and has been utilized for several films. Mr. Natan, general manager of the Pathé-Cinema Company, has understood, since its introduction, the entire significance of this general procedure, and the Hypergonar is actually included in the production program of that company.

As stated by the author of the previously mentioned report, the calculation and the construction of such lenses are a delicate problem. We have been able to solve it, thanks to the coöperation that has been given us by Professor Chrétien, technical director of S. T. O. P. Company, and to the collaboration of the Institut d'Optique of Paris and of its eminent director, Colonel Deve.

The optical perfection of the cylindrical lenses obtained is unrestricted, and the photographic quality of the views taken by our apparatus is limited only by that of the best spherical objectives that it has been possible to use with them.

It seems indeed that the essential character of Professor Chrétien's solution is rather difficult to appreciate, inasmuch as some specialists in cinematographic optics have failed to understand it.

For example, it is not accurate to say that "if satisfactory performance is possible in the horizontal meridian, a symmetrical lens is also possible whose focal length is the same as that in the horizontal meridian in the case of both the camera and the projection lens."

In fact, the construction of such symmetrical objectives, perfectly corrected for the apertures that the cinematographic industry demands, has not yet been realized. It is the same with the lenses required for the "wide film." No objective of great aperture and great field can, at the present time, be constructed with satisfactory optical qualities, whereas the combination of a present-day objective of 50-mm. focus, opened to $f/2.7$, for example, and of a Hypergonar, gives a perfect system from the point of view of definition, as we have demonstrated experimentally with the aid of our apparatus.

The theoretical reason for this apparent antinomy is that the straight calculation of a symmetrical anastigmatic objective demands putting into coincidence, in the same plane, the two image focal surfaces called the tangential and sagittal, over the entire extent of the field; whereas the solution for the "Hypergonar" only involves the correction of the tangential image. To state precisely this important technical point, allow me to enter into some theoretical details. To simplify the account I am confining myself to the consideration of the aberrations of the third order:

If $P = -\Sigma \frac{\phi}{r}$ signifies the Petzval curvature of the optical system under consideration, A its coefficient of astigmatism, one knows that the curvatures ρ_s of the sagittal image and ρ_t of the tangential image are given by the formulas:

$$\rho_s = P - A \qquad \rho_t = P - 3A$$

In a symmetrical objective one will therefore obtain flatness of the image only by simultaneously satisfying the two conditions, $A = 0$ and $P = 0$. The latter is well known under the name of the Petzval condition. One can satisfy it only by introducing negative lenses of high power into the combination, a thing that singularly increases the difficulty and limits the constructional possibility of objectives that must finally be convergent.

The theoretical importance of the Hypergonar will therefore appear evident to the optical specialists if one observes that in its calculation only the consideration of the curvature ρ_t intervenes and that, in addition, the system must present a strong preponderance of divergent elements in its assembled state. The Hypergonar respects the results acquired by more than a half century of struggle against the astigmatic aberrations of photographic objectives.

In the above-mentioned report, we find another inaccuracy. It is an error to assert that it is optically impossible to maintain the coincidence of the focal planes for the vertical and horizontal meridians with variable object distances, and to say that such systems always produce an image infected with astigmatism except for the distance determined by the object for which they have been calculated.

This erroneous assertion shows that people are even today under a

FIG. 1. Negative made with an objective of 50-mm. focal length and an anamorphotic system that doubled the field.

FIG. 2. Three sound tracks united on one film.

FIG. 3. Combination of the anamorphotic image and the three sound tracks.

FIG. 4. Print from Fig. 1 when restored to its normal proportions.

Examples of Prints Made with the Aid of the Hypergonar Lens pessimistic impression from Abbé's theory of anamorphotic systems, giving real images directly and necessarily requiring cylindrical lenses with orthogonally arranged generatrices.

Our systems formed of cylindrical lenses with rigorously parallel generatrices are not afocal but rather focal systems, working uniquely on their Bravais planes, the relative position of which is adjustable as for ordinary focusing and can instantaneously be brought into coincidence with an object situated at whatever distance. It is only in the case of the object situated at infinity that the Hypergonar becomes automatically afocal in the two meridians.

It is in consequence of that incomprehension, or, perhaps, simply to conceal the counterfeiting, that certain inventors have patented the introduction of corrective caps for distance, composed of additional spherical lenses!

The Hypergonar can be put in front of the apparatus for taking the views and removed immediately without any alteration of the focus adjustment. This constitutes an essential practical advantage that all operators will appreciate.

One point that ought to be carefully examined is the unfortunate part played by the grain of the emulsion: the enlargement of the image on the screen is limited by the size of the grain. Such consideration is the only excuse for the colossal and burdensome transformation of equipment involved by the "wide film."

The Hypergonar solution is much more advantageous than that of the wide angle objective. In fact, the linear dimensions are doubled by the projection in both cases. With the symmetrical objective, the surface of the grain is quadrupled, while it is only doubled with the Hypergonar. There is an enormous difference to the eye.

It is quite evident, moreover, that this procedure allows one to profit by the advantages that the large film ought to present, when used in the taking of views. As the copies are obtained by means of anamorphosis, the grain of the negative—the only practical trouble—is automatically reduced in the same proportion.

It would be necessary, nevertheless, that the optics of the wide film should permit a definition superior to that allowed by the grain of the negative emulsion on the edge of the amplified field. We have yet to wait until some one produces a wide negative (65 or 70 mm.) of satisfactory quality. Wide image and wide field are not the same thing.

The technical tendency of today, as regards quality of sound, is to record several separate sound tracks on the same film, each track being specialized, *viz.*, one for music, one for speech, one for accessory sounds, *etc.* It is undoubted that this method considerably improves the quality of the sound, while affording the possibility of producing the acoustical equivalent of the stereoscopic effect. Unfortunately, the method is hardly practicable, as it is not possible to print more sound tracks on a film without further reducing the dimension of the picture.

Large producing companies working along such lines have endeavored to obtain a perfect sound record on a track not more than 1 millimeter wide, whereas the size previously adopted, 0.1 inch, was already rather too small.

Our picture anamorphosis process entirely solves this new problem. The various sound tracks may thus be allotted the full width required from the acoustical point of view, without affecting the breadth of the projected image, which even permits an increase to the panoramic size on the screen.

Finally, we recommend the adoption of a normal film, that will bear two sound tracks of 2.5 millimeters each, leaving a free space of 19 millimeters for the picture track. Anamorphosis applied to the picture in the ratio of 1.7 will bring the image on the screen to the ratio of 18 to 31.6—its length and height being therefore in the ratio of 1.75, an intermediate figure between 1.618 (whirling square) and 1.81 (recommended by the S. M. P. E. for the new 50-mm. standard film). If the ratio of 2 is adopted for anamorphosis, the ratio on the screen will be 18 to 38, say, 1 to 2. The desired anamorphosis ratio depends on the number of sound tracks and on the proportions of the image on the screen.

It seems that the foregoing information is of interest because the Hypergonar reduces to naught the two serious objections formulated in the Committee report referred to, against anamorphotic systems with cylindrical lenses.

REFERENCE

[1] Proceedings of the Michelson Meeting, *J. Opt. Soc. of Amer.*, **XVIII** (March, 1929), pp 174–175.

THE USE OF THE PHOTOELECTRIC CELL IN CINEMATOGRAPHY*

LEOPOLD KUTZLEB**

Summary.—*Three instruments employing the photoelectric cell designed by Messrs. Gans & Goldschmidt of Germany are described. These instruments are (a) an exposure meter employing the Mihaly circuit and galvanometer; (b) an instrument for calibrating the light intensity of lamps used in printing machines; and (c) an instrument for determining the brightness of projection screens.*

The introduction of sound films has forced the film technician to take an interest in technical and scientific problems that did not concern him before. The photoelectric cell, for example, which reproduces the sound by converting the various light intensities falling upon it into modulated electric currents, is one of those instruments that now play an important part in the work of the film technician. The characteristics and functioning of the photoelectric cell have often been discussed,[1] so that it is not necessary to go into these details here.

Due to its highly sensitive and, under certain conditions, reliable reaction to light of various sources and intensities, the photoelectric cell is capable of serving many purposes. We would refer the reader, for example, to an article published last year dealing with the use of a photoelectric cell in making objective density determinations.[2] Reports have also been published on experiments carried out, chiefly in the United States, with a view to utilizing the objectivity of the light determinations that can be obtained by means of the photoelectric cell as a reliable controlling factor in the whole cinematographic process from the time the exposure is made to the projection of the finished picture. In this connection particular attention is drawn to the printing light control strip system devised by M. W. Palmer and A. J. Richards,[3] in which the "face value" of the principal actor is determined during the exposure by means of a photoelectric cell and recorded on the negative to form a basis for the printing

* Translated from *Die Kinotechnik*, **XIII** (Jan. 5, 1931), No. 1, p. 8.

** Charlottenburg, Germany.

process, which again is controlled by means of a photoelectric cell.

The following article deals with apparatus that have recently been designed by Messrs. Gans & Goldschmidt with a view to solving this and similar problems and that at the same time are an indication of the progress that has been made. The instruments in question are designed for making objective determinations of radiation, and vary in construction according to the different purposes for which they are to be used. The manufacturing firm has purposely refrained from constructing a so-called "universal" instrument since, in consideration of the many factors that play such an important part in making accurate measurements of this kind, such an instrument would not always fulfill all requirements. Of these various designs we have selected those that are used for the following purposes:

(1) The determination of the exposure required in taking the photograph.

(2) The determination of the intensity of the illumination in the printing gate of the printing machine.

(3) The determination of the brightness of the projection screen.

All these instruments are based on the same principle, and, in combination with the Mihaly compensator, offer considerable advantages over other similar devices. Unfortunately, the patent situation is such that it is not possible at the present time to give further details concerning this invention. Its importance, however, may be realized from the fact that with the use of the Mihaly circuit it is possible to use a very small current for the photoelectric cell, while the readings are made by means of a finely adjusted rotating coil galvanometer instead of the filament electrometer otherwise required. In the past it was necessary to apply a voltage of 100 to 200 to the photoelectric cell, while with the new apparatus a voltage of only 4 is required. This not only lengthens considerably the life of the photoelectric cell, but also increases the accuracy of the determinations made with it; since, due to the lower strain placed upon it, the characteristics of the cell are not so liable to change.

THE EXPOSURE METER

This instrument consists mainly of three parts: the photoelectric cell with its socket and stand, a box containing the measuring instrument and the necessary wiring, and a 4-volt storage battery, which supplies the current. The first two parts are shown in Fig. 1. On the left is shown the small cannon-shaped instrument which contains the photoelectric cell. The tube in front of this cell serves only to limit the amount of light falling on the latter to that reflected by a restricted portion of the object to be photographed. The socket of the lens is supported by trunnions whose bearings are mounted on a stage which in turn can revolve on the base plate. The cell and the tube can therefore be focused on any portion of the scene to be photographed. The cell is connected to the box containing the wiring system by a well shielded cable. The box is also provided with terminals to which are connected the battery, and a switch for operating the instrument. Mounted on the box is the measuring instrument with its indicator and scale; the latter may be calibrated in

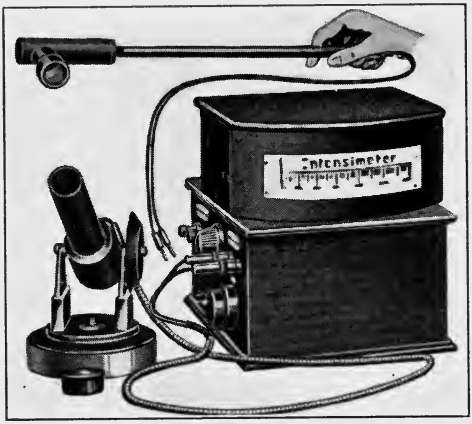

FIG. 1. The exposure meter, with photoelectric cell, Mihaly circuit, and galvanometer.

lux or any other desired unit. (Fig. 1 shows, in addition, an instrument to be held in the hand, which contains in the light-proof container mounted at right angles at the end of the wand, a photoelectric cell which is used for making x-ray determinations. This may be ignored in so far as this article is concerned.)

Although the exposure meter has already been developed beyond the experimental stage, there are yet one or two points, particularly in connection with the design of the scale from which the readings are taken, that must be modified. The writer therefore wishes to offer some suggestions as to how, in his opinion, this instrument may be improved to fulfill the practical requirements of the cameraman.

When determining the exposure time required, the cameraman's chief aim is to avoid underexposed shadows; and for him, when working in the open, it is not so much a question of the length of the exposure but rather a question of the proper stopping down of the lens aperture; whereas, in the studio, where most of his work is done, it is not a question of exposure time nor of lens aperture, but more a question of determining the amount of light required in each case to produce a well exposed negative. Today this is of the greatest importance, since in sound work the exposure time has been reduced from 0.031 to 0.020 second (corresponding to 24 picture changes). It must also be borne in mind that the amount of light used must be restricted to a minimum, in consideration of the cost of current and the comfort of the actors. When working out of doors, however, the minimum amount of light required to produce a good negative also plays an important part, not only because in this case the light is very often of low intensity, especially if the scene to be photographed contains extensive shadows, but also because one often has to work with a small lens aperture in order to obtain the desired depth of focus. The result of an exposure depends largely upon two factors, *i. e.*, time (T) and intensity (I). Since in the case of motion pictures, due to the prescribed number of picture changes, the exposure *time*—assuming that the full lens aperture and largest shutter opening are used—is fixed, T must be regarded as a constant factor. The intensity of the light and its effect on the photographic emulsion are chiefly governed by:

(*a*) The reflecting properties of the subject to be photographed;
(*b*) Atmospheric influences;
(*c*) The reflection losses at the camera lens surfaces.

If the photoelectric cell of the exposure meter (which is placed beside the camera) is focused on a certain portion of the scene to be photographed, the factors mentioned under (*a*) and (*b*) will have the same effect on the cell as on the film, although the light reaching the film will be diminished, due to the loss of light in the lens. The lenses used in modern photography are usually composed of four separate lenses, *i. e.*, with eight individual glass surfaces, each of which reflects 4 per cent of the light, to which must be added the loss of light due to absorption; so that, even without making allowance for the aperture used, the light suffers a considerable loss of intensity in its passage through the lens.

It therefore appears advisable to scale the exposure meter in such a way that the light intensity will always be indicated in lux produced on the film by the portion of the scene upon which the instrument is focused. Naturally, everything depends upon the power and general construction of the camera lens. It is therefore advisable to base all calculations on conditions that are unfavorable in respect to loss of light due to the lens but favorable in respect to the lens aperture. It is suggested that the scale be adjusted to a modern powerful anastigmat comprising eight exposed surfaces. More powerful lenses may be considered as special lenses designed for special purposes, and when these are used the necessary adjustment can easily be calculated. If a lens of smaller aperture is used, however, or the standard lens is stopped down, all calculations may be avoided by fitting a revolving step wedge disk to the front end of the lens tube, so that the light falling on the photoelectric cell may be adjusted to correspond to the aperture of the lens used. If the scale on the exposure meter is based on a relative lens aperture of $f/2.3$, four wedge filters of the densities 0.3, 0.6, 0.9, and 1.2, respectively, will suffice to make the galvanometer readings correspond to lens apertures of $f/3.2$, 4.5, 6.3, and 9.

If the instrument indicates the "lux on film" as described above, the cameraman need only mark certain points on the scale in order to simplify the conversion of the galvanometer readings.

Obviously the lux figure representing the amount of light that must be brought to bear upon the film if any density at all is to be obtained, *i. e.*, the threshold exposure—for the time being, of one given emulsion—must be ascertained. For example, in order to obtain any density on a Pankine film in white light, a light intensity of 0.004 meter-candle second* with an exposure time of 0.02 second, or 0.2 lux, is required. As pointed out, to each "lux on film" value a higher value known as "lux on cell" is coördinated; but it would hardly be possible to indicate this toe value (which in the case of ultra-rapid emulsions would be even higher) on the galvanometer, since this instrument in its present form is not capable of recording values below 1 lux with sufficient accuracy. The scale could, of course, be extended to indicate lower values, but the galvanometer would have to be replaced by a recording instrument which would be of little use in general photographic work.

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* These determinations were made with an Eder-Hecht wedge and the aid of a Davis and Gibson daylight filter. The tests were developed in a Metol fine grain developer at 19°C. to $\gamma = 1$.

However, for the same reasons as those advanced against the practice of designating the sensitivity of photographic emulsions by the toe value, we also need not consider these values in calibrating the galvanometer. It is important, however, to determine the point of the characteristic curve where the toe merges into the linear portion of the curve. According to the suggestions made by Jones and Russell at the 7th International Congress held in London,[4] this has been defined as the point whose slope is 0.2. For the Pankine film mentioned, this point corresponds to an exposure of 0.018 CMS;* *i. e.*, with an exposure time of 0.02 second, a light intensity of roughly 1 lux on film. The straight portion of the density curve begins at about 0.040 CMS, equivalent to 2 lux on film with an exposure time of 0.02 second.

The galvanometer scale in its present form ranges from 0 (or, more correctly, from 1) to 15 lux on film, covering in the case of Pankine film almost half the straight portion of the curve, and densities up to perhaps 1.4. If the film technician has indicated on the scale the points mentioned above, these should suffice for his purposes. Since an adjustment of the contrast values of a negative in proportion to the original is possible only if the exposures lie on the straight portion of the curve, ** the cameraman will always strive to keep within these limits in outdoor work. This he can easily do by directing the photoelectric cell, which stands close to the camera, toward the darkest portion of the scene to be photographed, adjusting the revolving step wedge disk so that the indicator of the galvanometer can not sink lower than just above the mark indicating the beginning of the linear portion of the curve (upper indicator point). The camera lens is then stopped down to the aperture indicated on the wedge disk. When working in a studio, where this method usually can not be used, the cameraman must regulate the light source in such a way that when directing the instrument toward the darkest parts of the scene the indicator will not sink below the lower indicator point, and he can then always be sure that the negative will show no glassy shadows. With the aid of the exposure meter it is also possible to determine the contrasts embodied in the scene and to make photometric determinations of certain portions of the scene, as, for instance, the face of an actor, not only

* *Vide supra*, p. 532.

** Any deviations caused by lens reflection must be left out of consideration in this case.

in respect to its own brightness but also in comparison with its surroundings. The artistic effects that can thereby be attained with suitable studio illumination need not be gone into here; only one point should be mentioned, and that is the well-known fact that many a cameraman spoils his pictures because he is afraid that the darker portions of the scene—the face of a person standing in the shadow, *etc.*—may be too dark; and, to be on the safe side, he throws on a little more light, so that the entire effect is spoiled and the picture becomes flat and insignificant. "Only those who have the courage to work in darkness will be able to produce really artistic effects."

All that has been said above in connection with marking the critical points in reference to the intensities of light can be applied in principle to that portion of the curve where the straight portion of the characteristic curve passes into the region of overexposure although, of course, one would have to extend the scale by introducing suitable gray filters. It is questionable whether this precaution is really necessary. It would, however, make possible the determination of the brightness scale of the scene and whether it can be reproduced by the emulsion in question. Such cases occur very seldom, especially since the present-day emulsions possess a sufficient latitude for most subjects.

If the cameraman works in the manner described above, and so remains within the points marked on the scale for those portions of the scene that possess the least brightness, he will be able to deliver to the printing laboratory negatives that are of a most uniform character. Such uniformity, in this age of automatic negative and positive developing machines, is most desirable, but it is impossible to attain it by visual judgment of the light intensities. It is obvious that the human eye reacts quite differently when the operator arrives at the studio in the morning after a good night's rest, from the way it reacts in the evening after a long day spent in the bright studio lights under the continual strain of working with magnifying glasses and reading closely printed scales.

The figures mentioned above for the marking of the scale are based on sensitometric tests made with Pankine film. With the aid of a calibration curve the corresponding figures can be found for any given emulsion. In obtaining the data for such curves, the development times and the composition of the developer must, of course, be adjusted to correspond to the average specifications issued by the printing laboratories and film manufacturers.

The values obtained can be recorded either on the scale itself—perhaps in different colors—or on a celluloid sheet, which can be placed over the scale as desired.

One point must be mentioned which is of some importance, and that is the fact that neither the emulsions nor the photoelectric cells react uniformly to light rays of various wavelengths. In other words, if two objects that reflect light in different colors produce the same degree of light intensity on the film or on the photoelectric cell, the effect need not necessarily be the same in both cases, nor need the reaction of the photoelectric cell and the emulsions be proportionately equal. The inaccuracy of the measurements resulting from this fact could be almost eliminated by using for each emulsion (slightly orthochromatic, highly orthochromatic, panchromatic) a correspondingly adjusted photoelectric cell. This, however, would increase the already somewhat high price of the exposure meter out of all proportion to the benefit obtained therefrom. The caesium cell incorporated in the exposure meter designed by Messrs. Gans & Goldschmidt reacts uniformly to the whole visible range of the spectrum; and, therefore, may be said to fulfill all requirements in this respect. One could also, of course, fix suitable color filters in front of the cell, and so exclude all rays which, depending upon the character of the emulsion, have no effect on the sensitive emulsion, and in this way obtain better results.

There are many exposure meters on the market that are based on the visual principle, and, under certain conditions, they are capable of giving more or less accurate service. The photoelectric cell is purely objective in its measurements, its indications are in every case reliable, and, as indicated above, it is capable of doing far more than simply determining the length of exposure required. In view of the considerable financial risks and the artistic effects involved in each film, it is to be expected that this new instrument will arouse the greatest interest among film technicians.

APPARATUS USED FOR CONTROLLING THE LIGHT INTENSITY OF LAMPS USED IN PRINTING MACHINES

Before prints can be made from a negative the latter must be timed; *i. e.*, the light intensity, or rather the exposure required for each negative in the gate of the printing machine to attain the best possible results must be ascertained.

In timing a negative, either by the visual method or by means of special apparatus, a certain light value is obtained which represents the characteristic constant of the negative in question. A correct positive can be obtained with the aid of this constant only if the intensity of the light source does not vary. The light emitted by incandescent lamps changes in intensity, however, owing to the gradual deterioration of the filament. The electrical resistance of the filament changes and a black deposit is caused to form on the walls of the lamp, and it is continually necessary to adjust the intensity of the light in the gate of the printing machine.

The visual methods employed in the past in this connection were inaccurate and unreliable, since the human eye is subject to physiological influences that can not be controlled. The apparatus devised by Messrs. Gans & Goldschmidt for this purpose therefore represents an important step forward in the development of printing

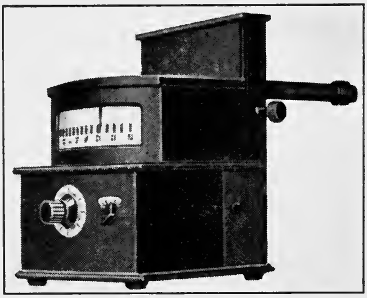

FIG. 2. Instrument for controlling the light intensity of lamps used in printing machines.

technic. This instrument combines the photoelectric cell with the Mihaly circuit, and by its aid all printing lamps can be accurately and easily checked.

This instrument is shown in Fig. 2. In appearance it is similar to the exposure meter, excepting that the photoelectric cell is affixed to the apparatus; the tube fitted in front of the cell serves only to form a light-tight connection to the printing gate which, as a rule, is not easily accessible, owing to the construction of the printing machine. To the front of this tube is fitted a rectangular frame, which is placed over the printing gate while the measurements are made and which is absolutely light-tight.

In order to make the required determination, the instrument needs only be placed close to the printing machine, any difference between the level of the tube and the printing gate being adjusted by means of a tooth rod and worm gear (note the milled knob below the tube in the illustration). The battery current is then switched on (4 volts), the readings of the indicator noted, and, if necessary, the position of the lamp or the current supply adjusted until the indicator points to the correct reading. In this manner it is possible, especially in printing laboratories where several printing machines are in operation, to control the lamps very quickly and accurately.

INSTRUMENT FOR DETERMINING SCREEN BRIGHTNESS

The standardization of screen brightness in the cinemas has long been the unfulfilled wish of every film technician. Not until we have uniform screen brightness in all theaters will it be possible for the

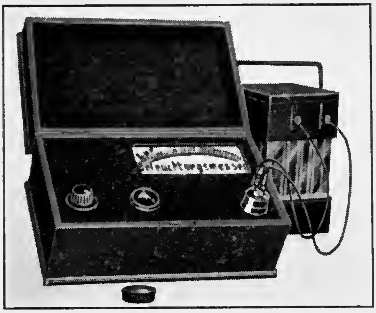

FIG. 3. Instrument for determining screen brightness.

printing laboratories to deliver prints that will always be of the correct density wherever they may be exhibited. The practice often resorted to in the case of trade shows, of adjusting the density of the print to suit the particular requirements of the theater in question, should have been abandoned long ago. To avoid being misunderstood, we wish to point out that the term "screen brightness" does not mean the intensity of the light thrown upon the screen, but the light reflected from the screen toward the audience. Since the reflecting power of different screens varies considerably, especially of the porous screens used for sound film projection, the screen brightness of two surfaces can vary widely even though the illumination may be of the same intensity in both cases.

The apparatus devised by Messrs. Gans & Goldschmidt for determining the screen brightness is shown in Fig. 3. It consists of a small compact box in which both the photoelectric cell and the measuring mechanism with the Mihaly circuit are contained. In the front right-hand corner is the plug for the storage battery; in the center the photoelectric cell which, when not in use, is covered by the cap lying in front of the box; and on the left is the switch for operating the instrument. Above the cell and the plug is the scale of the galvanometer. In order to ascertain the screen brightness, the box needs only be placed opposite the center of the screen, while the projector is operated under normal projection conditions but, of course, without film. The distance must always be the same in proportion to the diagonal of the screen, if the determinations are to be comparative.

The instrument is usually calibrated from 0 to 50 or 150 lux. The scale can be extended as desired by placing over it a closely fitting lid with holes (similar to the tube sensitometer) or by means of neutral gray filters. The surface brightness of the screen can also be determined from different points in the auditorium in order to obtain an idea of its scattering properties. This instrument will also indicate the intensity of the light thrown upon the surface of the screen.

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THE SENSITOMETRIC CONTROL OF SOUND RECORDS ON FILM*

ALFRED KÜSTER AND RICHARD SCHMIDT**

Summary.—*The paper describes a method of measuring gamma by means of the Agfa gammameter without its being necessary to make absolute measurements of density or plot sensitometric curves. The results obtained with this instrument are presented and are applied to a discussion of the Callier and Schwarzschild effects on the gamma of the variable density sound track.*

The importance of controlling gamma in recording sound by the variable density method has been dealt with often before. It is the purpose of this paper to show how gamma can be measured with the Agfa gammameter, by means of which one can determine the gamma values very simply and quickly, without measuring the densities and actually plotting the sensitometric curves. Fig. 1 shows a photograph of the various units that comprise the instrument.[1] On the left is shown the exposure box, in which the sensitometric strips are flashed; on the right, an illuminator and a set of comparative tablets upon which the developed strips are examined. The exposure box is equipped with a 40-watt frosted lamp, and on the top is a glass plate carrying a density tablet of 5 steps in neutral gray. The film to be exposed is placed upon this tablet, which is then covered; and an exposure is made the full width of the cine film for a varying number of seconds, according to the sensitivity of the material to be tested. The ratio of light transmitted by the lightest and darkest steps on the density scale is 10 to 1, or, as expressed in terms of density, log OU = 1.0. The amount of light transmitted increases from one step to the next by a factor of 1.8 (log $\Delta OU = 0.25$). The range of 10 to 1 for the variation in light would seem to be sufficient for the purpose of the gammameter, as there is at present no variable density method that covers a greater range of exposure with a variable slit and a constant source of light. It is very important that measurements of gamma be taken only over that portion of the sensitivity curve that

* Translated from *Die Kinotechnik*, **XIII** (Apr. 5, 1931), p. 123.
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is actually used in recording sound upon the film by this method, as there is usually a difference in the slope of this curve at various densities of the film.

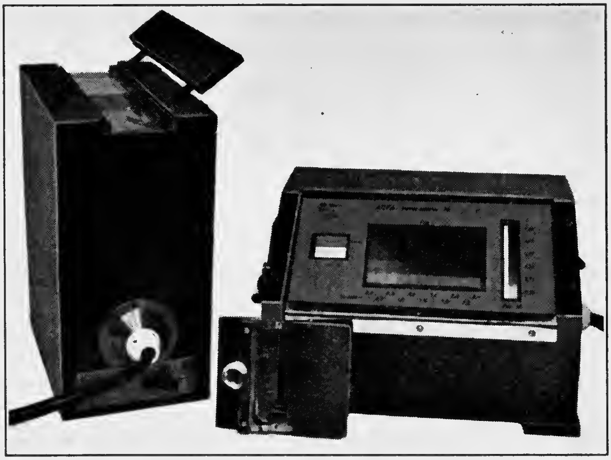

FIG. 1. Gammameter: left, flash box; right, comparison box; center, nickel mask.

The gammameter strip should be developed at the same time as the sound negative; in fact, they can actually be printed upon the same film, or the test strip may be attached to the sound negative and put into the developing machine at the same time. After devel-

FIG. 2. Gammameter test strip with sound track.

opment, there will be on the test strip five different steps of density, as shown in Fig. 2. This printed scale may now be placed upon the glass plate of the comparison illuminator in such a way that the darkest step of the scale to be measured covers the lightest portion of the scale upon the comparison tablet as shown in Fig. 3. The face of the comparison box shows eleven narrow density scales of five steps each, set side by side. These densities are so made that they match with the exposed test strip in such a way as to give the gamma values 0.4, 0.6, 0.8, 1.0, 1.2, 1.4, 1.6, 1.8, 2.0, 2.2, and 2.4. In order to find the correct reading on the exposed strip, it is necessary to move it across the face of the box until all 5 steps on the strip that is being tested appear to have equal density when superimposed upon one of

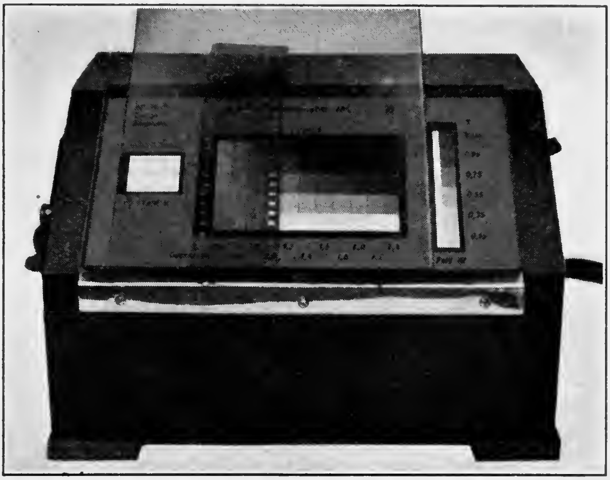

FIG. 3. Testing gammameter strip; a uniform density is shown in the second scale from the left. For convenience in making the readings, a transparent shield, placed over the face of the gammameter, is used to hold the film down.

the eleven comparative scales. We then have a gamma reading at that point. Fig. 3 shows that the second scale from the left, when viewed through the test strip, shows a uniform density and, at the lower end of this strip, we read the gamma value 0.6. It is very easy to get the exact gamma reading with this method up to a value of 1.4, but with higher gamma values, there is a tendency for the light from adjacent areas so to blind the eye as to make exact comparison difficult. For this purpose, the equipment includes a small nickel frame, shown in Fig. 1, which can be used in reading gamma values higher than 1.4.

It has been shown that it is possible, with the indications of the gammameter, to control development to certain gammas in a continuous developing process. Assuming that the degree of development of the sound track is the same as that of the test strip, it was found in our experiments that there are two effects that tend to cause measured gammas for the sound track to differ from those for the test strip: one, the "Callier effect," described in a previous paper,[2] wherein it was shown (not overlooking the influence of the sound recording and reproducing optical units) that the effective gamma in the sound print was about 1.2 times as great as the gamma shown in the diffused light of

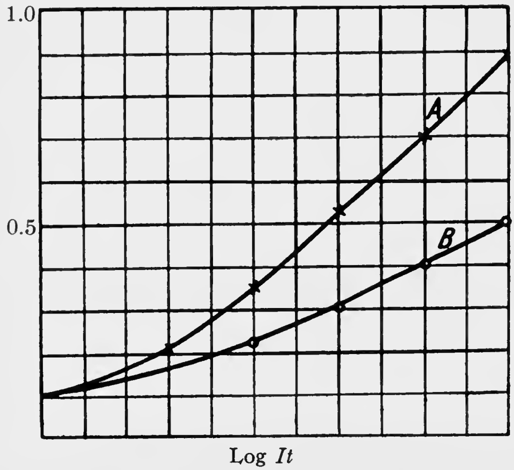

FIG. 4. Agfa *Tf3** film developed in Agfa 12 developer; *A:* sensitometric strip exposed 20 seconds; *B:* sensitometric strip exposed 1/20,000th second.

the gammameter. The other phenomenon that influences the gamma of the sound record but, in the opposite direction, is the "Schwarzschild effect." If the gamma of the sound record and that of the gammameter test strip both be judged in diffused light, the gamma of the sound record will be lower than that of the test strip that was developed at the same time. In practice, these two phenomena to some degree compensate for each other, leaving a factor, described later in this paper, by which the value given by the gammameter must be multiplied in order to give the true gamma of the sound record under sound reproducing conditions.

* *Tf3* film is a specially made sound film used extensively in Europe.

As this is the first time that the Schwarzschild effect has been considered in reference to sound recording, we feel that a more complete description of it is in order. For the purpose of demonstrating this effect, the same sensitometric scale was printed twice on the same film, Agfa *Tf*3 (see Fig. 4). In the case of *A*, the exposure was 20 seconds; in the case of *B*, $^1/_{20,000}$th of a second. All conditions, that is, color of light, development of film, *etc.*, were maintained constant except the time and the intensity of the light. The difference in gradation that was obtained with these two exposures is shown in Fig. 4. The test strip *B*, which was exposed with the high intensity of light for a short time, has a flatter gradation than the other one, *A*, which was exposed with a low intensity of light for a long time. The development of the film undoubtedly has some influence on this effect,

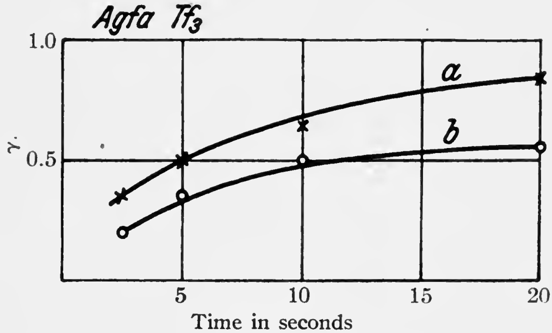

FIG. 5. Showing effect of rate of development; *a:* gammameter test strip; *b:* sound record.

and experiments along this line are still being carried on. It was necessary to determine whether the difference in gradation could be explained on the basis of a slower development of an image such as *B*, or whether even with maximum development the gamma of *B* was actually lower than that of *A*. The answer is shown in the curves in Fig. 5.

The time of development in minutes has been indicated on the abscissa and the values of gamma on the ordinate. Curve *a* is the gamma-developing time curve for long exposure and low intensity (the gammameter strip) and curve *b* is the gamma-developing time curve for short exposure and high intensity (sound record). The Agfa No. 12 developer formula was used. These curves show that the gammas of *A* are higher than those of *B*. It is also possible to find from curve *b*, and curve *a* the corresponding gammas for the same developing time. For example, in Fig. 5 we find the gamma of the test strip on *Tf3* film, curve *a*, to be 0.55 after 6 minutes' development. The corresponding value for the sound record, curve *b*, is a gamma of 0.35. We find also that a gamma of 0.55 is obtained for the sound record, curve *b*, with a developing time of 18 minutes, while curve *a* shows that 18 minutes' development of the gammameter strip produces a gamma of 0.9. Curves may be plotted for each kind of film material and developer,

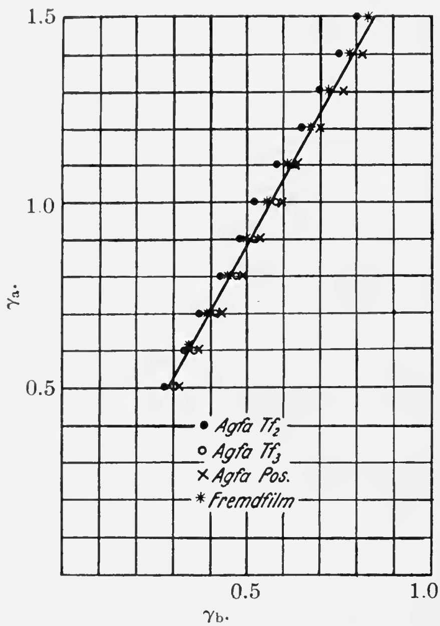

FIG. 6. Gammas of sound record plotted against gammas of test strip.

and from these curves the correct developing time for any desired gamma of sound record can be determined, and the constancy of the value can be tested with the gammameter test strip.

We can still further illustrate these facts by plotting the gammas (γ_b) of the sound record against the gammas (γ_a) of the test strip, both having been given the same developing time as in Fig. 6, where values are shown for four types of film used for sound reproduction. The values for the same material and the same developing time form an almost straight line. Using Agfa No. 12 developer formula the line points toward zero, making with the abscissa axis an angle whose tangent has an average value of 1.7. We can therefore conclude that the gammameter test strip gamma is 1.7 times as great as the gamma of the sound record developed for the same time in No. 12 developer formula.

If we now combine the results of the Schwarzschild and Callier effects on the gamma of the sound record, we find that the Callier effect caused the effective gamma of the sound record (in the optical system of the reproducer) to be 1.2 times as great as the gamma obtained by diffuse density measurements; whereas, on account of the influence of the Schwarzschild effect, the gamma of the test strip is 1.7 times as high as the gamma of the sound track. The effective gamma of the sound track is then equal to the gamma indicated by the gammameter, divided by 1.4. The quotient of 1.4 is obtained by dividing the Callier factor of 1.2 into the Schwarzschild factor of 1.7. If a developing formula other than No. 12 be used, the factor will, of course, be different. A later paper will deal with these factors for various developers.

Summarizing the results, we find that with the same time of development, sound records that have been made with high intensity and short exposure will show a lower gamma than a sensitometric strip that has been given a longer exposure with a lower light intensity. We have found that for Agfa No. 12 developer, the gamma of the sound record is 1.7 times as low as the gamma of the sensitometric strip. On the other hand, the effective gamma of the sound record as exposed through the optical units of the sound reproducing equipment is 1.2 times as high as that of the sensitometric strip, which has been developed for the same length of time, when measured in diffused light. As the result of both these phenomena, whose influences are opposed to each other, we find that the sensitometric strip as measured in diffused light and developed in Agfa No. 12 developer has a gamma 1.4 times as great as that of the sound record similarly developed. Therefore, it is necessary to develop the gammameter test strip to a gamma equal to 0.8 if we wish to obtain a gamma of 0.55 on the sound record.

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MOTION PICTURES IN THE U. S. NAVY*

CHARLES E. FRASER**

Summary.—*This paper presents briefly the part played by the motion picture in the general scheme of the Naval organization, touching on its entertaining, instructional, and recruiting value. For entertainment alone the Navy owns, in duplicate, 467 features, and is acquiring monthly an average of 25 features and 5 short subjects. The Naval requirements of censorship, processing, longevity, and special machine design are mentioned, in addition to the probable future requirement dealing with the restoration of historical film records that have deteriorated with age. Exchange problems and methods are discussed.*

For many years the motion picture has been an integral part of the Navy's recreational resources, and it is estimated to comprise about 45 per cent of the personnel diversion aboard ship. The ultimate fighting efficiency of the ship is only as effective as the morale of the crew. Napoleon's analysis was that morale is to material in the ratio of 3 to 1. In time of war the ship's personnel will probably be so busy, and the routine will be such that the motion picture apparatus will be abandoned. It is therefore a peace time equipment.

When a ship leaves port for fleet rendezvous or to attend manœuvers, the regular routine begins; under normal conditions it will comprise three shifts for some divisions and one shift for the remainder. Eight hours are thus devoted to duty and sixteen hours to recreation and rest.

It is not good for the morale of the crew to enforce idleness. Idleness may arouse thoughts and states of mind that may or may not be for the good of the service. At any rate, the part of the sixteen hours in which the members of the crew are unemployed and awake is given to recreation, under the direction of those who have a deep interest in the welfare of body, mind, and soul.

Athletics answer very well for the body, and hence athletic diversions are used to the utmost. The results of this form of diversion are visibly apparent. The control of the mind and soul is not so easy

* Presented at the Spring, 1932, Meeting at Washington, D.C.

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and not so visible. The motion picture assists in filling this need admirably, and therefore vast sums, compared with those spent for other forms of diversion, are expended upon this form of amusement. The Navy maintains the largest entertainment enterprise in the world—over 300 "theaters," three large distribution exchanges, and 1000 feature programs constantly in circulation.

The expense of the motion picture entertainment is not a public expense entirely. Much of the equipment is purchased with private funds collected from the Navy personnel. The pictures are purchased on contract, and are paid for with private funds, also contributed by the Navy personnel. The machines are maintained by the Navy. This part of the expense is paid for with public funds. By far the greater part of the expense of this valuable means of recreation is borne by private contribution of the Navy personnel. The pictures purchased on contract from the producers are, before being accepted for circulation, carefully censored, in accordance with the standards of entertainment, education, and morality established by the Navy. The moral standard that was established proved rather embarrassing recently. The Naval Department ruled out all gangster pictures, and, as about four out of five productions at that time were of that type, it was difficult to obtain satisfactory features. The advent of sound aggravated this condition, as in the silent pictures only the action required censoring, whereas in sound pictures both action and speech must be considered, and as a consequence, the available material is further limited. Often pictures that were passed by the National Board of Censors as fit and proper for the general public, regardless of ages, were prohibited for use in the Navy. Our morals are, therefore, well guarded.

On November 1, 1931, the Naval contract for over one million dollars worth of sound picture equipment was completed, and all apparatus was delivered for installation. Since that date, practically all the Naval ships in the territorial waters of the United States have been equipped with the sound picture apparatus.

This apparatus was described in detail before the Society in October, 1931.[1] The equipment at that time was untried, none having been delivered. It will be sufficient, however, to state now that it is functioning well and up to expectations, evidencing the wisdom of the designers and builders as to its performance under the stringent conditions imposed by Naval service.

However, many features embodied in this apparatus were found, during the course of construction, to need improvement, not particularly in design, but rather in respect to adapting the equipment better to the service. Profiting by the experience thus gained, the purchasing specifications were completely rewritten on March 1, 1932.

One of the most important changes refers to the standardizing of a single type and size of projector for all classes of Naval service. Such a procedure will simplify the operator problem, making it necessary to familiarize the men with only one kind of projector, and will facilitate the repairing, which is done in the Navy's shops. It will also make it practicable to stock a limited number of spare parts, and will make all Naval projectors interchangeable throughout the service, a condition that is highly desirable because of the isolation of the exhibiting units.

The projectors, in addition to being standard for all service, are of the semiportable type, a base, which will fit any projector, being used for booth installations.

Considerable trouble has been experienced in connection with using the ship's d-c. lines as sources of power. The present exciter lamps are rated at ten and twenty-seven volts; they are excited from the ships 110-volt d-c. lines, the current being limited by means of a suitable resistor. The new equipment must be completely operated by a 60-cycle, 115-volt, a-c. source. Where direct current is required, it must be supplied from power packs. The power specification was prompted both by difficulties experienced with present apparatus and by the possibility that on future Navy ships of certain classes alternating current may be used almost exclusively.

When silent film was used, all stock was "processed" after delivery at the exchange. The Mackler process was used, a form of wax processing, which cleaned the film and made an attempt to waterproof it. The waxing process was only partially effective, but it was the best available at the time. Although the films were protected to a limited degree from dampness, they were far from waterproof.

When using sound film, any form of processing or treatment that is used must take into account the sound track. One of the first difficulties encountered on the original investigation of sound pictures on the U. S. S. Texas in 1930 was in connection with "processed" sound film. The processing wax softened under the effect of tropical heat, and moisture and wax accumulated in the sound gate to such an extent as to cause a complete shutdown of the performance.

This occurred not only with film taken aboard at New York City, but with film obtained at Panama, Cuba, and New Orleans as well.

This experience showed that a sound gate must be developed that would not be affected by reasonably large deposits, or that the wax now used in the "processing" must be eliminated.

The film used by the Navy undergoes treatment to which no commercial film is subjected. All film aboard ship must be stored above the gun deck. This means above the dry line of the ship, as the gun deck and all that is above are subjected to atmospheric moisture and water. To be sure, the film is stored in the regulation metal shipping containers, but these are designed primarily to be fire-proof and not water-proof.

The film must be handled with great care, both in and out of the machines, for two reasons: the first is that of cost, as the film is purchased outright; the second is that the distribution system, under which the shows pass from ship to ship, would be interrupted seriously if a film were to become damaged prematurely. Some films must be used 50 or more times before being returned to the exchanges for extensive overhauling. Using normal film in good condition, we can be assured of giving 500 performances with our projectors without damaging film to any extent. This is, of course, assuming that the film will be properly handled by operators and shippers, and that it is passed through the machines in good condition. These requirements are not always fulfilled, but we can figure on 75 shows per film under normal conditions. It is clear, therefore, why the Navy requires that the film operating parts of the machines be so designed as to impose as little wearing of the film as possible. These requirements have been severely criticized in the past by manufacturers of projectors, their contention being that the film deteriorates from causes other than wear before 800 showings have been achieved. The Navy requires that the continuity of circulation by programs be maintained with long periods between major repairs. The only way to accomplish this is to eliminate as far as practicable the causes of damage. Experience has shown that stored film will last one year. Therefore, if the damage sustained during handling can be so regulated that major repairs will not be required during the first year, even up to the maximum number of showings, we can reasonably be assured of continuity of circulation of programs. We pay in design, not for economy in film consumption. but for the assurance to the Navy of a movie show.

The undesirability of making major repairs of silent film was obvious, but the cutting of sound film without making the necessary replacement of footage may ruin a show by interfering seriously with the sound continuity and intelligibility. Repairs would have to be made at sea without making replacements; and, therefore, the condition that was, to say the least, undesirable in the case of silent subjects, namely, that of making repairs at sea, becomes intolerable with sound pictures.

All film and feature pictures are obtained under contract, included in which is a clause restricting the performance entirely to officers and enlisted personnel of the Navy. Civilians, even at isolated stations, are not permitted under the contract to witness Navy motion pictures. Under such a contract the Navy can obtain the latest pictures, and can show them without interfering with local exhibitors.

The Navy at present is obtaining an average of 25 features and 5 short subjects per month. There are at present 467 features in circulation in the service. These are all in duplicate, half being sent to the east coast and half to the west, comprising 934 complete feature programs in use. At present, the Navy has on hand about 8500 reels of sound film. All the above figures apply to film used for entertainment only. As the procurement continues from month to month, this figure is rapidly being augmented.

There are about 1400 silent features on hand, but these are being removed from the service and scrapped as fast as they are returned to the exchanges. A large proportion of these films are in the Asiatic station where only silent apparatus is at present installed. Equipment for sound, however, is being shipped, and it will be only a short time before the entire Navy will be equipped for sound reproduction.

In addition to the entertainment of the Navy, the motion picture plays an important part in training officers and men. There are in the Navy several ships that are fitted out as floating studios for producing silent film. On these ships it is possible to photograph, develop, assemble, and print complete motion pictures.

The pictures are generally limited to educational subjects, principally ordnance. Complete photographic records are made of every target practice, and the pictures are taken in sufficient locations to give a true story of the gunnery. These pictures are then used to demonstrate just what happened when the scores were low or high; they are exhibited only before classes of officers in training, accompanied by lectures and data pertaining to spotting. The use of this form of the motion picture, it is needless to say, is highly confidential. The inauguration of stereoscopic or three-dimensional pictures would be invaluable in this class of work.

There is yet another class of service, silent at present, but rapidly entering the sound field. The Navy Recruiting Bureau, in addition to making and publishing film on subjects valuable to the recruiting service, is in charge of thousands of feet of film invaluable beyond measure, for the reason that it can not be replaced. This film consists of the motion pictures taken during the World War, of inestimable value in point of Naval strategy. This film was made 14 years ago, and the negatives have, therefore, been carefully stored over this period. Prints have been made, but so far as wear is concerned, the negatives are in good condition. The film is gradually deteriorating with age, and in a relatively short time will become too brittle to use safely for printing. There are at present about 100,000 feet of this film on hand. The Navy is at present investigating the possibilities of the so-called reconditioning processing. It can be appreciated that the adoption of any such treatment will be approached with extreme caution.

At the present time all Navy film is being "processed" after printing, so that new film is delivered already processed. The method used is fairly satisfactory, but the films have not to date been in the circuit long enough to enable us to reach a definite conclusion as to the merits of the process. No provision has so far been made for cleaning and reprocessing sound film at our exchanges; but this will eventually have to be done, as the volume of film in service increases and as the film is returned from the circuit in need of major repairs.

The Navy at present is greatly interested in discovering a satisfactory processing system that will render film oil-proof and waterproof, and will not allow dirt to accumulate or a deposit to be left on the film gates. This processing must not interfere with the quality of the sound or the scene. Any system that is to be used, to be successful for Naval service, must be such that the processing material will become an integral part of the film and emulsion structure after application. The material that is used must also be such that it will not chemically affect the film as to tensile strength or aging. This latter is important, as all Navy film is purchased outright, and is used for years before the subject becomes obsolete.

In addition to processing, a system of reconditioning the stored film in the war library will, in a short time, be an urgent necessity, if this film is to be preserved for future use.

An effort has been made in this paper to describe the part played by motion pictures in the general scheme of the Naval organization. Motion pictures have a definite value from the morale standpoint. They furnish, to be sure, entertainment, but entertainment only as it affects the efficiency of the personnel. The motion picture is permitted aboard the Naval ships only in respect to its general value to the organization, and occupies its place purely by virtue of its usefulness, as is the case with all equipment on a fighting unit of the Navy.

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FINISHING A MOTION PICTURE*

W. C. HARCUS**

Summary.—*The motion picture editorial problem is discussed in the form of a comprehensive outline of the steps involved in creating a finished production seven or eight thousand feet long from the several hundred thousand feet of film photographed and recorded for this purpose. Illustrations are given disclosing the problems confronting the director and film editor who are responsible for this work. The contributions of other technicians are described in some detail. A description of a typical Hollywood preview is given and its value to the producer demonstrated.*

It may never have occurred to those who have not been directly concerned with the production of motion pictures that a picture is far from complete when work is finished on the stages and the actors have been dismissed. As a matter of fact, in most cases the expenditure of time and money up to this point has simply resulted in the accumulation of several hundred thousand feet of picture and sound track film. Since the average length of feature pictures as shown in the theaters is but seven or eight thousand feet, it is apparent that the greater part of this tremendous mass of material can not be shown. The dramatic and artistic values of the completed production will depend to a very large extent upon the skill and intelligence used in selecting the material and upon its arrangement in a clear and logical order that will develop and hold the interest and attention of the audience before which it is to be presented. A very important contribution to the success of a picture is made by the group of men who are responsible for the editorial function.

In considering the technic that has been developed for editing film, it may be presumed that in the preparation of the original scenario or script the dialog and action were completely thought out in detail so that all the necessary material is at hand. In the economical production of sound pictures it is essential that each scene be weighted according to its proportional value to the production as a whole and its approximate footage estimated; also that each scene be con-

* Presented at the Spring, 1932, Meeting at Washington, D. C.

** United Artists Studio Corp., Hollywood, Calif.

sidered from this standpoint as to the camera angles needed to portray best the proposed action. This amounts to cutting the picture tentatively in advance of shooting and may be called pre-editing. A unique example of skillful pre-editing is disclosed in the first scenes of a recent photoplay, *Dr. Jekyll and Mr. Hyde*, in which the audience views the action through the eyes of Dr. Jekyll, and does not see him until he eventually approaches a mirror. In another instance, the ballroom scene in a recent Chevalier picture was photographed in synchronism with a previously recorded sound track of *One Hour with You*, which ran the full length of a sequence. It would have been impossible to obtain the smoothly flowing transitions from one group of players to another, or the high-quality song record, with a less skillfully planned and executed handling of the action. While it is possible to change some of the action in a picture while it is in production, this has to be done with discretion, as it may adversely affect portions of the work that have been completed as well as the previous plans for the work that has yet to be done. Certain types of comedy, such as the pictures in which the four Marx brothers appear, use a script as general outline; but most of the stage business and humorous lines and gags are more or less spontaneous, and are developed on the set.

Pre-editing was not so necessary for silent pictures, which consisted essentially of illustrated titles that could easily be rewritten and re-illustrated. In the case of sound pictures, recorded dialog can not be changed so readily, as audiences are accustomed to reading the lips of the actors, and immediately notice and criticize speech that is not in exact synchronism with the picture. An example of an attempt to change the dialog is seen in *Beloved Bachelor*, in which Paul Lukas is heard singing a lullaby to a child. Several attempts were made by Lukas to match words to a recut version of the picture by a dubbing process, but all were imperfect to an extent that was commented upon by many audiences. While words and phrases can be deleted by skillful cutting, a retake of picture and sound is generally required to obtain an acceptable result when it becomes necessary to change dialog delivered in close-up.

While the production company is working on the stages, the picture and sound negatives are processed each night, so that during the next day all prints desired by the director are available for review. These prints are called "dailies" or "rushes," and are carefully processed by the laboratory so that the quality of the photography and sound can be accurately judged as well as that of the direction and acting. From those that fulfill certain technical requirements, the director selects the best one of each group of takes of the same scene for use in the picture.

All motion picture production is handled on the double-film basis; that is, the picture is on one negative and the accompanying sound record is on another. With few exceptions, the daily prints are also made on separate films, creating a problem of obtaining and maintaining synchronism. Various methods of establishing synchronizing marks on the picture and the sound negatives which depend to some extent upon the camera motor system used are in use; but in their simplest positive form these methods consist in making punch marks on each at the beginning of every take. These marks appear on the daily prints together with identification slates or numbers that are used as cross-reference records by a script girl on the stage. The daily picture prints are classified according to the cameras used, all those made with a single or master camera being designated "*A* angles." If more than one camera is used simultaneously, the work of the second camera would be called "*B* angles"; a third, "*C* angles"; and so on. The "*A* angles" are assembled for the daily review in synchronism with the sound track; the *B*, *C*, and other angles are each assembled so that they will be in synchronism with the same sound track to avoid printing an additional duplicate sound record. In order later to permit removal of the original synchronizing marks during the cutting operations, serial numbers are applied to the edge of each foot of the daily prints, this being done in such a way that by matching the edge numbers all the angles of a given take will be placed in exact synchronism with the sound track.

The film editor and his assistant proceed to break down the assembled daily after selections have been made, and the rejected takes are stored for possible future reference. The selected takes are then assembled in continuity in so far as complete material is available at the time, to form each scene and sequence and eventually the finished picture. The mechanical technic of assembling the selected takes in continuity is fairly simple. The principal tools required are: a synchronous rewind consisting essentially of two or more sprockets mounted on the same shaft so that film being rewound from a number of reels will remain in synchronism at the sprockets at all times; a Moviola or small film-viewing machine so arranged that picture and sound films can be run through in contact to locate the exact point for cutting; a film-splicing machine; and a pair of scissors. In some studios most of the rough cutting is inspected on sound reproducing Moviolas, in others the inspection is handled in small review rooms equipped for projecting separate picture and sound film. As each sequence is cut together by the film editor in accordance with the script and the current ideas of the supervisor and director, it is reviewed again and again so as to "smooth out" the awkward spots, the takes and angles being changed as required to obtain the best result. Since this work is carried on as soon as possible after the material is shot, those portions that seem to warrant retakes or added scenes can often be made while the company is still on the same set.

Within a few days after the production unit has finished shooting, the editing of the sequences is completed, and it is then possible to complete the assembly of all the sequences into a "cutting print" (sometimes called a "working print"). The cutting print forms the first rough semblance of the finished picture, and is generally found to be from ten to fifteen thousand feet long. It becomes the task of the supervisor, director, and film editor to refine and rearrange the elements of the picture into a smooth, coherent, well-balanced photoplay of normal length. Certain scenes and sequences are shortened or removed so as to quicken interest and maintain the tempo; others are lengthened so as to emphasize essential detail. It is usually at this stage that many of the incidental bits of action that were thought to add "atmosphere" to the production are eliminated, to the disappointment of many a Hollywood extra player. In a recent production, *Broken Lullaby*, for example, almost as many of the beautifully directed characterizations of the townspeople of the little German village were eliminated as were retained. Occasionally a production is temporarily stopped before completion in order to determine whether certain sequences in the script are really essential; such an instance occurred during the filming of *Shanghai Express*, when completion of a preliminary cutting print disclosed that a very thrilling (and costly) running battle between government troops and revolutionists on two moving railway trains was unnecessary. In other cases, particularly when transparency and trick photography are involved, the shooting is deferred until the first rough cut of the reels concerned is available, so that the photographic quality can be matched more precisely and so that the action in these more complicated processes can be compared with that already completed. Such was the case in *The Right to Love*, when all the action in which Miss Chatterton played two rôles simultaneously was cut completely, prior to shooting the transparency work in which both characters were introduced into the one negative.

The time required to complete the cutting print varies considerably, depending upon the nature of the picture and the individuals doing the work, as well as upon the release date that has been scheduled. As outlined above, editing commences as soon as the picture begins on the stages, and occasionally the cutting print is ready for approval a week after the shooting is finished.

Methods of handling the subsequent work, after the cutting print is approved, are subject to variation, depending upon the practice that has been developed in each studio. One of the most successful procedures, technically, will be described. The approved cutting print is sent to the film laboratory and the negative is cut to match it as a sample. A double-film "feeler print" (or "second working print") is made from the cut negative, and is compared with the cutting print for accuracy and to ensure that words or syllables have not been clipped from the sound track. The feeler print is then reviewed by representatives of the studio technical departments, who consult with the supervisor and director as to proposed music, sound effects, titles, and so on, and who outline the work that remains to be done. Those sequences on which work is to be done are listed, and additional "dubbing prints" are made by the laboratory.

A sound-effects cutter now appears as an important member of the staff. From the accumulation of recorded music and sound-effects tracks in the film library, he obtains much of the additional material that is required to enhance the picture, as agreed upon. This he assembles in synchronized reels, or as loops in the case of continually recurring sounds, and turns them over, together with the dubbing prints, as "units" to the scoring and dubbing departments for action. Several of the studios have two or three million feet of library tracks available for this work.

The scoring and dubbing, as is well known, results in the combination of new music and sound effects with the originally recorded dialog, and is done by specialists who fulfill, as nearly as possible and consistent with the limitations of present equipment, the specifications of supervisor and director. This phase of the work develops unexpected production values in many instances, and warrants the closest attention and interest of all those concerned. In the dubbing of *Shanghai Express*, for example, nearly sixty thousand feet of sound track were re-recorded, to obtain precisely the desired balance of dialog and sound effects during the train journey. Special recordings were made of a heavy train running at the speeds shown in the picture to insure correct sound quality. Similarly, in *Sky Bride*, the extraordinarily effective dubbing work was the result of paying infinite attention to detail and to the possibilities of sound. Recordings were made of all available types of aeroplanes in order to obtain exactly the quality of sound desired. If the aeroplane sequences were visualized as they would be without sound, the dramatic contribution of the sound effects to the picture would be appreciated.

As soon as the daily sample prints of the dubbed and scored work are received, selections of the best takes are made by representatives of the departments concerned and are cut into the feeler print for review by the supervisor and director. The feeler print is carefully arranged in reels not exceeding one thousand feet in lenght, the end of each reel being cut at a fade-out between scenes, or at some point where there is no significant sound, to facilitate change-overs from reel to reel in the theater. It is then returned to the laboratory, and the negative is recut to include the new material with scoring and sound effects.

Up to this point all the cutting and editing has been done on double films, the picture being on one set of reels and the sound on another. It now becomes convenient to make the first composite or movietone print, and this is done for preview purposes, the print being called the "preview copy." The picture is then ready to show for the first time to the studio management generally and to the public. Arrangements are made to project it at some local theater as a part of the regular show. The Hollywood preview is a unique institution, and a brief description may be of interest to those who have not had the opportunity to attend one.

A breathless hush with just a brief ripple of applause sweeps over the audience as a silent title flashes on the screen: "A Mammoth Preview—This film is still in process of editing. As you leave the theater a postcard will be handed you. If you will mail it with your comments, it will be greatly appreciated by The Mammoth Film Corporation." Although this title is shown for but twenty seconds, it seems minutes. It fades and the well-known trade-mark appears, to the accompaniment of music or sound effects, followed by the title of the picture and the credit leader. There is a burst of applause and a general buzz of excited comment, which often culminates in a subdued cheer when some screen favorite who happens to be the vogue heads the cast. Another moment, and the opening title fades into the first scene of the picture; the audience settles itself and the preview is under way. The author has observed many strange and unexpected audience reactions at the two hundred previews he has witnessed, and can vouch for the fact that the picture seldom seems exactly the same as it does in the studio review rooms where it is viewed and criticized by those who have "lived with it" for weeks. Different audiences generally receive the picture in about the same way, but some executives believe that a more reliable reaction can be obtained when the preview is advertised to attract people who enjoy the type of picture being shown. Most audiences make a desperate effort to avoid showing emotion and will titter and laugh at a tense or tender scene rather than wipe away a tear. The studio representatives are from long experience quite sensitive to the real feelings of the preview audience, and can generally diagnose the faults and weak spots of the picture at this showing.

No one has learned the formula for making pictures that will appeal to and please every individual who may see them. While the script is always edited initially with known censorship requirements in mind, and the dailies are reviewed in many studios by a censor representative, nevertheless details that may be considered questionable creep into all pictures. Even though every effort is made to delete such items before release to the theaters, the non-uniform standards of the several censor boards in the various states of this country and abroad create a story and editing problem which to some extent is incapable of complete solution. Because of this situation, it is sometimes necessary to modify the prints shown in some localities to a form that hardly resembles the studio version.

Finally the studio management approves the picture for release, although it may be said that it is seldom that any one concerned is entirely satisfied with any picture. However, since it is necessary to work within budgets and to meet release dates, the time available for making refinements eventually ends. The negative is subjected to a final cutting, and a movietone "answer print" is made by the laboratory. The answer print is made with great care to secure the optimum photographic results, reference being made to sensitometric and printer light data derived from the laboratory work done on the previous daily, feeler, and preview prints. The answer print is reviewed by technicians who make appropriate modifications of printer light settings, *etc.*, in advance of a final sample print called the "studio copy." The studio copy represents the standard to which all subsequent release prints are made to conform, in so far as this can be controlled directly by the studio and its local laboratory technicians.

The evening of the première showing comes with its bright lights and brilliant assemblage. There is applause for the stars, the producer, the director, who have used the film medium as a tool to create a new entertainment. The more perfect the illusion of reality, the faithfulness of tone and color values reproduced, the smoothness of continuity and movement, the less conspicuous become the contributions of the many unknown technicians whose untiring efforts have effected this pleasing result.

RECORDING ARTIFICIAL SPEECH IN MOTION PICTURES*

C. W. BARRELL**

Summary.—*For the first time motion picture recordings have been made of human speech recreated by the artificial larynx. A brief description is given of the mechanical voice box that replaces the natural larynx when that organ has to be removed by surgery. The operation of the artificial larynx is contrasted to the action of the human larynx, and the vocal organs in general are shown in combined realistic photography and animated drawings from the sound motion picture, "The Voice That Science Made," which the paper serves to introduce. Some sidelights are thrown on the production of this novel film experiment in popular education.*

With the development and refinement of sound motion picture apparatus, most of the voices of nature have been successfully recorded, from the chirp of the cricket to the roar of the lion. Now, for the first time, the synthetic or mechanically created speech of men using the artificial larynx has been recorded. This remarkable little by-product of telephone research was developed by engineers of the Bell Telephone Laboratories. It has received considerable publicity as an instrument for restoring the power of speech to men and women who have had their vocal cords removed by surgery.

Prior to the invention of the artificial larynx, all such persons were, by the nature of the operation performed upon them, bereft of speech and cut off from vocal intercourse with their fellows. Such a fate can be imagined better than it can be described. This is probably one reason why so few operations involving the removal of the larynx were either attempted or carried to a successful surgical conclusion even as late as ten years ago. The patient's dread of permanently losing the power of speech often caused him to postpone the operation until he was beyond the aid of surgery.

Today the situation shows a change for the better. Recent improvements in the design of the artificial voice box and mastery of the technic of its use have helped to allay the fear of permanent vocal disability following the laryngeal operation, as the patient for whom this type of surgical treatment has been recommended will now give

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* Presented at the Spring, 1932, Meeting at Washington, D. C.

** Western Electric Co., New York, N. Y.

his consent in time to promote its successful consummation, knowing that he can be equipped with an adequate mechanical substitute for the lost vocal cords.

To present this message of reassurance in a simple and realistic manner, as well as to signalize one more interesting step in the progress of the art of communication, has been the object of filming the story of the artificial larynx.

As the overcoming of handicaps represents the essence of drama, we felt that the dramatic element would not be lacking in our film treatment, although, as a matter of fact, we have leaned backward

FIG. 1. Mr. Ernest Bennett using the artificial larynx.

to avoid overemphasizing the pathos and emotion inherent in the subject. We have tried to tell only a straightforward story of the triumph of scientific ingenuity over human disability in terms simple enough to prove understandable to an average film audience.

When the question of filming *The Voice That Science Made* was first considered there was a feeling on the part of some of our people that technical difficulties of a serious nature would be encountered in attempting to record voices generated by the artificial voice box. But having talked over the telephone with the gentlemen directly concerned in the experiment, I felt confident that these obstacles could be surmounted by taking particular care in preparing and rehearsing for the recording. This was because the artificial voices seemed to register more clearly over the long distance wires than many natural voices that I have heard under the same circumstances.

The sound track was recorded and the scenes were photographed at the sound laboratories of the Bell Telephone Laboratories, the work being accomplished smoothly and quickly through the intelligent and generous coöperation of the three exponents of the new voice, Mr. Ernest Bennett of the *Jeweler's Circular*, Mr. E. A. Barvoets of the J. B. Lyon Printing Company, and Colonel Charles C. Burt of the United States Army, retired. None of these gentlemen

FIG. 2. Close-up of the artificial larynx. The upper tube is inserted into the mouth somewhat like a pipe-stem of soft rubber. The lower tube fits over an orifice at the top of the patient's chest, and receives the air from the lungs.

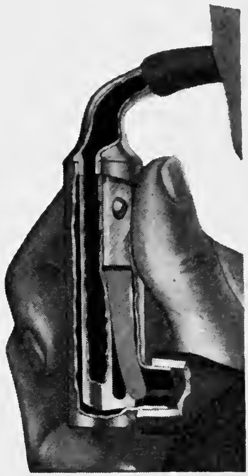

FIG. 3. A phantom animated drawing of the artificial larynx.

had ever faced a microphone or a motion picture camera before, but all three performed with the ease and aplomb of Hollywood veterans.

The placement of the microphone for the scenes in which the artificial voices were recorded was not particularly difficult. The important consideration was to keep the microphone close enough to the speaker to obtain the clearest possible articulation. At no time was the distance greater then two feet.

Animated drawings play an important part in the film, in explaining the action of the natural vocal organs as well as the operation of the artificial larynx. The scene showing animated drawings superimposed upon actual photography was first simultaneously recorded and photographed. Then, as a source of information and to provide a key for animation, a complete study was made of the position assumed by the tongue, palate, and lips, and of the muscular contractions and expansions of the oral cavities when producing speech sounds. This study was based upon drawings made by Professor C. H. Grandgent of Harvard University.

Each syllable recorded on the sound track was marked to obtain a frame by frame record. A positive print of the scene was then numbered and projected frame by frame, so as to obtain tracings of the lip positions for the sounds involved. Each drawing was numbered to correspond to the film frame number.

The lip action and the working key obtained by reference to Professor Grandgent's study of the vocal organs were used as guides in preparing the drawings of the oral cavity and its contents. Then the drawings were photographed frame by frame in combination with a duplicating print of the actual scene. Thus we obtained a composite of animated drawing and realistic photography. The finished scene is approximately twenty feet in length, but it required 285 separate drawings.

INERTIA IN THE SERVICE OF CINEMATOGRAPHY

W. C. PLANK*

Summary.—*This paper is concerned principally with the opposite rôles played by mechanical inertia in the two types of projector, the continuous and the intermittent, special emphasis being placed upon the continuous type. By employing the inertia of the moving parts of the continuous projector, the attainment of accurate registration of successive images is greatly facilitated, whereas, in the intermittent type of projector, the inertia of the moving parts, becoming manifest between successive projections, adds materially to the difficulty of obtaining accuracy of registration, not to speak of the strains induced upon the moving film and parts of the projector.*

In a previous paper[1] the writer pointed out the most significant attribute of the continuous cinematograph, namely, that the law of inertia operates in its favor. In the mechanical arts it is always advantageous to avoid a contest with a natural law, whence it becomes a proceeding of twofold usefulness when we cease to defy inertia and impress it into the service of cinematography. The striking antithesis presented by the rôles played by inertia in intermittent and continuous cinematographs will serve eventually to divide the history of motion picture registration into two well marked periods: the first, in which the law of inertia was opposed consistently; and a second, in which the accuracy of registration was made to depend upon inertia.

We are now entering upon the second period, and motion picture technicians will be eager to learn what improvements in cinematography it holds in store for them. Some have been described previously. In the present paper we purpose to show how the momentum of the flywheel may be employed to increase the precision of motion picture projection; and why the method employing it should be able to maintain a higher standard of quality of projection than the intermittent method in general use.

The claim to greater precision is based upon the proposition that the most precise method of dividing a motion picture film into evenly spaced divisions or frames, is imparting a uniform motion to it and

* San Francisco, Calif.

spacing off the frames by the regular periods of a rotary member revolving at a uniform velocity. This is the fundamental principle of registration in continuous cinematography. An important and practical feature of the principle is that the flywheel offers a simple but exceedingly effective means of closely approximating the ideal conditions in the motions of the film and the rotary member. The system, in which this principle is applied for purposes of registration in the motion picture camera, printer, and projector, may be designated the art of continuous cinematography. It is a distinct motion picture art, characterized by greater precision of registration, and by

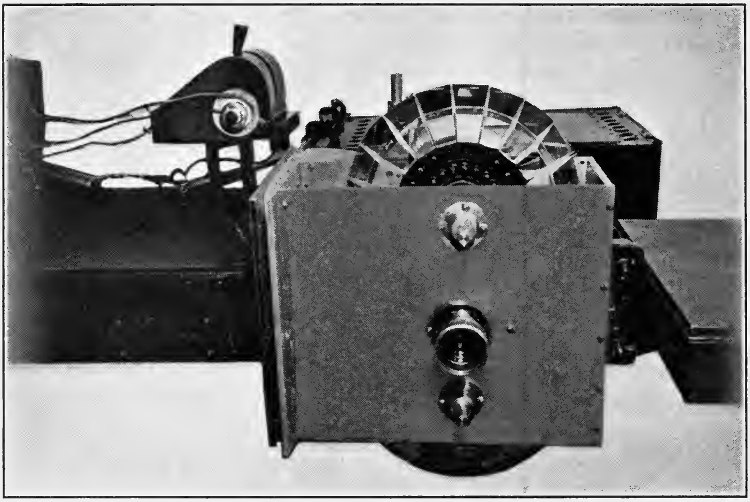

FIG. 1. Apparatus devised by the author.

unique and useful effects that add continuity, plasticity, life, and beauty to the projected image.

In the paper mentioned previously, registration in the continuous cinematograph was shown to depend upon four different factors: a uniform motion of the film, uniform motions of the compensating elements, synchronization, and the adjustment or registration of the compensating elements. As sufficiently heavy flywheels will assure the evenness of the motions, and as synchronism has more to do with maintaining the picture in frame, it may be stated that the most important factor in the registration is the positioning or indexing of the compensating elements. Given a compensating principle that is sufficiently perfect to afford an image having good definition and flatness of field, the performance of the continuous cinematograph will depend almost entirely upon how perfectly the compensating elements have been matched and indexed.

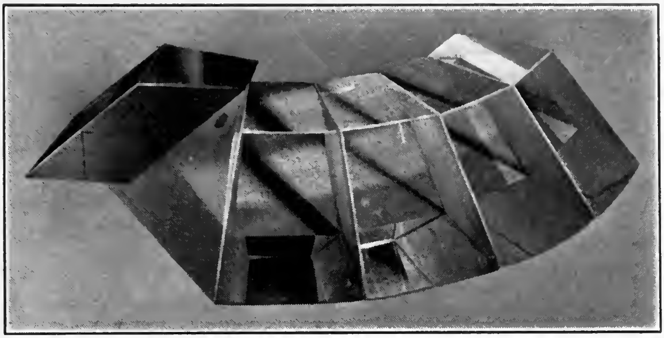

FIG. 2. The rhomboidal prisms used for compensating. The distance between the parallel reflecting surfaces determines the "optical intermittent movement."

Technicians in the industry who are interested in the subject of continuous cinematography should be warned of the many premature opinions that have been issued and circulated on the impracticability of this method. A particularly harmful and misleading one was the

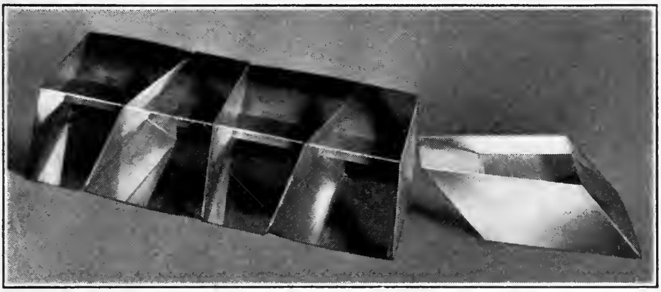

FIG. 3. Another view of the compensating elements.

opinion, given out some years ago by a veteran motion picture engineer, that film shrinkage makes continuous projectors impracticable. Technicians familiar with the flexibility of optical printers and continuous projectors in respect to film shrinkage will regard this opinion as a joke; but it was taken seriously by many. And the rumors extant that continuous cinematographs are impracticable because it is impossible to construct them with sufficient accuracy, are, no doubt, due to the propensity of some motion picture engineers to express and circulate premature opinions.

The truth of the matter is that any amateur who is skillful in the use of tools can construct one that will register with extraordinary accuracy. Reference to Fig. 1, illustrating the apparatus devised by the writer, will show this. It is true that the compensating elements,

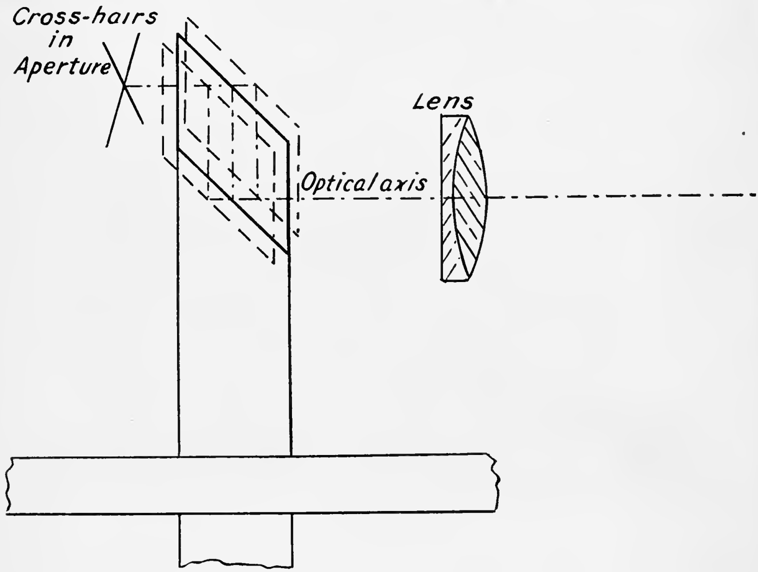

FIG. 4. Diagram illustrating why the prisms are insensible to movements or adjustments other than with respect to the radius. Neither the displacements illustrated nor a displacement perpendicular to the plane of the paper have any effect upon the image.

gears, and sprockets must be made by experts. These parts, however, can all be produced with sufficient accuracy and uniformity. There is nothing impossible or even unusual about manufacturing them within the tolerances required. And there is nothing difficult about constructing the remainder of the mechanism, which consists, essentially, of means for revolving two wheels of compensating elements in opposite directions. The left- and right-hand spiral gears employed for this purpose are the most important parts of the mechanism and must be cut accurately.

The compensating elements are rhomboidal prisms, which are peculiarly easy to match and index. The distance between the parallel reflecting surfaces of these prisms (Figs. 2 and 3) determines the distance the axial ray is to be carried downward, or the amount of the "optical intermittent movement," for a given number of elements on a wheel. An advantage to be noted is the unusual precision with which such flat parallel surfaces can be worked. For this reason, it may be claimed that the optical intermittent movement can be made with greater precision than the Geneva movement ordinarily employed; and that it possesses a further advantage in not being subject to wear.

The uniformity of the displacement or off-set of the axial ray within the prisms is not readily affected in the mounting of the prisms (see Fig. 4), for if the faces are maintained perpendicular to the optical axis the prisms become insensible to every movement or adjustment but one—the adjustment with respect to the radius. This property not only makes the prisms easy to mount, but renders them peculiarly insensible to vibrations. Inclining a prism forward or backward with respect to the optical axis (Fig. 5), moves the projected image laterally upon the screen, and adjusting it with respect to the radial position moves the image up or down. With the means shown in the diagram these two adjustments may be effected with the greatest nicety, and it becomes a simple matter to make the prisms register with precision.

The reflective systems have an advantage in that it is not difficult to match a plurality of plane reflectors or optical flats. Any number of them can be made that will reflect images matching very accurately in size and composition; and as we have shown, it is not difficult to make the reflected images register with accuracy. The off-set or displacement of the axial ray within the rhomboidal prism is varied readily by inclining or tilting the prism. This is equivalent to varying the dimension between the reflecting surfaces of the prism; hence very liberal tolerances may be allowed in the dimensions and angles of the prisms and corrections made in this manner. These details are given to show that the difficulties of constructing a continuous cinematograph have been exaggerated and that it requires no extraordinary skill to make one.

A requisite of the first importance in the compensating principle employed is a rectilinear displacement of all the image points. The definition and flatness of field of the image will be found to depend upon how closely this requirement is fulfilled. Maintaining the image in sharp focus throughout the optically effective movement of the compensating element is an indispensable condition. Any opaque matter, such as the divisions between the compensating elements, will otherwise cause a movement in the image when they cross the light rays. In effecting a straight-line displacement of all the image points, the rhomboidal prism elements exhibit their most peculiar and valuable property. Whether in the camera, or upon the screen—when the film is held stationary and the projector turned—the motion imparted to all the conjugate points is a rectilinear one.

An advantage worthy of notice is that the compensating principle

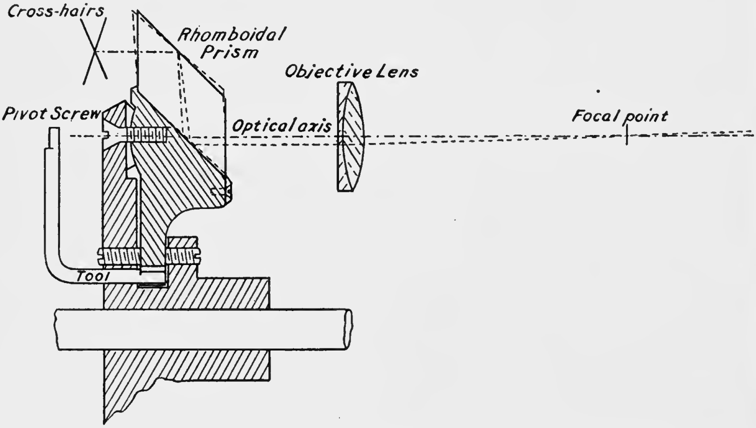

FIG. 5. Inclining the prism with respect to the optical axis moves the image of the cross-hairs laterally upon the screen. Very little of this adjustment is necessary. Adjusting the prism with respect to the radial position, about the pivot screw, moves the image up or down. Spaces up to $^1/_{16}$th inch may be left between the prisms.

is independent of the objective lens. The moving film appears stationary when viewed directly without the lens in place. Objective lenses of any focal length may be employed, and it becomes possible to form a real image within a few inches of the mechanism. A compound objective lens system may therefore be used. It has certain advantages, such as affording a flat field with a short throw and wide angle, and of masking the image with unusual sharpness of outline.

The conditions as to definition with the rhomboidal prisms are very similar to those in prism binoculars, for the axial ray enters and emerges normally to the faces of the prisms; and in its passage through the prisms it likewise undergoes total reflection four times.

But in the continuous projector the illuminating system has a great deal to do with the quality of the image, and special attention must be given to it. Inappropriate condenser lenses may impair the image and be inefficient as to illumination. With an illuminating system designed for the special conditions encountered, a brilliantly illuminated image of the highest quality may be obtained.

The error that is inherent in the compensating principle of all continuous projectors of the strictly rotary type is often the subject of inquiries. Rapid movements blur out the image, so at full speed this error will resolve itself into a blur of the highlights, which becomes manifest on the screen as travel-ghost. As it occurs only through the upper and lower zones of the objective lens, and is faintest where it is the greatest, it is not so apt to be noticed as the travel-ghost of intermittent projectors, which occurs with much stronger illumination. In the present device, the travel-ghost is controlled only by the number of elements on a wheel, for the diameter of the wheel bears no relation to it. Sixteen to twenty prisms on a wheel reduce the travel-ghost to negligible proportions. The effect of the inherent error is also modified considerably by the objective lens. In its downward movement the compensating element brings successive zones of the lens into action, and these zones may vary in aperture, spherical aberration, perspective, and with respect to the sine condition. These variations affect the intensity and the amount of the travel-ghost.

Film shrinkage is compensated for by means of a thin lens interposed between the prisms and the film. This lens is adjustable, so it is a simple matter to magnify the film up to its proper size. The amount of magnification required is usually so little that the weakest sort of lens suffices for the purpose.

The projectionist who is accustomed to the use of tools will now see that it is not very difficult to construct a continuous cinematograph; and that with ordinary care he can make the compensating elements register upon the screen with the greatest precision, and with all the accuracy the dividing head used for indexing was capable of. In fact, any careful person may readily attain registration of so precise an order that the factor of wear must not be allowed to affect it in any way, otherwise such precision were futile. But motion picture registration is here placed upon a much higher plane; it concerns itself only with uniform motions and no longer deals with wear. A surprising amount of wear may be tolerated in the mechanism so long as it does not affect the evenness of the motions. The teeth of the spiral gears, for instance, may be worn thin without affecting it. Wear is thus eliminated as a factor in the continuous cinematograph.

With the compensating elements assembled and accurately indexed, we may proceed to show how inertia is impressed into the service of cinematography. Nothing will serve our purpose better than to refer again to the case cited in the previous paper, in which the compensating elements and the film are driven by separate means. To assure uniform motions in the wheels of compensating elements we shall now mount heavy flywheels upon the two shafts that revolve them in opposite directions. The film is to be driven by a smooth drum mounted on a freely revolving spindle that carries a heavy flywheel and a pulley on its outer end. A rubber idler presses the film tightly against the drum to prevent it from slipping. For the present, the pulley of the spindle is connected to a variable speed motor by means of a light belt.

The relation of the registration to the motions of the compensating elements and that of the film may now be shown. If the compensating elements are held stationary and the film is moved downward, the image of the film will, of course, move upward upon the screen. With the compensating elements revolving at standard speed and the film held stationary, the opposite effect takes place and the image of the film appears streaking downward on the screen. By starting the film in motion, however, and gradually increasing its velocity we may, just as gradually, slow down the motion of the image until we arrive at a point where the frames are held stationary upon the screen. This is the point at which the film photographs and the compensating elements are in synchronism.

The picture may now be kept in frame. On inspecting the image we shall experience something unusual in a motion picture, for it is possible to approach close to the screen to examine it as though it were a stereopticon view. The first thing that attracts the attention is the smoothness of registration—an impressive feature of continuous projection. Freeing the registration from the tyranny of the perforations makes a noticeable difference in the accuracy and smoothness of projection. And we shall gradually become aware of a restful quality in the projection that is new and distinctly "different." This is not to be wondered at, for the picture has been projected by a distinctly different system of cinematography.

Certain crudities in projection, which have long made persistence of vision the foundation and indispensable condition of cinematography, are now missing. The dark periods, or gaps in the projection, have been filled in. The image has been invested with continuity, which gives to it a peculiarly restful and pleasing quality. Persistence of vision is no longer involved in viewing it, and the eyes become aware of the fact. There are many technicians in the industry who seek to minimize the ill effects of intermittent illumination in our motion picture theaters; but it is safe to predict that not a single one of these could be persuaded to use an intermittent light to

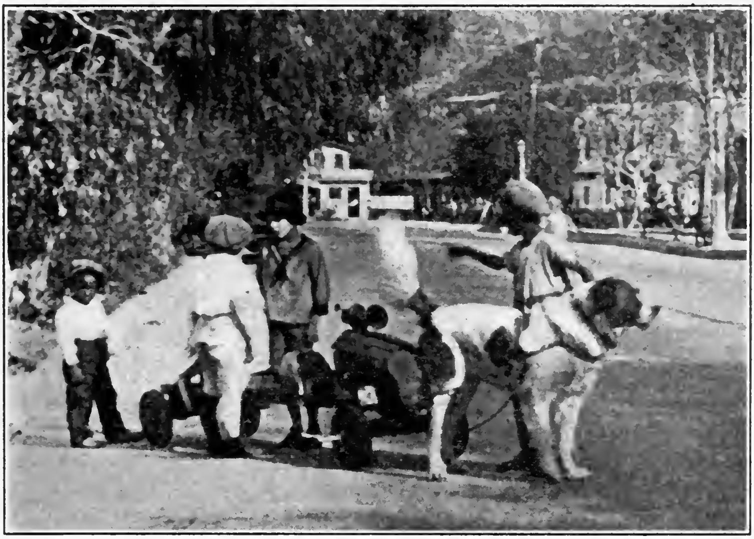

FIG. 6. Photograph showing composite image on the screen, in the middle of what would be the dark period in intermittent projection.

read by at home. In that case they would not hesitate to point out why it is injurious. Projectionists who have a proper regard for eyesight and are studious of its welfare, will appreciate motion picture projection that bears the inimitable trade-mark of continuity.

The continuity of the projection is illustrated in Fig. 6, which shows a composite image on the screen in the middle of what would be the dark period with intermittent projection. These dark periods, in both camera and projector, represent time in the action, which it is impossible to record on the film; so the unusual utility of the continuous projector in reproducing motion on the screen will become apparent when it is shown that it tends to fill in these gaps in the photographic record and to supply the missing action. Capable technicians have questioned the possibility of this. And it must be admitted that it is not possible when the difference in postures between two successive film photographs is so great that no overlapping of the parts occurs when the two images are superposed upon the screen. When there is an overlapping of the two original postures, however, a conspicuous intermediate posture is often formed. The singular property of continuous projectors to form these postures has been described in the paper mentioned above, but the following supplementary details may be added.

The thin hand of the colored boy holding the dog in the photograph illustrates one of these intermediate postures, for it will be observed that it is just half way between the faint outlines of the two original postures from which it was formed. The highlights of the complemental frames tend to obliterate the two original postures except where they overlap, and thus to form a more conspicuous intermediate one. It will be noticed that the index finger of the boy's hand does not appear in the intermediate posture because it failed to overlap.

But the gaps in the photographic record are filled in still more completely by a second phenomenon, which occurs during the dissolve-period, and which we can account for only by the irradiation of the retina. A narrow fringe or border (either of light or shadow), adjoining a larger area, will make the larger area apparently expand or contract with a variation in the illumination of the fringe. For this reason, the thin hand and wrist of the boy will appear to expand or thicken upward, to the upper outline of the fringe, if the upper fringe be gradually darkened until it is of the same shade as the rest of the arm. This apparent motion depends upon the variation in the illumination, and hence it is gradual and continuous and the equivalent of a continuous succession of postures. Therefore, when the change from one film photograph to the other is made very slowly with the continuous projector, the boy's hand will appear to move from the lower posture to the upper one in a continuous and very lifelike manner. The movement thus demonstrated between the two still images represents the action that is missing in the film, that it is impossible to record. It is a subtle and useful motion picture art that can produce the missing action on the screen.

Synchronization of the film photographs and the compensating elements will be found necessary, however, to maintain the picture in frame; for, if the velocity of the film were increased beyond the point of synchronism, the picture would commence to creep upward on the screen. It is here that we find, at last, a use for the perforations. A sprocket on the mechanism, anywhere below the drum and its spindle, may now be used to drive the film, which in its turn will revolve the spindle and its flywheel. We may thus maintain the picture in frame without sacrificing any of the evenness of motion imparted to the film by the inertia of the flywheel. A trace of a loop, between the sprocket and the drum, will serve to absorb the effects of irregularities in the perforations. Wear and inaccuracies in the perforations are thus eliminated as factors in the registration of the continuous cinematograph. Projectionists will readily see in this a practical feature of great significance.

Professional propagandists never cease circulating reports of how impracticable continuous projectors are; so it may prove a surprise to many who have been so misled to learn something of the great practical features of continuous cinematographs. Of these, the most extraordinary is the immunity from the effects of wear. This is the objective constantly striven for in mechanical devices. The reason is quite obvious. The relative worth or value of a mechanism must be reckoned in terms of useful service. A mechanism that lasts twice as long as another is really worth more than twice as much, because the cost of removing the worn one must be considered. For this reason there can be no more important test of practicability than practice—useful service. And by this important test the vibrating mechanisms will be found wanting in practicability, for a sturdily constructed continuous cinematograph will outwear from five to fifty of them.

But the immunity from the effects of wear is extended by the continuous projector to the films that it uses; hence, this practical feature must also be considered when the question of practicability is raised. This is important, for with the other method the film becomes a part of the mechanism, and inaccuracies in the perforations are inaccuracies of the mechanism as far as the effect upon the screen is concerned. But in order to appreciate the continuous projector fully, another feature of great practical importance must be considered—its flexibility as to rates of projection. The intermittent mechanisms lack this practical feature, and any increase in the rate of projection must necessarily involve a loss of accuracy with them. The increase in the rate since the advent of sound has resulted in such a marked falling off in the quality of motion picture projection throughout the country, that it has become a matter of concern to the industry. Let us investigate some of the reasons for it.

All the stresses in the intermittent mechanisms as well as in the films have been increased by the higher rate. This unexpected overload has fallen upon a system that was already taxed to the limit of its accuracy. Intermittent mechanisms always have been subject to periods of erratic behavior, due to the uncertain factors of heat, dryness, stickiness, grit, and wear that affect them; and this tendency to behave erratically increases with the rate. But the gravest defect of the intermittent method is that the errors in the perforations of the film must be added to the errors of the mechanism. Upon the intermittent principle, the registration is made to depend upon the accuracy of every perforation of the film. Wear and inaccuracies in the perforations are wear and inaccuracies of the intermittent mechanisms, because in these the film is always employed as a mechanical chain connecting the frame at the aperture with the teeth of a sprocket or of a claw movement. Hence, it may be said of this method, that the registration can never be more accurate than the least accurate or weakest link of this chain. And how weak these links really are! Being of thin celluloid, they are highly subject to wear, to flexure, to breakage, and to loss of shape. Among the more properly designed parts of the precision mechanisms this crude chain is always an incongruity.

But we must judge of the adequacy of a mechanical part, not only by the workmanship and the strength of the material, but largely by the work it must do. And of this crude chain, nothing short of a miracle in the way of performance is demanded—precise registration at the rate of twenty-four severe jerks a second. At sixteen jerks a second, the method was taxed to the very limit of its accuracy. Is it any wonder, then, that the quality of motion picture projection has fallen off so noticeably since the rate was raised to twenty-four? The intermittent method lacks flexibility, and in nothing is it so apparent as in the way the films are overtaxed. The weakest parts of the films, the portions between the perforations, bear the full brunt of the blows; and as they must necessarily spring or "give" under the strain, another variable factor is introduced into the registration. This is the amount of the flexure, which not only varies with the strength of every link, but is directly affected by every variation in the thickness and smoothness of the film. Tension shoes under excessive pressure are indispensable to the intermittent principle, and these make the registration dependent also upon the condition of the film's surface. The serious accumulation of errors that is possible from camera to projector will now be apparent.

It requires no technician to see that a method that defies the law of inertia so flagrantly must lose its accuracy and incline toward the impracticable very sharply with an increase in the rate. It may be true that in our best theaters, with the mechanisms and the films in the best of condition, the loss of accuracy due to the higher rate is not easy to detect. But such a loss is inevitable, and it is only because rule-of-thumb methods of testing the registration at the screen are employed that it escapes notice. Refined photographic methods, such as that of running a motion picture camera in synchronism with the projector, would tell the sad story of the increased stresses. Such a method would reveal, in well defined gradations, the inevitable increase in errors as the rate was increased from sixteen to twenty, and then to twenty-four frames a second. And how much more marked will the depreciation be, when films are used that have already been subjected to the undue stresses and excessive wear at the higher rate, for upon the intermittent principle, inaccuracies of the film are inaccuracies of the mechanism.

These considerations are sufficient to show that the former quality of motion picture projection, enjoyed before the advent of sound, is not likely to be restored upon this imperfect and unscientific principle. But most of the causes of inaccurate projection are avoided when we cease to oppose the law of inertia. And when the momentum of the flywheel is utilized to impart a uniform motion to the films, old and badly worn films may be projected with surprising smoothness and steadiness because the condition of the perforations has nothing to do with the registration. Freeing the registration from the tyranny of the perforations and establishing it permanently upon the basis of uniform motion, or inertia, is the outstanding achievement of the continuous cinematograph.

Unfortunately, the subject of continuous cinematography has never received sufficient attention from the motion picture industry, or we should not witness the wasteful spectacle of a major industry in a persistent, foolish, and expensive contest with a law of nature. It is needless to say the industry must pay and pay, for that is the inevitable consequence of opposing a natural law. The impressive thing in this case is the size of the annual payment, and the fact that nothing is received in return for it. Our railway industry is much wiser. Its more experienced engineers have long since learned that in the long run it never pays to oppose a natural law. Hence, they spare no expense to level off grades and ease curves to avoid the wasteful contest with nature. But the notoriously wasteful motion picture industry continues in its folly of opposing the law of inertia flagrantly and ceaselessly. Investigators of the industry's wastefulness would do well to look into this cause of waste, for it is doubtful whether greater economies can be effected elsewhere within the industry.

The laws of nature are inexorable, and can not be defied without penalties. The excessive depreciation of equipment and films is the penalty the motion picture industry must pay. But the deterioration in the quality of motion picture projection that has occurred since the advent of sound is the penalty that more nearly concerns the general public. This seriously challenges the practicability of the intermittent method.

REFERENCE

[1] PLANK, W. C.: "Some Interesting Properties of Continuous Projectors," *J. Soc. Mot. Pict. Eng.*, **XVI** (June, 1931), No. 6, p. 709.

BOOK REVIEWS

The Principles of Optics. Arthur C. Hardy and Fred H. Perrin. *McGraw-Hill Book Co., Inc.*, New York, N. Y., 1932, 632 pp., $6.00.

This new book is designed to meet a specific purpose—to serve as a text-book for third-year students of physics who, contrary to the usual assumption, are none too well grounded in mathematics. Its method is to elucidate the optical principles involved in the behavior of light when confronted by lenses, prisms, and mirrors rather than to serve as a series of mathematical exercises based upon the electromagnetic theory of light. Its writing was conducted in much the same manner as the assembly and packing of the baggage of an experienced explorer. The total available space was limited. The resources were collected in the form of the available text-books on optics; the complete array was laid out for inspection. Then began the process of concentration, the elimination of useless bulk, while striving to retain everything of value. Upon thumbing the pages of the book, the reviewer was greeted by the simple straightforward demonstrations of a number of fundamental optical principles, the formulation of which, and subsequent application in lens systems, required in the older texts considerable space.

The book covers the usual field of optics. The reviewer was particularly pleased to note the informative treatment of the concept of aperture as affecting the light available for image formation, as well as the usual discussion of lens aberrations of the well-known types. Some interesting uses of cylindrical lenses for special optical apparatus are included. A chapter devoted to the scientific aspects of photography and a discussion of photoelectric cells is somewhat of an innovation in books on optics.

H. P. Gage

Motion and Time Study. Allan H. Mogensen. *McGraw-Hill Publishing Co.*, New York, N. Y., 1932, 228 pp., $2.50.

Although the book is primarily devoted to the subject of eliminating waste of time and motion in industrial operations, the extent to which the motion picture camera, and, of course, the projector, is used in making the necessary micromotion studies justifies the appearance of a review of the book in a journal devoted to motion picture engineering.

One chapter is devoted to the methods followed in using the motion picture camera in order to analyze complicated motions into their component motions. A motion picture taken of the individual performing the motions to be studied, a microchronometer being included in the field, provides the material for analysis. The procedure to be followed in conducting the analysis is described.

Another chapter is devoted to the description of motion picture equipment and the manner of using it. Still another chapter is concerned with the use of motion pictures in training industrial operatives and others. Although emphasis is placed upon the value of motion pictures in making time and motion studies, appropriate references to other means of making the studies are made where the circumstances indicate the greater utility of these methods.

S. Harris

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SOCIETY ANNOUNCEMENTS

NEW YORK SECTION

At a meeting held on November 16 at the Electrical Institute, in the Grand Central Palace, New York, N. Y., the report of the Sub-Committee on Laboratory Practices, of the Committee on the Care and Development of Film, was presented by Dr. R. F. Nicholson, chairman. Following a discussion of the paper, the remainder of the evening was devoted to a pre-release showing of a motion picture feature.

CHICAGO SECTION

At a meeting held at the Electrical Association, in Chicago, on October 6, a paper on "Sound Absorption Material" was presented by Mr. George Baker, of the U. S. Gypsum Co. This paper discussed the principles of sound absorption, materials, *etc.* The newly elected officers of the Chicago Section for 1933, announced at the meeting, are as follows:

R. F. Mitchell, *Chairman*
B. W. Depue, *Secretary-Treasurer*
O. B. Depue, *Manager*
J. E. Jenkins, *Manager*

PACIFIC COAST SECTION

At a recent meeting held at the RKO Pathé Studios, at Hollywood, Calif., a symposium on motion pictures in color was presented, Mr. J. Klenke, chairman of the Program Committee presiding. Mr. J. A. Dubray described and demonstrated the Bell & Howell Morgana process; Mr. C. Dunning described some new developments in a color process on which his firm is working; the cartoon color process used by the Technicolor Motion Picture Corp. was announced by Mr. J. A. Ball, and a "Silly Symphony," *King Neptune*, was projected; Mr. W. T. Crespinel announced and demonstrated the new work of the Cinecolor Corp.

Following announcements of the newly elected officers of the Section, plans were evolved for subsequent meetings to be held this season. The new officers are:

E. Huse, *Chairman*
G. F. Rackett, *Secretary-Treasurer*
C. Dreher, *Manager*
J. A. Dubray, *Manager*

STANDARDS COMMITTEE

At the recent meeting of the Standards Committee, held at the General Offices of the Society at New York, N. Y., proposed revisions of the Standards Booklet

ASA-Z22–1930 were considered and collated into a tentative form for final approval by the Committee in the near future. The booklet is being completely revised to make it accord with up-to-date practice in all possible respects and new drawings are being made. Material dealing with sixteen-millimeter standardization will be added later, after final action is taken on the report of the Standards Committee published in the November issue of the JOURNAL on page 477.

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OF THE

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By action of the Board of Governors, October 4, 1931, this Honor Roll was established for the purpose of perpetuating the names of distinguished pioneers who are now deceased:

LOUIS AIMÉ AUGUSTIN LE PRINCE
WILLIAM FRIESE-GREENE
THOMAS ALVA EDISON
GEORGE EASTMAN
JEAN ACME LE ROY

PAMPHLETS, BOOKLETS, AND CATALOGUES RECEIVED

Copies of the publications listed here may be obtained free of charge by addressing a request to the manufacturer named. Manufacturers are requested to send new publications to the General Office of the Society immediately upon issue.

Bell & Howell Co.: Bulletin describing new B & H stand for animation, title, and film slide making, and for document and general copying work. A complete unit consists of an Eyemo 35-mm. spring-driven camera, a rigid supporting stand, a mount for the camera, two reflectors for photoflood lamps, a "single shot trigger," provision for centering and framing subject, and a series of numbers replacing the usual footage calibrations on the lens focusing scale. Address: 1801 Larchmont Ave., Chicago, Ill.

Jenkins & Adair, Inc.: Bulletin No. 27, describing a newsreel type of sound-on-film recording equipment, including lists of equipment, designated as normal, limited, and abbreviated, for portable sound-on-film recording systems. Bulletin 1-*F*, describing Jenkins & Adair audio-frequency apparatus, transformers, retards, and amplifier accessories. Address: 3333 Belmont Ave., Chicago, Ill.

National Carbon Co.: Bound covered booklet describing National projector carbons, their manufacture and use. Chapter contents: Carbon; Manufacture of Projector Carbons; The Carbon Arc; D.C. Old Type Low Intensity Lamps; A.C. Low Intensity Lamps; D.C. Low Intensity Reflector Arc; *SRA* Projector Carbons; D.C. High Intensity Arc; Summary of Operating Precautions; Carbon Arc Spot and Flood Lamps, Stereopticon and Effect Machines; Brushes. Address: Box 400, Cleveland, Ohio.

AUTHOR INDEX, VOLUME XIX

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