TECHNICAL INFORMATION
for the use of
the PROJECTIONIST

TECHNICAL INFORMATION
for Projectionists

Published by **G.B-KALEE, LTD.** **No. 1**

PROJECTOR INSPECTION ROUTINE *

Precautions to be Taken

By A. BUCKLEY

WHILST regular examination of projector mechanisms takes place in a proportion of theatres, it is felt that there is much room for improvement in this direction. Since the possibilities of film damage are considerably reduced by careful projector checking, for this reason alone it is desirable to have machines kept right up to the highest pitch of perfection possible.

The projectionist, working year in, year out, on the same outfit, becomes so accustomed to the routine work that quite often minute faults become big ones and are apt to be unnoticed. Not all projectionists are engineers or mechanics ; and there are many things a projectionist *should not do*. Yet systematic checking and prompt replacement of *certain parts* will ensure regular and trouble-free picture presentation.

In projection—as indeed in many other spheres—one must strive and not overshoot that happy medium existing between " leave well alone " and " a stitch in time." If a projector is running satisfactorily nothing more than a superficial check is required. Intelligent lubrication, regular cleaning, and *particularly* very careful handling of detachable film gates are, of course necessary. It is with the idea of helping those who are uncertain just how to perform the systematic check that these notes are written.

Checking Sequence

The projector-soundhead check—preferably done weekly—should commence at the upper magazine or spool-box, and terminate at the take-up point. Working progressively downwards, checking every item : sprocket, stripper, pad roller, gate part, etc., it becomes—after a time—quite a routine job. The experienced projection engineer can superficially check any projector in a few minutes, and there is little reason why every projectionist should not develop that sense and make it a regular job.

Until recent times, upper spoolboxes were very much alike in this country. True, spindle sizes varied between ½in. and 5–16 in., and, whilst some were fitted with friction washers—to prevent over-running—others simply used metal to metal surfaces. Later years have produced a new kind with a very thick spindle; this seems to have overcome several defects in earlier types. Generally speaking, if an upper shaft is properly adjusted and lubricated it will not give trouble.

Fire-trap Rollers

In some cases fire-trap rollers—or valve rollers, as they are called in America—are fitted to the spool-box ; in others to the mechanism. These rollers should be examined every week for signs of flatting, ridging and free action. Systematic checking will—of course—preclude any possibility of badly flatted rollers, but on the initial check offending parts should be removed and replaced. Stiff rollers should be freed and correctly lubricated. American projector rollers are oiled at the pivots and not in the middle, whilst British rollers are sometimes lubricated from the centre, and occasionally at the ends. If the sides of the fire-traps are cut or show signs of contact with the film then " weaving " due to bent or buckled spools is the cause. Defective spools are best in the scrap department ; they can, of course, be pressed out, but there does seem to be a tendency for such spools to return to their former distorted shape ; new spools, however, are not really expensive.

NOTE.—*When using certain U.S. machines it is very essential to run the upper spool counter-clockwise ; that, is when the large magazine roller is on the projectionist's left. Only under such conditions does the fire-trap function correctly and the film feed properly.*

Upper and lower sprockets seem to last for an amazingly long time and rarely give any trouble at all. Nevertheless, they should receive the same minute examination as the rest of the machine. Strippers of the pre-set type require no skill to remove or replace ; whilst the other kind need to be carefully reset each time they are removed. Where adjustments radial-

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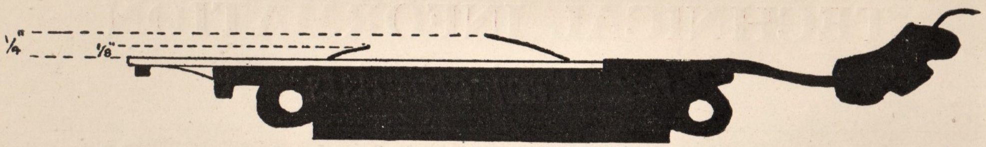


(1)

ly and laterally are necessary the stripper should be spaced from the sprocket by means of a thin shim and aligned laterally by means of a dental inspection mirror. The pad rollers should rotate freely and should be set so that the thickness of a film join exists between the roller and the sprocket. Properly cleaned and lubricated, pad rollers should last for a decade or so.

Importance of the Gate

The film trap—or gate—is the all-important part of any projector. Minute defects here play havoc with films and are a potential source of continuous trouble and film mutilation. After a period, the back plates—or film trap shoes, as the Americans call them—become recessed and worn immediately opposite the pressure pads, or skates. Once these hollow parts exist, additional strain is placed on the film, and it is advisable to replace them when in this condition. Skates or pressure pads should bear truly on the back plates and if any ridging occurs at the edges they should be replaced immediately. Damage even to one reel of sound-film will possibly be more costly than half a dozen sets of gate parts. The insurance against film damage alone is in itself a good reason for regular and systematic replacement of worn parts.

Correct Adjustment

Normally, the tension on the gate should be very light, merely enough to hold the film quite flat. With adjustable door-pads, skids, skates, runners, or whatever the manufacturer calls them, the tension can often be altered to suit the film. On British machines the adjustment is continually variable. With the only American-built machine used in Great Britain the adjustment is pre-set, and it is usually satisfactory for any type of film base. For the guidance of projectionists wishing to check the correct tension, Fig. (1) shows how the springs should appear with the door-pads removed.

Fitting Intermittent Sprockets

In cases where intermittent movements must be dismantled to fit a new sprocket, it is considered unwise—except in special cases—for projectionists to do this work. The job should be done by the manufacturer's representative, for he has the necessary lapping tools, reamers, extractors etc., and is better equipped to make any minor adjustments to the movement at the same time.

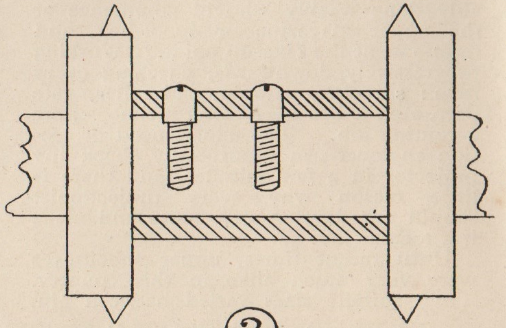
An intermittent sprocket should fit the shaft perfectly and need little more than a slight pressure to place it in its correct position. If the sprocket is a little tight it should *not* be forced on to the shaft; it should be slowly and gently lapped in by means of a mild abrasive such as metal polish, rouge and paraffin, or some such compound. Nothing more than a slight pressure should be needed to place the sprocket in its final correct position. If the sprocket is an *easy* fit when tried at first it should not be used; it should be returned to the makers and replaced by one which fits snugly.

Procedure Hints

Some extra care is needed in cases where two 6 B.A. screws are used for locking up the sprocket, and the following procedure is recommended after the sprocket has been correctly fitted to the shaft.

(*a*) Try both screws in the sprocket before fitting it to the shaft.
(*b*) Try both screws in their respective holes in the shaft.
(*c*) Fit the sprocket to the shaft.
(*d*) Engage the first screw and drive nearly home.
(*e*) Fit the second screw nearly home and tighten each one alternately until they are tight. Use a small driver which fits the screw head and one which has a short handle.

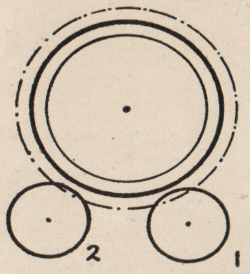
Fig. 2 shows how the screws should fit.



(2)

Intermittent Roller Adjustment

Intermittent rollers should be spaced exactly the same as pad rollers, *i.e.*, twice the thickness of standard film. On most machines this is a simple process, but on at least one projector some care is necessary; for two rollers are employed and the adjustment should be done as shown in Fig. 3. The right-hand roller (1) should be set at the required distance by means of the adjusting cam; the adjustment should be locked in this position. Secondly, the left-hand roller (2) should be set by means of the adjusting screw and finally locked up. On this particular projector care must be taken to see that the left-hand roller clears the intermittent teeth when the gate is opened, otherwise the teeth and roller will be damaged.



(3)

If, when the above adjustments are made, the teeth are fouled by the roller, the latch on the side of the gate-door may be the trouble. A further trouble sometimes experienced on this projector is that if the lower cradle, or shoe, is touched—either by the hand or film—the gate-springs open. This is caused by a defective catch-plate. A new plate is the only certain cure.

British machines employing gate-shoes can be adjusted by means of a small screw, whilst those fitted to American-built machines are pre-set and not adjustable by the projectionist. With these machines the lower gate-skirt can easily be distorted by rough handling. This will throw the intermittent guide-shoe out of alignment.

Sound-Head

The remarks about pad-roller adjustment also apply to most types of sound-heads, and the projectionist will usually include the inspection of sound-gate or drum in his weekly check.

The final item in the routine inspection is the lower magazine—which includes fire-trap rollers and take-up. The friction take-up—which is universal in this country—usually employs leather or cork as a friction medium. Both can be temperamental—particularly leather. Whilst a little oil is permissible in several designs, too much of it induces erratic running. Belt-slip should not be tolerated otherwise two sources of slip are possible. Belts should be of the correct diameter and kept in good order.

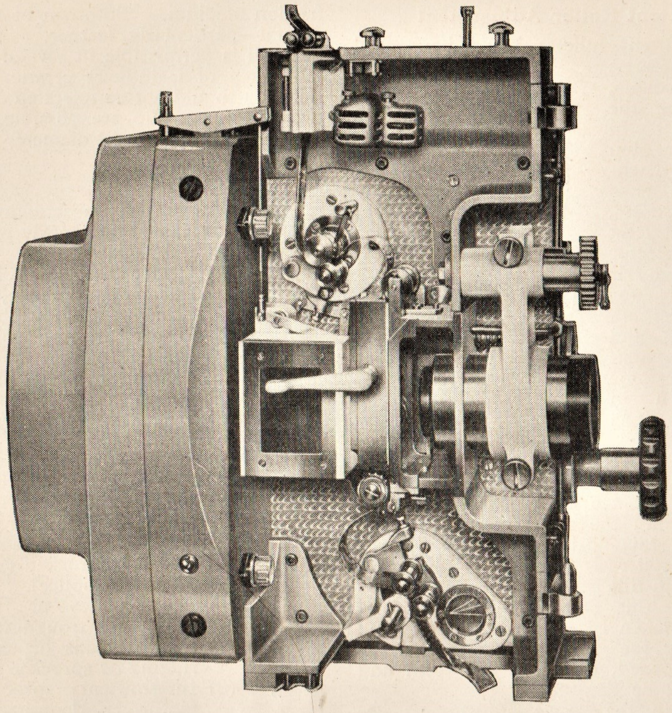
Routine Check

Summarising our observations, the order and details of the weekly projection inspection are as follows :—

Check (1) Upper magazine spindle for freedom, tolerance, correct adjustment and lubrication.
„ (2) Upper fire-trap rollers for flatting, uneven wear, freedom in running, fluff, deposits, etc.
„ (3) Upper sprocket for toothwear, deposits, etc.
„ (4) Upper stripper for fluff and foreign matter—adjustment.
„ (5) Upper pad-roller for freedom of rotation, presence of flatting, correct spacing from face of sprocket (thickness of a film splice).
„ (6) Back plates—or film-trap shoes—for troughing.
„ (7) Pressure-pads or skates for ridging or sprocket marking.
„ (8) Intermittent sprocket for toothwear, deposits, etc.
„ (9) Intermittent shoes—or rollers—for flats, adjustments and correct operation.
„ (10) Safety shutter for efficiency.
„ (11) Lower sprocket assembly as for 3, 4 and 5.
„ (12) Sound drum for deposits, ease of rotation, etc., or
„ (13) Sound gate for correct tension, wear or dirt.
„ (14) Optical unit for cleanliness.
„ (15) Lower fire-trap rollers as for 2.
„ (16) Take-up assembly — cleanliness and condition, adjustment, etc.
„ (17) Adaptation gear for cleanliness and security of all recessed screws, etc.

By making a routine check every week the projectionist will develop confidence in the correct use of tools—he may even make special tools of his own design for certain purposes; but he should never attempt any work—except in emergency—unless he is certain of the outcome. A little knowledge is dangerous, and if in doubt the representative of the manufacturer is usually glad to advise or help.

This is the first of a series of Monthly Technical Bulletins to be published in the interests of "*Better Projection.*" We feel that Projectionists will welcome such articles and will like to keep them for information and reference. For that purpose they will no doubt find the binding cover useful.
If you would like to have a copy of all future issues, would you please complete and return the enclosed postcard.



Some of the special features of the

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Projector Mechanism

1 The Gaumont-Kalee '21' incorporates a single-blade high-speed shutter, passing 20% more light with less flicker and improved definition. The Gaumont-Kalee '20' and '19' models are fitted with the standard two-blade shutter running at normal speed.

2 Provision for extra wide aperture lens of 2.77 ins. diameter, with micrometer adjustment.

3 Completely detachable gate and mask-plate for ease in cleaning and maintenance.

4 Low voltage lamps for speedy and easy threading.

5 Built-in electrically operated change-over device, operated by single switch control from either machine position.

6 Built-in 'Pyrene' automatic fire extinguisher as an optional extra.

7 Totally enclosed mechanism with all parts running in an oil-bath with pump circulation. Lubrication visible through sight glasses.

8 Completely removable intermittent unit.

9 All gears have helical teeth for quiet running, and are paired metallic and non-metallic.

10 Designed on unit lines throughout; interchangeable for easy replacement and service.

11 The Gaumont-Kalee Projector can be used with any type of arc lamp and sound reproducer.

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TECHNICAL INFORMATION
for Projectionists

Published by **G. B-KALEE, LTD.** **No. 2**

THE HUMAN SIDE OF GETTING A WELL ILLUMINATED PICTURE*

By GIO GAGLIARDI

Assistant Chief Engineer of Sound, Projection & Maintenance, Warner Theatres, Newark Zone

DETAILED studies of methods of improving the quantity and quality of light delivered to the screens of our motion picture theatres have been made by various manufacturers, and the results have been reported from time to time in the trade magazines and in the *Journals* of the Society of Motion Picture Engineers. In almost every case, some worthy suggestion has been made of a method which would tend to increase the efficiency of projected light; however, practically all of these reports have presupposed laboratory set-ups, or optimum field conditions.

In other words, the experimenter always strived for maximum efficiency under best conditions, and assumed that these would be carried out in the field. It is no wonder then, that when SMPE committees, and manufacturers' representatives investigate actual field results, they come back with data which indicate that field results fall below optimum conditions in a preponderant number of cases.

In a recent series of tests by the SMPE screen light committee, it was found that only 20% of the projection systems tested were able to utilize over 90% of the available light. The other 80% fell below this mark, many to such an extremely low level as 50% of maximum light.

It was found also that two projection systems in the same house varied sometimes as much as 50% in efficiency—a condition which, obviously, should not be tolerated.

Some of the causes of such inefficiency are mismatched and defective equipment. If lenses are not matched properly in speed with the lamp optical system, heavy light losses may occur; and if reflectors or condensers are badly pitted and dirty, or lenses are clouded and oil-soaked, the resulting light will be below optimum. These losses can be remedied only by change of equipment.

There are however, other losses produced by everyday operational procedure which I believe cause a great amount of annoyance and which can be remedied or at least alleviated by continuous and strict attention on the part of the operating projectionist. I refer to proper positioning, adjustment and operation of the light source and of the lamphouse optical system for the production of a steadily lighted screen.

It must not be forgotten that the light at the arc must be projected on the screen continuously minute after minute, hour after hour, without interruption or variation from house opening to closing time. There can be no greater annoyance, it seems to me, than to view a black-and-white feature and see it change intermittently from dirty blue to sepia brown. It seems an anomalous condition that the newest carbon trim which has given us the highest quality of light at a very economical price, is the greatest offender in the above respect. A study of this carbon's physical dimensions, and the optical systems with which it should operate, will give us a plausible explanation of this absurdity, and also supply the reason why the use of this type carbon requires careful supervision constantly.

In publishing this second issue of our monthly "Technical Bulletin," we would express our sincere thanks to the many hundreds of projectionists and theatre managers who have written in praise of this idea. It is very gratifying and encouraging to know that the publication has been so well received. Copies of No. 1 are still available on request.

* *This article from "MOTION PICTURE HERALD" is reprinted by kind permission of the Editor*

USEFUL CRATER AREA

The useful crater of a suprex positive is extremely small. A 8mm suprex has an effective crater diameter of only about two tenths of an inch, and for a 7mm suprex the effective crater diameter is only one and a half tenths. Of these craters, even a smaller section is utilized in order to obtain better side-to-center light distribution, so that for 8mm suprex the crater area which supplied the maximum amount of light is only one and a half tenths of an inch in diameter. In order to cover the film gate completely, the image of this crater must be enlarged from six to seven times.

To perform this optical work, practically all modern lamphouses use a reflector which is shaped something like the tip end of a football. It is an *ellipsoid.*

All longitudinal sections of an ellipsiod look like ellipses, and all right-angle sections look like circles. As shown in *Fig.* 1, an ellipsoid has two focal points F1 and F2 on its longitudinal axis X-X. Now if a reflector were made in the shape of an ellipsiod, any light coming from a light source placed at F1, would be reflected to the other focal point F2 as indicated by the rays F1 to D to F2, F1 to E to F2, etc.

Not all of the ellipsoid can be used as a reflector. Since the carbon crater projects light in one general direction, only the section of the ellipsoid facing the arc is used as a reflector (as indicated by the heavy arc A-C-B in *Figure* 1). The area, or size, of the reflector will determine the amount of light that will be collected from one focal point and reflected to the other focal point. Accordingly, in the lamphouse the carbon crater is placed at F1 facing the mirror, and the film aperture plate is placed at F2. *Fig.* 2, which is drawn to scale, shows the proper location of a lamphouse and a projector in the complete development of the ellipsoidal optical system.

The diameter of the mirror A-B, the distance of the carbon from the mirror F1-C, and the distance of the film aperture plate from the mirror F2-C, are rigidly fixed and are entirely dependent upon each other. It is *absolutely imperative* that these dimensions be kept constant in order to hold the light output of the projection system at a maximum.

LAMP OPTICAL SPEED

All lamphouse manufacturers provide installation dimensions and operating instructions and these should be followed exactly. *Figure* 3 shows a typical optical diagram (the drawing is based on an Ashcraft lamp installation). You will note that the distance from the film aperture plate to the rear of the reflector is 32 inches, and that the distance from the carbon crater to the rear of the reflector is 5 inches. This indicates that the magnification factor for this system is 32 divided by 5, which equals 6.4. This means that the image of the carbon crater, in being reflected on the aperture plate, will be enlarged 6.4 times. The speed (*f* number) of this reflector can be computed by dividing the distance *A* by the dimension *B*. In this case, 29 divided by 14 gives a speed of approximately 2.08 (*f*/2.08).

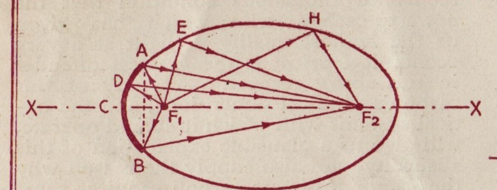


FIGURE 1—Path of light in ellipsoid reflector. F1 and F2 are focal points on axis X-X; A, B, C, etc., are points of reflection.

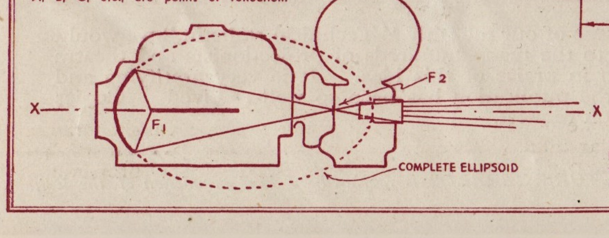


FIGURE 2—Scale drawing indicating proper location of lamp relative to projector. F1 is positive carbon crater; F2 is film aperture; both are conjugate focii of the ellipsoidal reflector.

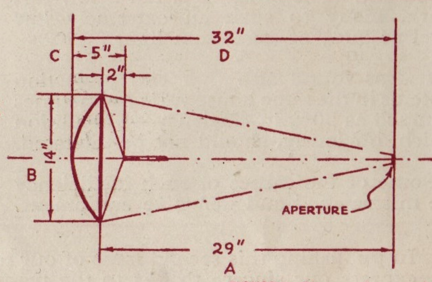


FIGURE 3—Diagram of a typical reflector lamp optical system. Letter symbols indicate distances as referred to in text.

Calculate what will happen to the light transmitted to the screen: *Distance D* has been changed to 35 inches, and *Distance A* now becomes 32 inches. The whole system has to be refocused as well as possible, and both the effective speed and the magnification have changed.

Assuming that the same optical laws apply, the new effective speed of the reflector becomes *A* divided by *B*, or 32 divided by 14, which gives us *f*/2.29, which is slower than before and will produce a loss in light. (The amount lost can be calculated by taking the *inverse* ratios of the squares of the *f* numbers—in other words, the light passed by the new speed of *f*/2.29, is to the light passed by the old speed of *f*/2.08, as 2.08 squared is to 2.29 squared; and that is 4.33 divided by 5.24, or approximately 83%).

So we have lost 17% of the light. But that is not all. The positive crater of the carbon is normally located at the proper focal center of the ellipsoidal reflector and should be kept there in order to utilize the full surface of the reflector. By changing dimension *D* to 35 inches, the magnification of the reflector will be increased to a value equal to 35 divided by 5—a magnification of 7. In that case the utilization of the arc spot on the film aperture is diminished, with a loss in light of approximately 16% (6.4 squared to 7 squared, or 40.96 divided by 49, or 84%, and 84 from 100 equals 16).

Thus the act of moving the lamphouse merely 3 inches away from its proper place, can decrease the projected light by as much as 33%!

The foregoing calculations are presented in order to show what may be one of the contributory causes of the difference in efficiency between field and laboratory measurements. Another defect of the projected picture, and this one is readily noticed by the theatre patron, is the change in light quality, or colour. The National Carbon Company has published data on this effect in various issues of the SMPE *Journal.*

One of the important requirements for uniform light on the screen is to have the arc *accurately maintained* at the proper distance from the reflector. This necessity can be made clear by looking at the crater diameter in its relation to the reflector.

Now let us assume that someone in the field does not like those particular dimensions and decides to change them. The lamphouse is moved, say, *back* 3 *inches.*

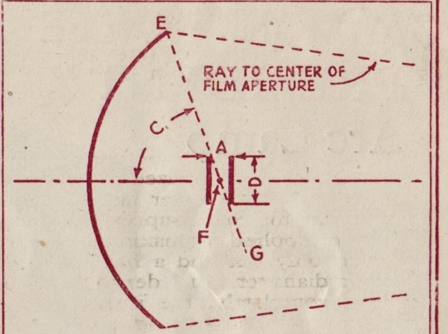


FIGURE 4—Schematic diagram of reflector in relation to light source. The movement indicated as A is the maximum which will permit light source D to transmit light rays to the center of aperture plate.

Figure 4 will be used for demonstration. This sketch is drawn out of proportion in order to emphasize the point. Let *D* represent the *useful* diameter of the carbon crater, which was pointed out to be only 0.15 inches for an 8mm carbon; *F* is the focal center of the reflector and should be the exact center of the crater in its proper burning position. The line *E-G* indicates the maximum collecting angle of the reflector, and you can see that a crater of diameter *D* can only be moved a maximum distance equal to *A* if we want the reflector to collect the light from all the useful surface of the crater.

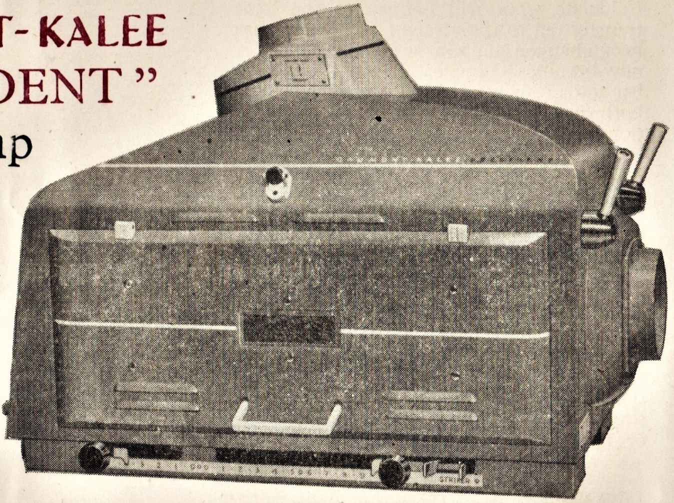
Because of the large angle (C) of modern reflectors, distance *A* is only approximately one third of the useful crater diameter, or 0.05 inches. This means that the positive crater, in this instance, can move a maximum of only 0.025 inches on either side of the exact mirror focal center, otherwise the light will begin to suffer in intensity and distribution.

An increase in the motion of the crater will cause bad discoloration. If the positive carbon is moved too close to the reflector, the light rays traveling to the center of the aperture originate from the cooler portion of the carbon in *back* of the crater, which results in brownish light on the screen. Similarly, if the carbon is too far from the reflector, the rays originate from the arc stream in *front* of the crater, which results in a blue light on the screen.

Thus it is that *accurate positioning* of the arc is of critical importance. The accuracy and efficiency that can be maintained depend to a great extent upon the good quality and the operating characteristics of the lamphouse mechanism, and on the attentiveness of the projectionist as well.

THE NEW

GAUMONT-KALEE "PRESIDENT" Arc Lamp



maintains a constant light with complete elimination of colour and flicker, and provides perfect screen illumination.

Some of the Special and Exclusive Features include :

TWIN-FEED MOTORS: Avoids the complication and weakness of variable ratio mechanisms. Maintains uniformity of screen illumination.

SHADED POTENTIOMETER CONTROL for each motor.

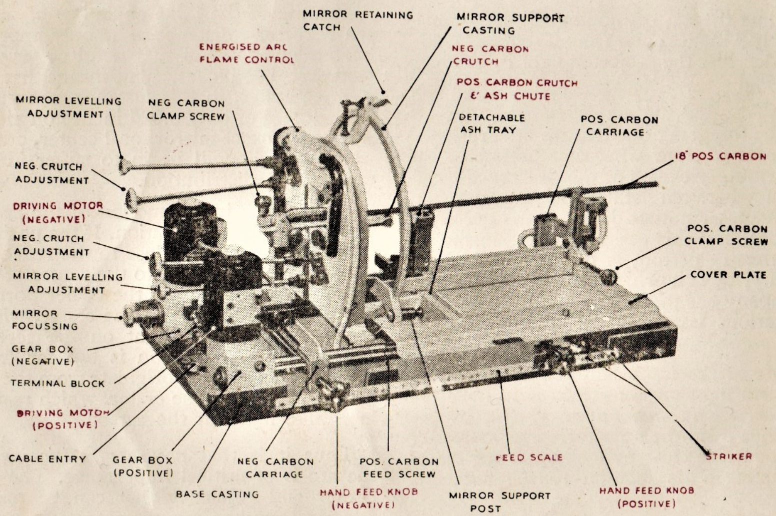
ELLIPSOIDAL MIRROR 14-inch diam. (metal-backed for longer life) giving maximum collection angle.

ELECTRO-MAGNET ARC FLAME CONTROL to ensure flickerless arc burning.

CARBON SCALE outside lamphouse gives visual indication of length of carbon travel.

CONTROL PANEL at rear of lamphouse.

FULL WIDTH DOORS with automatic locking for easy access ; automatic interior illumination.



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TECHNICAL INFORMATION
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STABILITY OF ARC CONTROL *

Main Causes of Current Variation

By R. HOWARD CRICKS, F.B.K.S. F.R.P.S.

EVERY projectionist recognises that the arc is electrically a very unstable piece of apparatus, and needs a ballast if it is to function with consistency. From the carbon makers and rectifier manufacturers we see curves of the electrical characteristics of the arc. But I suspect that many projectionists do not fully appreciate the relation between these curves and their daily job of keeping a well-lit picture on the screen.

The electrical resistance of the arc is made up of two factors: the resistance of the carbons, contacts, and connections, which is exceedingly stable; and the resistance of the flame and its areas of contact with the carbons, which is far from stable. In practice the former of these two is so small as to be almost negligible.

The chief causes of variation in the second are the length of gap; the manner in which the flame licks the carbons—this chiefly dependent upon the relative heights of the carbons, but partly upon the air currents and magnetic fields; and—a negligible factor today while an identical trim is employed—variations in the carbons.

The actual resistance in ohms also varies to an appreciable extent according to the current flowing. Therefore it is convenient to express the resistance not in ohms, but in terms of voltage drop; since the ohms decrease as the amperes increase, it follows that for a given gap and carbon position the arc voltage will vary little with the current. The arc volts range from 70 for a Hall and Connolly-type arc, 45 for the average low-intensity arc, 35 to 40 for arcs employing small H.I. carbons, down to 19-25 for the A.C. arc.

We are faced then with the problem of maintaining a constant current through a resistance which is continually varying in value. If the current is not maintained reasonably constant, then the light on the screen will vary both in intensity and colour. The contribution to the solution of this problem offered by the automatic feed of modern lamps must not be overlooked, since it enables the probable variations to be brought within much smaller limits.

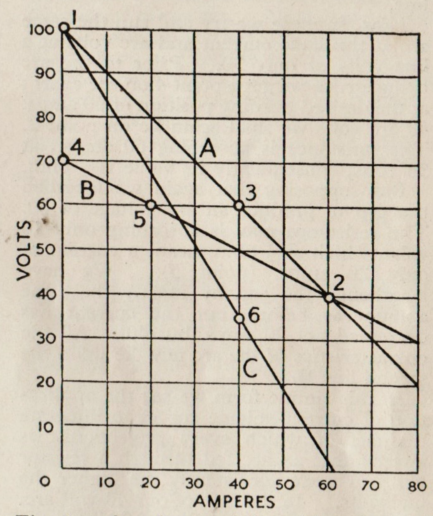

Fig. 1. *Arc characteristics with resistance ballast.* (*A*)—60*a.* 40*v.* *Arc on* 100*v. line ;* (*B*)—60*a.* 40*v.* *Arc on* 70*v. line ;* (*C*)—40*a.* 35*v.* *Arc on* 100*v. line*

BALLAST RESISTOR ABSORPTION

The method of control used until comparatively recent years was to run the arc on a line voltage considerably in excess of the arc volts, and to absorb the difference in a ballast resistor. Let us consider the electrical characteristics of such a system.

Fig. 1 shows the volt-ampere curves of an arc at two different line volts, 100 and 70. We will assume, for ease of calculation, that we are running a 60-amp. H.I. arc needing an arc voltage of 40.

Before the arc is struck—that is, when there is no current flowing—the full line volts will be shown across the carbons, equivalent to point 1. Disregarding what happens when the arc is struck and while

Abridged from two articles in "IDEAL KINEMA" by courtesy of the Editor it is burning in, by the time it is running at 60 amps, the voltage across it will be 40, and the position on the chart will be as shown by 2, on curve A. Now, at 40 arc volts the resistor is absorbing the balance of 60 volts at a current of 60 amps.; the value of the resistor is therefore 1 ohm.

Supposing we let the arc burn away to a longer gap, so that the arc voltage increases to 60. At this figure the resistor is absorbing only 40 volts, which for a value of 1 ohm means the current is only 40 amps (point 3)—the current has dropped 20 amps. It will be seen that these three points lie on a straight line, and calculations show that any other burning position of the arc we may choose, with the given line voltage and resistance value, produces a characteristic lying upon the same straight line.

Now, suppose we try and run the same arc at the same current and arc volts at a line volts of only 70. Prior to the arc being struck we get a point 4 on the chart; at the desired burning position of 60 amps. 40 arc volts we shall again be on point 2. The resistance is absorbing 60 amps., at 30 volts, consequently its value is ½ ohm.

But supposing that again we lengthen the gap to produce an arc voltage of 60. The resistance now is absorbing only 10 volts, which at ½ ohm means a current of only 20 amps. (point 5). We have lengthened the gap by exactly the same amount as before, but the current has decreased not 20 amps. but 40. All the characteristics of the arc now lie upon the second line B.

In this simple form we see the application of current-voltage curves to illustrate the fact of which every projectionist is aware: that an arc fed through a resistor will run more consistently the higher the line volts. In the case of our 40-volt arc, the difference between 100 and 70 line volts is equal to a halving of the electrical stability—which means actually far more difference in terms of light value and flicker.

CORRECTING A FALSE IMPRESSION

These curves may help to kill an idea which is very prevalent: that an arc resistor marked for a given arc volts is capable of running the arc only at that particular voltage. The first of our two resistors might be marked " 100 line volts 40 arc volts 60 amps." But a resistor is electrically merely so many ohms; it cannot dictate to the arc at how many volts it shall burn. All it can say is: " If the arc asks for too many volts, it will get fewer amps., and *vice versa*."

In practice we should not attempt to run an arc at different currents on the same value of resistance. We should adjust the resistor to suit the desired current. We might, for instance, wish to run the arc (probably with a different trim) at only 40 amps., when the arc voltage might be about 35—point 6 in Fig. 1. A suitable resistance value would produce, on the 100-volt supply, an arc characteristic shown by the line C.

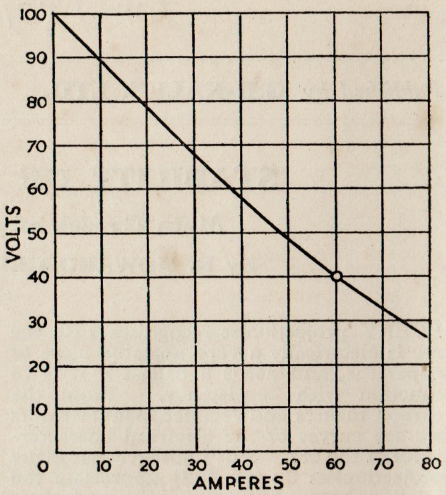

Fig. 2. *Characteristic of* 60*a.* 40*v. arc with choke ballast on* 100*v. line*

WHAT THE RECTIFIER DOES

In modern installations the ballast resistor is a thing of the past. Practically every rectifier today embodies anode chokes which restrict not the flow of direct current from the rectifier to the arc but the flow of A.C. into the rectifier—which, after all, amounts to the same thing.

Fig. 2 shows a typical choke control curve, for running the same arc as curve A of Fig. 1. While the actual value of voltage is complicated by the rectifier losses, we can for sake of calculation assume that the equivalent line volts to the arc circuit is 100, and therefore the impedance of the choke, reflected into the arc circuit, will be equal to the value of the resistance, of 1 ohm.

It is, however, a characteristic of a choke that as the current though it approaches saturation its impedance lessens. Consequently, instead of the straight lines of Fig. 1, we may with a choke, unless it is made unusually large for its job, get a flattening of the curve, as shown in Fig. 2 This characteristic of the choke is the principal reason for using a separate rectifier for each arc; obviously, with a single rectifier, at the moment of changeover the current through the choke would cause saturation, lowering the control factor and making the arcs unstable. A choke also causes a lowering of the power factor, which may be corrected, up to 0.8 or better, by means of a shunted condenser.

It is, of course, possible to combine the functions of the step-down transformer and choke into one unit, a reactive transformer, which is identical with the so-called inductor used for running A.C. arcs. As far as the characteristics of the arc are concerned, it is immaterial which type of equipment is used.

Because chokes are more costly than resistors, it may be preferred to use the choke only to establish the running current, resistors being inserted into the circuit to reduce the current for striking and burning in, during which time the efficiency is unimportant.

CHOKE CONTROL METHODS

Just as a resistance can be adjusted to suit different arc currents, so a choke can be provided with tappings for the same purpose. An exceedingly flexible system of choke control is embodied in both the Nevelector and the Hewittic Unitarc, typical curves of which are shown in Fig. 3. It will be seen that adjustment of the choke enables a wide range of arc characteristics

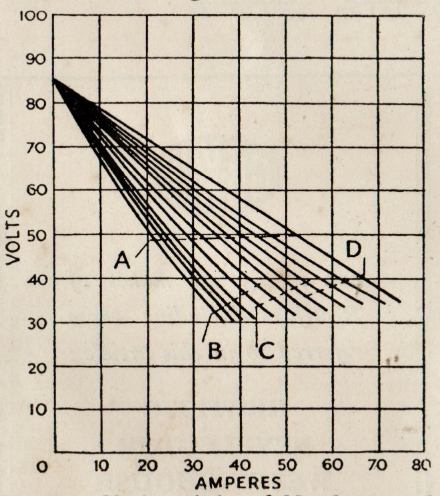

Fig. 3. *Characteristics of Nevelector and Hewittic Unitarc.* (*A*) *Low-intensity*, 22/52*a* 48/50*v.*; (*B*)—*High-intensity* 35/45*a.*, 32/38*v.*; (*C*)—*High-intensity* 45/55*a.*, 35/40*v.*; (*D*)— *High-intensity* 55/65*a.*, 36/41*v.*

to be obtained. In both cases the control is effected by means of coarse and fine controls, the former with three positions and the latter with four, giving twelve current ranges differing by about only 2½ amps. Fig. 3 shows how these ranges have been carefully selected to suit the current and burning voltages of both L.I. and H.I. trims; note that the same setting of the controls suits either L.I. trims at 22 to 52 amps., or H.I. trims at 35 to 65 amps. The flattening of the choke characteristic previously referred to is just visible on these curves.

A TAPPED TRANSFORMER

A different system of control is used in the E.C.C. Ecwelite rectifier, the characteristics of which are shown in Fig. 4. J. C. Milne, Rectifier Manager of that company, states:

" To design a rectifier which will cover high-intensity and low-intensity arcs from a range of 22 to 65 amps., although ideal for the manufacturer, is uneconomic and inefficient for kinema use. The Ecwelite rectifier, which does not employ chokes, and is a special system designed for kinema arc supply, has 16 tappings to cover a range, in the case of Model ' A ' from 45 to 65 amps., thus very much smoother arc control is obtained, and the no-load voltage varies with the arc voltage.

"The Ecwelite has been designed in three models to suit three different types of arc, and each model is designed to operate the arc for which it is intended with minimum power consumption, and to be perfectly stable in operation."

Examination of these various curves shows that the steeper the curve, the better the control of the arc. An almost vertical curve is obtained by the system used in the Westinghouse Westalite metal rectifier.

This circuit employs a principle different from any so far considered—that of resonance. If a choke and condenser are connected in series, the circuit will have a resonant frequency, given mathematically by the formula :—

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

At this frequency the reactance of the circuit disappears. Because the characteristics of the choke vary with load, this frequency varies with the current. By so choosing the values of the components and the degree of saturation of the choke that on a 50c/s mains the variation with current occurs in the correct position on the resonance curve, it is possible to get an almost vertical characteristic, which means such control of the arc that the current is virtually independent of the resistance of the arc. This is demonstrated in Fig. 5. Similar curves are produced at lower ratings for L.I. arcs.

ADJUSTMENT FOR CURRENT RANGES

The majority of Westalite metal rectifiers provide adjustment for different current ranges, within the limits of the dotted lines, not by means of switches but by means of adjustment of the air gap of the choke—a job not intended to be done by the projectionist. The idea is that once the chief has decided upon the correct arc current, it cannot be varied.

If, however, it is desired that the projectionist should have control as in the other systems mentioned, an alternative system is offered, employing the principle of a saturable choke to which I referred last month. This enables an infinitely fine adjustment to be obtained with a single knob.

Finally, a word as to efficiency. The changeover from a motor generator with ballast resistor to a rectifier with reactive control improved the overall efficiency

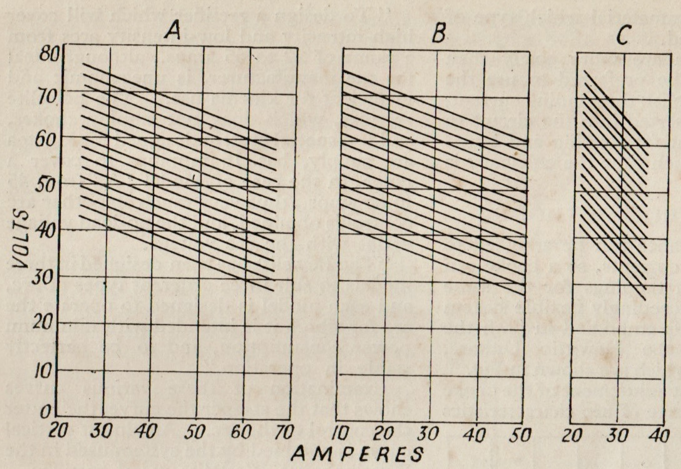

Fig. 4. Characteristics of three models of Ecwelite rectifier. A— High-intensity arc, 45/65 amps., B— High intensity arc 35/50 amps,, C— Low-intensity arc 35 amps.

from perhaps 30 per cent. or 35 per cent. to 65 per cent. or 70 per cent. Further, the high efficiency of the modern arc lamp has itself effected a considerable reduction in the current at which this improved efficiency operates. Consequently, any further improvement in rectifier efficiency is hardly worth while, since any possible advance in design could result in the saving of only a few hundred watts.

The really important factors today are reliability, stability of arc control, and adaptability to the desired arc conditions.

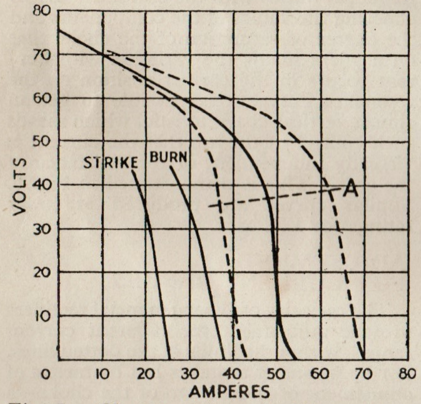

Fig. 5. Characteristic of Westinghouse Westalite rectifier. (A)—Range of H.I. arcs

This is the third issue of our series of " TECHNICAL INFORMATION FOR PROJECTIONISTS." Copies of Nos. 1 and 2 with a special binding case are still available on request. Projectionists are invited to apply for them, enclosing a 2½d stamp for postage

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TECHNICAL INFORMATION
for Projectionists

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ON 'BLOOMED' LENSES

With some recommendations on their care and maintenance

by J. WIGGLESWORTH. Technical Staff, A. Kershaw & Sons.

SINCE the early days of motion pictures, projectionists have been searching for increased illumination. The reasons for this demand include the development of larger and perforated screens of lower reflectivity and the ever-increasing projection of colour films. The history of projection equipment manufacturers' efforts to satisfy the projectionists' demands is to be seen in a long series of improvements to arc lamps, reflector systems and projection lenses. The most important advance was made in recent years with the introduction of coated or 'bloomed' projection lenses.

The tendency of a bare glass surface to reflect light rather than transmit all the light which falls upon it has always been a serious optical problem. We are aware of this 'back reflection': for instance, we know that a shop window with a dark background gives us sufficient reflection to be used as a mirror of sorts. Whatever use this 'back reflection' may have, it is definitely unwanted for optical projection, since it reduces the efficiency of optical systems by subtraction from the transmitted beam at all air-to-glass surfaces. In addition, light so reflected within a projection system of several surfaces may re-appear as 'glare spots' in the projected picture.

As long ago as 1892 it was known that reflection from a glass surface was reduced and light transmission correspondingly increased when a suitable coating was present on the glass surface. Many efforts to produce such coating artificially met with little or no success. In recent years, however, development of the high vacuum evaporation technique has made the production of coated lens surfaces a commercial possibility. Many improvements have been made in the properties of the thin films deposited on the lens surfaces by this method, and lenses so coated need no more careful handling than any good lens is entitled to. The increased light transmission of coated or 'bloomed' projection lenses is substantial and amounts to between 15 and 30 per cent.

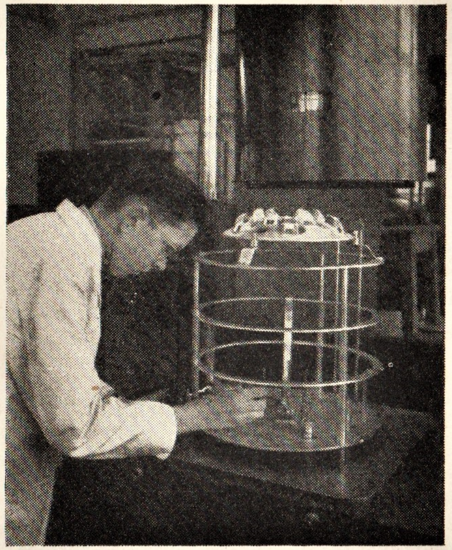
PIONEERS' WORK ON ANTI-REFLECTION COATINGS.

Although it had been known for many years that certain glasses developed surface tarnishes after exposure to the atmosphere, it was not until 1892 that any study of the effects of such tarnish was made.

About that time Dennis Taylor of York, the famous lens designer, made experiments on the light transmission of some tarnished lenses. These tarnishes had the appearance of a metallic sheen which was considered to be objectionable. Taylor found, however, that the tarnished lenses reflected less light from their surfaces than did identical new ones. Of greater importance was the corollary that the light no longer reflected by the polished surfaces was transmitted by the lenses and that these tarnished lenses produced images visibly brighter than did newly polished ones.

Dennis Taylor immediately saw the potentialities of this discovery, but his efforts to produce this tarnish on the surface of new lenses met with little success. Many attempts were made in subsequent years to discover methods of artificially producing the tarnish or coating on lens surfaces. In 1939 Miss Kathleen Blodgett, in the U.S.A., produced coatings on lenses by the deposition of metallic soap films, and, whilst the coatings so produced were extremely efficient from an optical point of view, the fragility of the deposit made the process impracticable for commercial use.

The first development of the hard coating process, now commonly used, was made by Dr. John Strong of the California Institute of Technology, and consisted of the deposition of thin film of hard calcium fluoride upon the surface of the optical lens



A technician in the Kershaw factory charging vacuum plant with fluorides for evaporation as "coatings" on optical components.

by evaporation of the fluoride in a high vacuum chamber. By this means he reduced the reflectivity of a plate glass surface from 4% to 0.6% and thereby increased the transmission through the two surfaces from 92% to about 99%.

THEORY.

The amount of light lost from a beam by reflection when it strikes a glass surface increases with the refractive index of the glass. For ordinary window glass the loss is about 4% per surface ; for the heavy flint glass it may amount to 10%. In the projection lens system—assuming a loss of 5% per surface—the presence of four surfaces will give a loss approaching 20%, thereby reducing the transmission to about 80%. This affects the projected picture or 'image' in three ways.

1 The brightness of the picture is reduced.
2 The reflected light reaching the image, after several reflections at lens surfaces, invades the darker parts of the picture and gives rise to haziness.
3 The reflected light may concentrate near the image plane to form 'glare spots.'

If, however, the surface of the glass be coated with a layer of lower refractive index, that is, a lens 'coating', then the initial loss at the surface of this coating will be less. Although we have added a new reflective surface—the inner face between the coating and the glass itself—the combined loss at the two surfaces is less than the light lost by reflection at the bare glass surface. This assertion may be checked by the formulae for computing the fractional amount of light lost by reflection of the two surfaces.

$$R_{ac} = \left(\frac{\mu_c - 1}{\mu_c + 1}\right)^2 \qquad R_{cg} = \left(\frac{\mu_g - \mu_c}{\mu_g + \mu_c}\right)^2$$

Where Rac to Rcg are the reflections at the air-to-coating and the coating-to-glass surfaces respectively, and 1, μc, and μg, are the refractive indices of air, of the coating, and of glass.

The phenomenon upon which non-reflecting films depends is that of interference and an explanation of interference effects is necessary for an understanding of anti-reflection coatings. Interference takes place between two beams of light because of their wave nature. Two waves of equal wave lengths, with a definite phase relation between them, can add up to zero on one hand, or to an augmented wave on the other. The phase relation or displacement between the two superimposed rays depends on how much further one beam has had to travel before meeting the other. Consider Fig. 2.

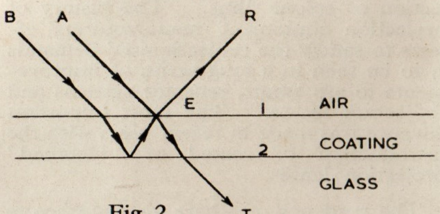


Fig 2

Suppose that a ray of monochromatic light A falls upon a glass surface (which has been coated) at a point E, and assume that we have selected the refractive index of the coating so that equal amounts of light are reflected at surfaces 1 and 2. Then ray R consists of the reflected portion of ray A, and, as will be seen, it is augmented by the contribution from ray B, which emerges at E in the direction R, after reflection within the coating. The second beam has travelled through the film twice before it meets the first beam. If the equivalent double 'coating' thickness is half the wave length of light, the two beams meet one half-wave out of phase, and cancel one another by destructive interference.

This energy cannot be destroyed and it re-appears as an increase in the transmitted ray T.

It has been found that to provide equal reflectivity at the air-to-coating surface and the coating-to-glass surface, the coating must have a refractive index which is the geometric mean of that of air and of the glass. Therefore, if μg is the index of the glass and μa is that of air, the ideal refractive index for the coating is found by :—

$$\mu_c = \sqrt{\mu_g \, \mu_a}$$

Since $\mu a = 1$, μc is the square root of the refractive index of the glass.

COLOUR CORRECTED COATINGS.

The coated lens appears coloured in reflected light. The normal coating reflects more in the blue and red portions of the light spectrum than in the green-yellow, where it was designed to have its maximum transmission efficiency, and light passing through the lens becomes tinted in the complimentary hue. The ordinary 'bloomed' projection lens, therefore provides a brighter screen but of pale yellow colour.

The thickness of the coating may be adjusted to provide maximum transmission at a pre-selected wavelength, and the colour composition of the transmitted beam 'corrected' so that the screen appears brilliant white.

CLEANING PROCEDURE FOR COATED LENSES.

The introduction of coated lenses has not altered recommended lens cleaning practices, and coated surfaces are no more difficult to clean than uncoated ones ; the penalty for neglect, careless cleaning, or lens mistreatment, is, however, much more obvious. We have already seen that the coating is about 1/4 wave length of light in thickness, that is, about 4 millionths of an inch thick, and like glass, its surface can be rapidly ruined by abrasion. Coated lenses should, therefore, be treated with the same degree of care as all highly polished glass surfaces. In no circumstances must abrasives come into contact with the surfaces.

The most efficient method of cleaning the projection lens surfaces is to blow the dust off, using a bicycle pump if possible, and if particles still linger, as is very likely, as a result of blowing with moist breath, then a soft camel-hair brush should be used to remove the fine particles. The brush should be flicked with the finger after passing across the lens surface to shake free the dust particles picked up. If grease or oil is present on the surface it should be removed with the aid of a piece of lens tissue moistened with methylated spirit. It is important, however, that the methylated spirit should be applied very sparingly. This solvent has a great propensity for penetrating into the lens cells, and should never be used unless really necessary to remove grease or adherent foreign matter. After removing the dust particles or grease, the surfaces should be polished gently with a dry lens tissue, using a circular movement. Most important of all is the necessity to avoid cleaning powders and abrasive materials. On no account must cleaning powders or fluids prepared for cleaning porthole glasses or reflectors be used on the surfaces of projection lenses, for, in spite of manufacturers' assertions that they do not scratch, all cleaning powders contain material likely to abrade lens coatings.

To summarise, the following rules should be carefully observed.

1 Remove dust by blowing or brushing with a fine camel-hair brush.
2 If grease is present remove it by means of methylated spirit sparingly applied on cleaning tissue.
3 Polish carefully with cleaning tissue.
4 Avoid the use of cleaning powders.

If these rules are followed the projectionist will keep his lenses working at high efficiency throughout the life of the projector with which they are used. The lens manufacturer has taken great trouble to produce coated projection lenses to give brighter and more evenly illuminated screens and with the projectionists' co-operation this object can be accomplished.

One of the lens polishing shops at Kershaw's factory in Leeds. Note the blocks of polished and unpolished lenses in the right foreground.

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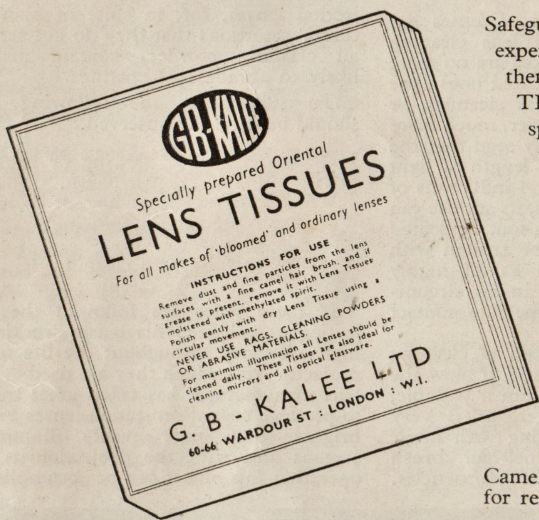

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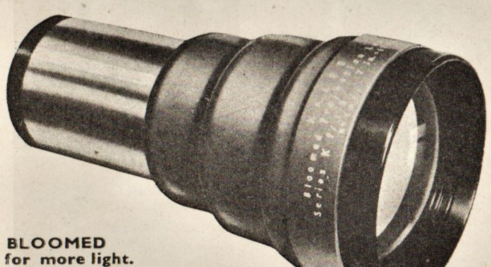

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TECHNICAL INFORMATION
for Projectionists

Published by **G.B-KALEE, LTD.** **No. 5**

THE DOUBLE REEL

by R. Howard Cricks, F.B.K.S., F.R.P.S.

SOME of us can still remember the time when film stock—negative and positive—was manufactured in lengths of 400ft. The printing laboratory received its supplies in 7in. tins, and after these reels were printed, they were joined together to make up reels of up to 1000ft. Later, as a result of the demands of the laboratories, the stock makers found themselves able to make film stock in 1000 ft. reels.

Now, in those days of silent films, it took about a quarter of an hour to run a 1000ft. reel; a change-over every quarter of an hour was not too bad. But in course of time exhibitors discovered that by running their programme faster, they speeded up the action and in many cases heightened interest in the film; they were furthermore able to run a double-feature programme and still get three or three-and-a-half programmes a day, and with a good programme that meant more money at the box-office.

But the projectionist objected to making a change-over every ten minutes or less. And so he hit on the idea of joining reels together in pairs, Reel 1 with Reel 2, Reel 3 with Reel 4, and so on. So began the practice known as "doubling-up," which at the advent of sound, with its eight- or ten-minute reels, became almost universal.

OBJECTIONS TO DOUBLING-UP

In years to come it will seem quite fantastic that the renter should have sent out films in 1000ft. reels, the projectionist should then have gone to the trouble of joining them in 2000ft. reels for showing, and at the end of the run should have broken them down to 1000ft. reels for return to the renter. Apart from the quite unnecessary work imposed upon the projectionist, every time a reel is doubled up and broken down it suffers damage.

First, alternately lead and tail of successive reels have to be removed and the reels joined together—a loss of at least one frame in each reel. However careful a projectionist may be in breaking down, he will lose another couple of frames; as a matter of fact, careless workmanship often results in the loss of considerably more frames. Then perhaps one projectionist will join together Reels 1 and 2, 3 with 4, and so on; the next man perhaps runs the news and trailers before the feature, and consequently joins the news and trailers with Reel 1, and then Reels 2 and 3 are joined together, 4 and 5, and so on.

Possibly, too, such a projectionist will be dissatisfied with the change-over cues provided by the laboratory (although every laboratory today endeavours to ensure cue-dots being easily visible) and may make his own private cues. The next man who doubles up in more orthodox manner refuses to show such a disfigurement, particularly in the middle of his double reel, and cuts out probably a dozen frames.

Yet another source of damage occurs if, when breaking down his programme on Saturday night (with the last bus due in five minutes!) a projectionist fails to separate a double reel at the correct point. First this means that the change-over cues go adrift, and the next projectionist may have to add his own. Secondly, it may mean that one reel will be so large that it will not go into the can without forcing. The result of this treatment is seen in the scores of photographs which have appeared in the Trade Press during the past few months.

THE 2000ft. REEL

Just before the war the Americans took the wise step of standardising the double reel, with a maximum length of 2000ft.; the renter received prints from the laboratory in 1000ft. lengths, and doubled up for despatch to the kinemas. We in this country were considering its adoption when the war put an end to any such progress.

But after the war—largely as a result of representations made by the British Kinematograph Society to the Kinematograph Renter's Society—it was agreed in principle that the double reel should be introduced, and the British Standards Institution was asked to prepare a standard. This was issued last year as B.S.1492: "35mm. Cinematograph Release Prints."

It is specified that the maximum length of a double reel shall be 2050ft., including leader and run-out (I urged that a minimum length should also be fixed, to prevent any risk of doubling-up, but this was not agreed). As shown in the drawing reproduced below, the familiar identification and synchronising leaders are specified, and at the end of the reel the change-over cues, run-out and identifying tail leader.

An important point is the recommendation that in each double reel, the picture action should start and finish on fades; and that significant sound should be kept at least 5ft. from the start and finish of the picture. The effect is of course to give more latitude in the timing of the change-over. To prevent emulsion pick-up, prints should be edge-waxed or otherwise processed.

DELAYS IN ADOPTING DOUBLE REEL

Now, projectionists who have read about this specification may have been disappointed that they should be still receiving many of their films in single reels. Let me point out some of the difficulties in the wholesale adoption of the double reel.

To start with, in a few cases renters' vaults are constructed for 1000ft. tins, and considerable alteration would be needed for larger tins. All existing stocks of tins and transit cases must be scrapped—and to buy new tins and transit cases today is, quite apart from the heavy cost, no easy matter. Therefore the change-over to double reels must be gradual, and may in fact take four or five years. In the meantime, every projectionist will give the next man a better show if he will take the utmost care in doubling up and breaking down, and will refrain from making his private change-over cues.

Although the double reel will mean that the projectionist will have fewer joins to make, he should nevertheless be provided with a joining press. It is in any case generally agreed that for the new non-flam. film base a press is virtually essential, and every projectionist should see that his rewind room is provided with a press, and should become accustomed to its use.

THE 2000ft. SPOOL

In America of course films are despatched on spools. The film is wound from spool to spool, and is never handled off a spool; difficulties of varying core sizes are avoided. But in America the spools are shipped directly inside the transit case; in this country, railway regulations would still require the spool to be enclosed in a can. This would necessitate still larger cans, and would mean that fewer reels would go into a case of given size. Furthermore, the weight of the spools would increase transport costs.

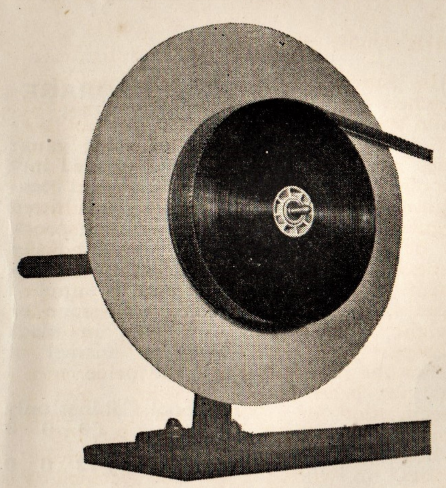
For the moment therefore this advance has not been proceeded with. But a specification for a 2000ft. spool has been issued by the B.S.I., known as B.S.1587: "Film Spools for 2000ft. 35mm. Release Prints," in which the spool is specified as suitable for "either transit or projection."

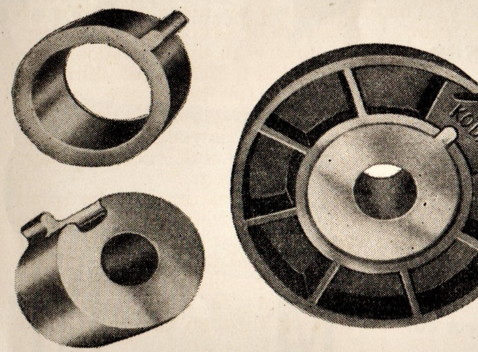
The spool has a diameter of $14\frac{3}{4}$ins. to 15ins., and a core of $4\frac{1}{2}$ins. to 5ins. Tests have shown that with such a spool, the maximum length of 2050ft. of film will still come at least $\frac{1}{4}$in. below the edge of the spool; much film damage is caused by the outside turns of film sliding over the edge of the spool, and such mishaps should not in future occur.

Two other useful features of the spool are that the lightening holes are required to be large enough to expose the film right down to the hub; and that the hub should be finished in white, so that it can be easily distinguished from the film. The projectionist looking through the window of his top box will therefore be able to see—without contravening regulations by opening the spool-box door—how much film is left.

It was proposed a few months ago to prepare a standard for transit cases to accommodate 2000ft. reels. The proposal was not proceeded with, for a very good reason: within the next two or three years we may expect to see non-flam. film becoming universal, and nobody as yet knows what will be the regulations of the railways in regard to the transport of such films. It is therefore impossible as yet to design a transit case, which has to comply with railway regulations.

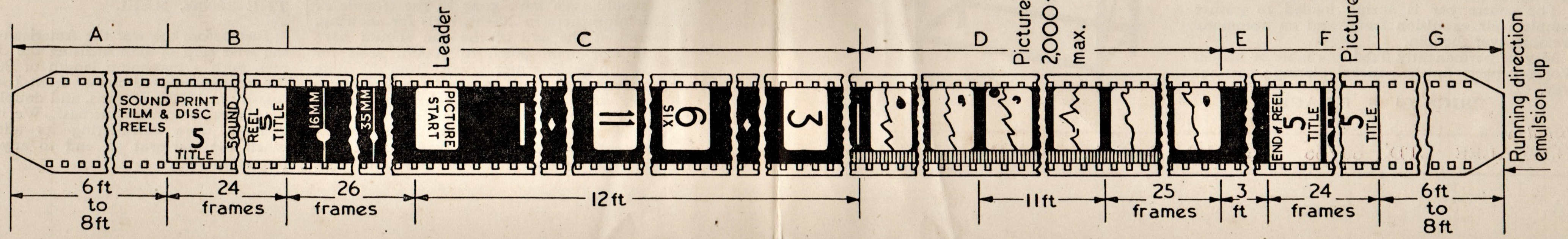
SPOOL BUSHES — *For transference of Double Reels*





ILLUSTRATED here are the "Premier" bushes which were the subject of favourable review by R. Howard Cricks in the November number of "*Ideal Kinema*." These adapter bushes facilitate the transference of double reels from the tin to the spool. They are made with variable bores to suit all rewinder spindle diameters, i.e., 5/16 in. (with keyway to take American standard spindles), $\frac{3}{8}$ in., $\frac{1}{2}$ in., 9-mm. (all recessed to allow for take-up pin) and a special $\frac{3}{4}$ in. bore to fit over the standard sleeve of the new "Premier" combined plating-on-and-off disc. The bushes are firmly held to the spindles by readily accessible grub screws. The outside diameter of all bushes is similar to give an easy fit with the bakelite cores supplied by the raw stock makers to the laboratories and subsequently used by them for despatch of processed film.

The method of use is most simple. The bush is fixed either to the rewinder spindle or, far better, to the "Premier" combined plating-on-and-off disc sleeve, as illustrated; this disc and bush is then placed over the can containing the film and core which are immediately decanted on to it and from which it is directly wound on to a projection spool. For breaking down, the method is the reversal of this procedure — from projection spool to disc and core and from disc to can. The cost of this new plating-on-and-off disc, together with an adapter bush, is only 30s. Alternatively, a pair of bushes,



one to fit the auxiliary spindle during spooling-up and the other to fit the spiral winder sleeve of the original "Premier" spooling-off plate, is only 10s.

Manufacture of the spools has proceeded on a quantity basis and large orders have already been received. One circuit has expressed itself, through its chief engineer as very pleased with the ease with which transfers can be made without the danger of spilling while the fit of the bushes is admirable. A very big demand is anticipated.

TECHNICAL INFORMATION

for Projectionists

Published by **G.B-KALEE, LTD.** **No. 6**

PROBLEMS of SAFETY STOCK

By **R. Howard Cricks.,** *F.B.K.S., F.R.P.S.*

Projectionists who show the Festival of Britain film, "The Magic Box," will find many of the sequences of technical interest. Among the earlier problems of William Friese-Greene in the invention of kinematography was to provide a material suitable for coating his emulsion upon, and for running through his camera. In one sequence we see him, amid noxious fumes, producing thin strips, 6 ins. wide, from large blocks of celluloid.

Celluloid is in many respects a very suitable substance for use as a film base; but several tragic fires in the early days of the motion picture drew attention to its dangerous inflammability, and for half a century efforts have been made to find a non-inflammable substitute having acceptable mechanical properties.

The raw material of celluloid is cotton, and recent research has shown why it is so suitable: nature has in fact been doing for millions of years what science has only recently succeeded in achieving—in building matter into long molecules (some large enough to be photographed in the electron microscope) which are tangled together and produce a material of high tensile strength.

THE FIRST PLASTIC

Celluloid was in fact the first plastic, and it is only within the last few years that scientists have succeeded in producing synthetic plastics having similar properties —and so far none of these synthetic plastics has properties equal to those produced by nature.

In the manufacture of celluloid —or cellulose nitrate, as it is called chemically—the cotton is reacted with nitric acid. Now this process is very similar to the process by which gun-cotton is produced, and the fact that it results in a highly inflammable material is not therefore to be wondered at.

Other acids may be used. For many years we have had so-called acetate film, made by substituting acetic acid for nitric; other acids that can be used are propionic and butyric. But none of the resultant materials had formerly characteristics equal to those produced by nitric acid; on the other hand, the results were comparatively non-inflammable.

CHARACTERISTICS OF BASE

Kodak safety base marketed since 1937 has been produced by a mixture of acetic and propionic acids. The Gevaert stock is a butyrate.

The characteristics of the base depend also upon the degree of chemical reaction permitted. While early safety base was known as a di-acetate, the new Kodak safety base is known as a tri-acetate.

Note that we describe the new base as 'safety' rather than 'non-inflammable.' Safety base is in fact about as inflammable

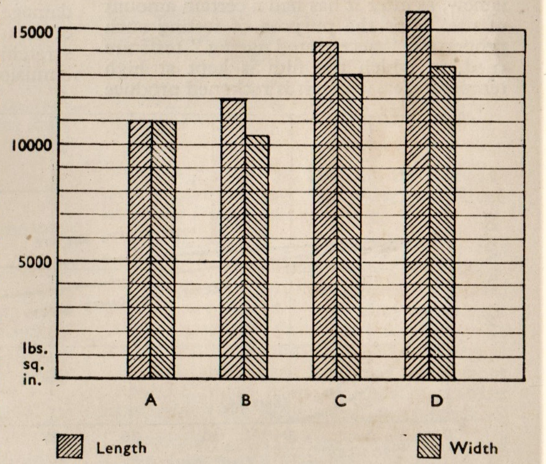


Fig. 1. *Tensile Strength of Kodak Film Stocks.* (**a**) *Acetate Base prior to* 1937. (**b**) *Acetate Propionate Base after* 1937. (**c**) *Tri-acetate Base.* (**d**) *Nitrate Base.*

as newspaper. Before the war the British Standards Institution issued a specification, No. 850:1939, which laid down two requirements of safety base: it shall be "difficult to ignite," which means to say that at a temperature of 300°C. it shall not ignite within ten minutes; and it shall be "slow burning."

For both requirements laboratory tests are laid down. A field test to indicate whether or not the film is "safety" makes use of a double-ended spoon; a ½in. punching of nitrate film is placed in one bowl, and a similar punching of the film to be tested in the other, and in turn they are held in the flame of a candle. Nitrate film will ignite with explosive force, while safety base melts or burns slowly.

STRENGTH AND FLEXIBILITY

Any projectionist who ran safety prints before the war will be well aware of the failings of the base. It tore very much more easily than nitrate, and quite soon became brittle. It was also difficult to splice; the use of glacial acetic acid was commonly recommended—too little failed to stick, too much buckled and rotted the film.

Technically the first two properties can be expressed in terms of tensile strength and flexibility. Fig. 1 shows the improvement in tensile strength, according to figures supplied by Kodak. It will be seen that the tri-acetate base is nearly the equal of nitrate, and much superior to either of its predecessors.

The brittleness or flexibility of a film must be considered not so much when it is new, as after it has had a certain amount of use. For the purpose of testing such properties, "accelerated ageing" tests are used, in which the film is kept at high temperatures, which it is reckoned produce

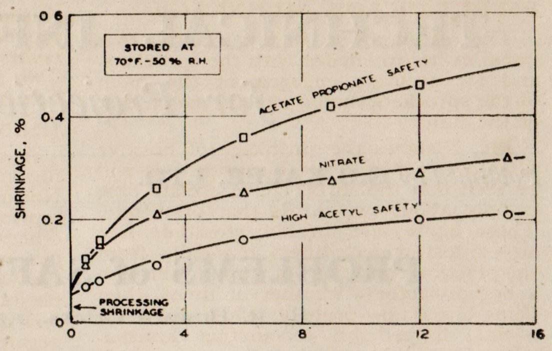


Fig. 3. *Shrinkage of Processed Film, stored in Circulating Air. — Courtesy of* British Kinematography.

the same effect as long-term storage at normal temperatures. The effect of such tests upon the flexibility of film base is shown in Fig. 2: nitrate, it will be seen, starts off rather more flexible than safety base, but rapidly becomes brittle; either form of safety base on the contrary retains its flexibility almost unaltered for a long period of time.

LIFE OF SAFETY BASE

We can therefore say that in tensile strength the new stock is practically the equal of nitrate, and in flexibility rather superior (the last is the reason why the new base feels so supple). But before we can say we are satisfied with the new base, two other factors have to be considered: what happens to it in the projector, and whether it can be joined easily.

Statistics show that 50% of all film damage reported by renters takes the form of scratching. The more serious form of scratching is on the emulsion, and as the emulsion on either base is identical there should be no difference whatever in this respect. As regards scratching of the base, this is no doubt a question of the hardness of the stock, and in this respect the new stock should be very little inferior to nitrate.

The second serious form of film damage is perforation tears and straining, which together account for 25% of reported damage. And here we come up against a feature of the new stock which, although to the manufacturer a decided advantage, may in practice prove to be a disadvantage. This factor is that safety base shows a much lower shrinkage than nitrate.

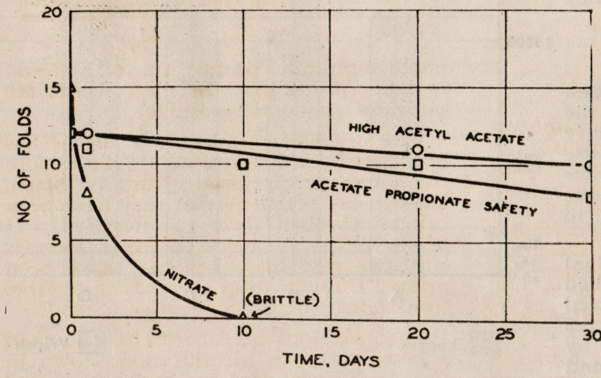


Fig. 2. *Retention of Flexibility of Film Base, measured by repeated Folding —Courtesy of* British Kinematography.

EFFECT OF LOW SHRINKAGE

The reason this is so important is that our film has to engage with the sprockets, and for accurate engagement the pitch of the sprockets should exactly match that of the film.

Fig. 3 shows the shrinkage of positive films over a period of 16 months. It will be seen that the shrinkage of acetate base is only about two-thirds that of nitrate. These figures are for film stored in free air—a test which differs markedly from the practical conditions of running through a hot projector a number of times, then being boxed up—probably while still warm —and shipped off to another kinema, where the films run through projectors of different type.

At my request Kodak recently made some measurements on a length of safety base which had been badly damaged in use—the perforations on one side were torn and on the other side badly strained. I hasten to add that the damage was obviously due primarily to a projector fault, but it is interesting to consider whether perforation pitch was an important factor.

The shrinkage of the film as it was removed from the container was 0.13%. After two hours conditioning at a temperature of 70°F and relative humidity of 60% (conditions similar to those of an average projection room) the shrinkage was only 0.04%. The shrinkage of nitrate base might well be four or five times as much.

In view of the importance of this matter, I have made the suggestion to the K.R.S. Print Condition Advisory Committee that tests should be made to ascertain the effect of this difference in pitch. My own view is that on a projector in perfect condition the effect will be slight, but any fault in the projector, and in particular emulsion pick-up in the gate, will impose additional strain upon the film, and lead to damage which in the case of nitrate might be avoided.

DIFFICULTY OF JOINING

Film cement does not act in the same way as paste joins two pieces of paper. It should be a solvent of the base, making a perfect weld. It appears that no such perfect solvent has yet been found for safety base. Experiments are proceeding in many directions, but in the meantime it is necessary for the projectionist—and the renters' examiner—to take every precaution, and to examine the splices of films on safety stock.

One point of difference from nitrate is that the cement takes longer to dry, and during the drying period the join must be kept under pressure. If only for this reason, therefore, a joining press of approved design is essential, and every rewind room should be so equipped. Two models have been approved by the C.E.A.

IDENTIFICATION of SAFETY BASE

A serious problem is the risk of confusion between nitrate and safety base. Not only is there the risk that a leader or reprints on nitrate may be cut into a print otherwise on safety; a number of projectionists have reported that stock bearing the words "Safety Film" has proved to be inflammable. The last is a source of real danger. It is due to the fact that a negative on safety stock bears the words

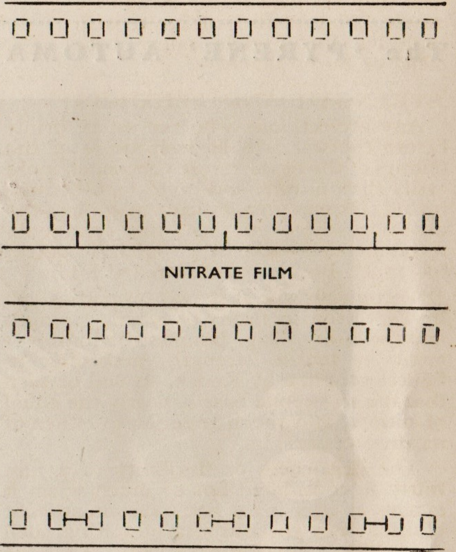


Fig. 4. *Eastman Kodak system of Identification of Film Base. Only Films showing the Marks between perforations, as in the lower sketch, are Safety.*

photographically printed in its margin; in the printing machine these words are imprinted upon the positive.

The original edge lettering always has black letters on a clear ground; if therefore the letters on a print are white on black, one can say definitely that they have been printed through from the negative. If however they are black on white, there is still the risk that they may have been printed through from the master positive from which the dupe negative is made.

Eastman Kodak in America have adopted a new system of identification shown in Fig. 4. A better idea has been introduced by Kodak in this country: instead of the plain line between perforations of safety stock, appears the letter S. This portion of the film is not exposed in any form of printing machine, therefore so far as one can foresee, any film bearing either of these distinguishing marks must definitely be safety.

SAFETY REGULATIONS

One final point should be mentioned. It will be years before all nitrate prints are out of circulation, and during this time safety regulations will be just as strictly enforced. Not until every foot of nitrate film is out of circulation can regulations be relaxed.

It may indeed be suggested that while there remains the risk that prints mainly on safety base may have leaders, run-outs, or reprinted sections on nitrate, there exists an added element of danger. The projectionist will therefore be wise if for some years to come, he regards every reel of film as potentially inflammable, and exercises the same precautions to which he has in the past been accustomed.

The various devices which have been evolved in the cause of safety — close-fitting fire traps, efficiently working safety shutters, and automatic fire extinguishers — must on no account be scrapped. After all, if a fire were to occur, it would inevitably be on the one chance reel of nitrate.

TECHNICAL INFORMATION
for Projectionists

Published by **G.B-KALEE LTD.** **No. 7**

Flicker Shutters on Cinematograph Projectors

By **L. AUDIGIER**

WHY "F-L-I-C-K-E-R"?

The prime function of a flicker shutter is to cut the beam of light from the projector lamp whilst the film is being transported by the intermittent movement from one frame to the next. If the light were not cut off whilst the film was moving, pronounced ghost effect would be observed on the screen.

It is only necessary to cut off the light once per frame, whilst the film is moving, to prevent ghost. At talkie speed this is a cut off frequency of 24 per second. In the customary 35mm. projector, Kalee, Ross, Simplex, Eclipse or any other, the usual design is such that the flicker shutter shaft rotates as many times per second as the number of frames per second that pass through the picture gate.

The flicker shutter of a machine running at 24 frames per second will therefore do 24 revolutions per second, or 1440 r.p.m. Prevention of ghost will be accomplished by a flicker shutter having only one blade rotating at this speed.

ONE OR TWO BLADES

An unavoidable characteristic of a flicker shutter is that it reduces the amount of light that gets through to the screen. One 90° blade will lose one quarter of the available illumination. Two 90° blades will give twice this loss. Why then increase the number of blades beyond that necessary to ensure freedom from ghost?

The reason is that although the human eye, and brain, are sufficiently accommodating to accept the rapid presentation of still pictures in sequence as a simulation of living movement, in other ways the eye is more exacting. Although it does not object to a picture frequency as low as 16 per second, it objects strongly to a flicker frequency of 16 per second.

Even doubling the flicker frequency, bringing it up to 32 per second, does not satisfy the eye, which still protests that the picture flickers. Not until the flicker frequency is increased to something in the neighbourhood of 48 per second is the picture accepted as sufficiently flicker free.

As has been seen, a single bladed shutter at talkie speed gives a flicker frequency of 24, so that a two bladed shutter will satisfy the requirements and give the required frequency of 48.

Except for a very few special types of 35mm. projector, such as the early Motiograph, which had a unique cam and pin type of intermittent movement, and the Arcadia, which was of the continuous motion type with a revolving mirror drum, for the past thirty years or more all commercial 35mm. projectors have had an intermittent movement using a pin wheel engaging with a four armed cross.

SPEED OF FILM

It is characteristic of all such maltese cross movements that the transport of the film from one frame to the next occupies a period of time equal to one third of the time that the film is stationary in the gate. At talkie speed, 24 frames are projected in one second, and during this second the film is at rest for a total of $\frac{3}{4}$ second, and for the remaining $\frac{1}{4}$ second is in intermittent movement from frame to frame.

The movement from one frame to the next is therefore accomplished in one twenty-fourth part of a quarter of a second or 1/96 second. Each frame remains stationary in the picture gate for 3/96.

The time taken to move the film from frame to frame is wasted so far as light transmission to the screen is concerned, because to prevent ghost the light must be cut off during this period. The light efficiency of the intermittent movement is therefore about 75%, and this figure does not vary with variation in the size of the cross. A large cross is no more efficient than a small one.

If the movement from frame to frame occupies 1/96 second, then the design of the blade which cuts off the light whilst the film is moving must be such that it cuts the light for the same period of time as that during which the film is moving. As the blade is rotating 24 times a second, it takes 1/24 second to complete one revolution, or 360 degrees. It is only required to cut the light for a quarter of this period, or 1/96 second, so a blade which is a quarter of a circle, or 90 degrees, meets the case.

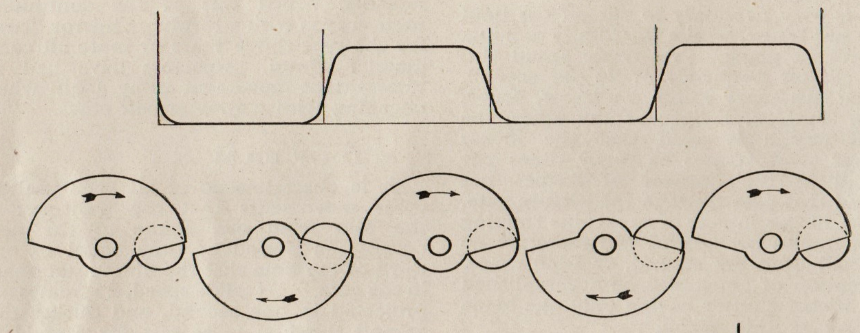
HUMAN OPTICS

Because the eye insists on a higher flicker frequency than would be given by this one blade, a second blade, of the same size and shape as the first, and at 180 degrees to it, has to be fitted to the shaft. This second blade cuts the light whilst the film frame is stationary in the gate, and reduces the 75% efficiency of the intermittent movement alone to a figure of only 50%.

At talkie speed it takes 1/96 second for the film to move from one frame to the next, and during this 1/96 second the pin wheel does one quarter of a revolution. In this 90 degrees of rotation the pin enters the arms of the cross, rotates the cross a quarter turn, and disengages itself from the cross.

making the flicker blade a full 90 degrees, it can be reduced to some smaller angle to correspond with total light cut off during only the middle 70 degrees of the cross movement. If it were not that the light beam is of finite diameter, the flicker blade too could be reduced to 70 degrees, but in practice something has to be added to this to allow for the time the blade takes both to cut into and clear the beam.

A rear shutter cuts the beam where it is of appreciable diameter. As an average for all makes of projector mechanism it is probable that the beam at the plane of the flicker shutter is some 2$\frac{1}{2}$ inches in diameter, and this in turn represents about 30 degrees of rotation of the flicker shutter. Fortunately it is not necessary to add the whole of this 30 degrees to the cover angle of the blades. During a portion of each twilight period the amount of light getting through to the screen is very small, and is coincident with a period when film velocity is low,



GK21 SINGLE BLADED SHUTTER 2 REVS. PER $\frac{1}{24}$ SEC

The rotational speed of the pin and pin wheel is uniform, but that of the cross is not. At the beginning of its 90 degree rotation the moving pin engages with the stationary cross, and then accelerates it from rest. With further rotation of the pin the speed of the cross is progressively increased until it attains a maximum midway through the cycle.

At the end of the cycle the pin disengages from the cross that it has brought to rest. For perhaps 20 degrees of the total cycle of 90 degrees, 10 degrees at the beginning and 10 degrees at the end, the movement of the cross, and consequently of the film, is so small that ghost will not be noticed on the screen even though light be permitted to pass through the film.

TIMING

Advantage is taken of this practically negligible movement of the film at the beginning and end of the cross movement to reduce the length of time during which there is a total light cut off. Instead of

so that ghost is not observed. However, of the 30 degrees, some 20 degrees has to be added to the 70 degrees of cover angle which would suffice if the beam were of infinitely small diameter, and the result is a flicker shutter having two 90 degree blades. In practice, all 35 mm. projectors with single two-bladed shutters have blades with a cover angle close to 90 degrees.

It has been shown that ghost is prevented by one blade, whilst the other merely increases the flicker rate to something acceptable to the eye. From this it might be thought that there was no necessity for the auxiliary blade to have as large an angle of cover as the master blade.

RATIO OF MASTER BLADE TO AUXILIARY

Provided the master blade were of a size to prevent ghost, an auxiliary blade of some smaller size would raise the flicker rate just as effectively as one of area equal to the master. The reasoning is perfectly

sound, the flicker rate would be the same, but the picture on the screen would not be acceptable to the eye.

A flicker shutter with 90 degree master blade and a 60 degree auxiliary blade would give the required two pulses of light per picture frame, but with unequal size blades the spacing between light pulses would be unequal. It is unfortunate that to the eye, unevenly spaced light pulses, or pulses of unequal length, are the same as flicker. Only when the pulses are evenly spaced and of equal length will the brain accept the resultant picture as sufficiently free from flicker.

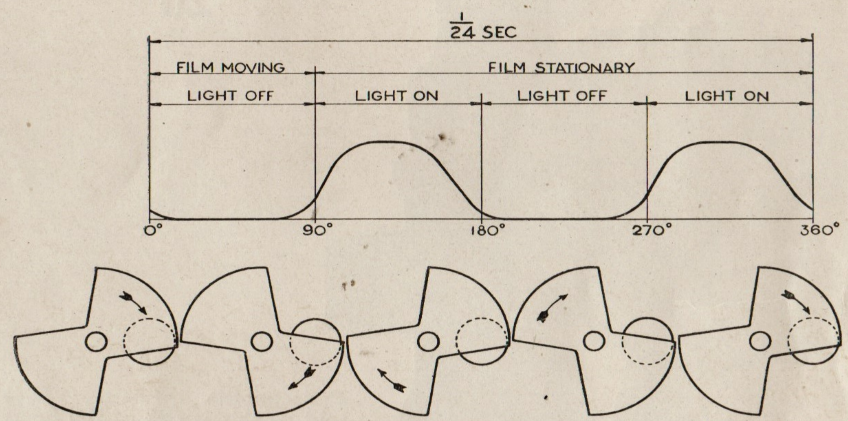
The duration of the light pulse, in comparison with the duration of the black out between pulses, has a bearing upon the degree of flicker observed on the screen. The longer the duration of the pulse as compared with the black out, the less, for any given average screen illumination, will flicker be noticed.

A.C. ARCS

A similar state of affairs obtains with an A.C. arc lamp, where again the light source is pulsating at twice the supply frequency. This slow " beat " flicker can be objectionable, but in many cases the trouble can be reduced by decreasing the cover angle of both blades of the flicker shutter. In theory it should be impossible to do this without risk of introducing ghost, but in practice it is often successful. A slight ghost in one corner of the picture is preferable to an overall flicker.

BLADE SHAPE

The blades of most flicker shutters are of simple shape with symmetrical leading and trailing edges. Some blades are of asymmetrical shape, and in some quarters a belief has arisen that one shape is better than the other.



USUAL TWO-BLADED SHUTTER I REV. PER $\frac{1}{24}$ SEC

Many normal rear shutter machines have flicker shutters with two 90 degree blades, so that the ratio between light pulse and black out is exactly 50 : 50. For a given light intensity on the screen, this 50 : 50 ratio will give a certain observed degree of flicker. Any improvement in the ratio of light to blackout will decrease the observed flicker, and any deterioration in the ratio will increase the flicker.

When an arc lamp is coupled to the unsmoothed output of a single phase arc rectifier operating from a 50 cycle supply, the light from the lamp pulsates at twice the supply frequency. When this light in turn is subjected to the action of a flicker shutter, the resultant light on the screen will have, superimposed on the normal rapid flicker, a slower flicker due to the " beat " between the periodicity of the light source and that of the flicker shutter.

Practical test with a particular projector mechanism under particular working conditions has more than once shown that a flicker shutter with blades of one shape resulted in more, or less, observed flicker on the screen than was obtained with a flicker shutter having blades of a different shape.

The reason for the different degree of flicker observed was not a difference in blade shape, but a difference in cover angle. The shutter with the better ratio of light to black out gave the better results.

HIGH-SPEED SHUTTER

In recent years, manufacturers of projector mechanisms have introduced machines with either twin two-bladed shutters, or with a single-bladed shutter rotating at double speed, as in the Gaumont-Kalee 21. The two alternatives are two methods of effecting a reduction in the time it takes a flicker blade to cut into and clear the beam. With a normal design of flicker shutter it has been shown that the finite diameter of the light beam results in each blade having about 20 degrees greater angle of cover than would be necessary were the beam of nil diameter.

If the diameter of the beam were halved, or if the time taken to cut the present beam were halved, it would be possible to halve the 20 degrees of additional cover angle which has to be added to each blade of the normal two-bladed shutter. The twin two-bladed shutter and the single-bladed double speed shutter halve the time taken to cut the beam, with the result that in effect, the cover angle can be reduced.

If with a two-bladed shutter of normal design the light efficiency were 50%, with twin shutters or a double speed shutter the light efficiency without hypothetical beam of 2½ inches diameter would be just over 55%, a gain of better than 10%.

Not only do projectors of these types give more light on the screen, but, because they improve the ratio of light to black out, they reduce the observed flicker on the screen.

Many projectionists continue to ask for the G.B-Kalee enamelled Lapel Badge. These are still available to others who would like them. Send your name and the address of your Cinema, with 2½d. stamp for postage, to Advertising Dept.

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TECHNICAL INFORMATION
for Projectionists

Published by **G.B-KALEE LTD.** **No. 8**

Light and the Angstrom Unit *

DISCUSSIONS of motion pictures, radio, television, radar, X-rays, and literally hundreds of other electronic devices bring repeated reference to wave frequency and wave-length and their measurement. It is necessary to define the characteristics of light radiation from a given source in exact terms, and the usual unit of measurement is the Angstrom Unit.

Knowledge of the generally accepted theory of light radiation is essential in order to understand the meaning of such a unit. As it well-known, all forms of radiant energy are compared to the ripples produced when a stone is dropped into a pool of still water, causing concentric waves to radiate in all directions. Light waves, radio waves, infra-red waves, ultra-violet waves and X-rays, all travelling at 186,000 miles per second, are of the same family (electro-magnetic) and are physically identical in nature as respects their speed of travel and their composition; they differ only in their frequency of vibration or wave-length. By frequency is meant the number of complete waves or cycles passing a given point in one second, and by wave-length is meant the distance between successive wave crests.

COLOUR AND FREQUENCY

A violet ray at the limit of visibility has a frequency of 750 million million vibrations per second ; a certain green ray has a frequency of 600 million million ; while one of the red rays has a vibration frequency of 400 million million per second. These frequencies are so high that even at the tremendous speed they travel the longest wave-length (or distance between wave crests) of visible radiation is but 0.00003 inch long, and the shortest about half that length.

Light also is known to be far more complex than it appears to the human eye. The eye cannot separate a beam of light into different colours. Daylight, for example, consists of an essentially even balance of all spectral colours. Colour is the perception of wave-length differentials within the visible spectrum. However, the eye does not respond to all colours. The infra-red or heat waves have too long a wave-length to be perceptible to the eye, and the ulta-violet rays have a wave-length that is too short to be seen. The colours between these extremes are referred to as the luminous (visible) rays and these may be further identified by the colour sensation they produce on the eye.

MEASURING STICK FOR WAVE-LENGTHS

Using minute fractions of the familiar units of measurement, such as millimetres, inches, feet and so on, would involve astronomical figures that obviously would be neither convenient nor practical. To use our shortest familiar unit of length, the millimetre, in defining wave-lengths would be equivalent to giving the size of this page in miles rather than inches. In order to establish a more convenient unit for measuring the wave-length of light, the Swedish physicist, Dr. A. J. Angstrom suggested a unit that is 1/100,000,000 centimetre in length. This is called the

* Reprinted from INTERNATIONAL PROJECTIONIST April 1952

Angstrom Unit, in honour of its originator, and usually is abbreviated to A.U. Colours in the luminous range of the spectrum may be defined by this scale as follows :

Violet	**4000 to 4500 A.U.**
Blue	**4500 to 4900 A.U.**
Green	**4900 to 5700 A.U.**
Yellow	**5700 to 5900 A.U.**
Orange	**5900 to 6300 A.U.**
Red	**6300 to 7000 A.U.**

Thus it is evident that the visible range of the spectrum is from 4000 to 7000 A.U. The shortest rays reaching the eye in natural sunlight are about 2900 A.U., which are too short to be seen.

range of available measuring units is comparable to the range of electromagnetic wave-lengths. That unit is used which best suits the length of the particular wave to be measured.

WAVE-LENGTH AND FREQUENCY

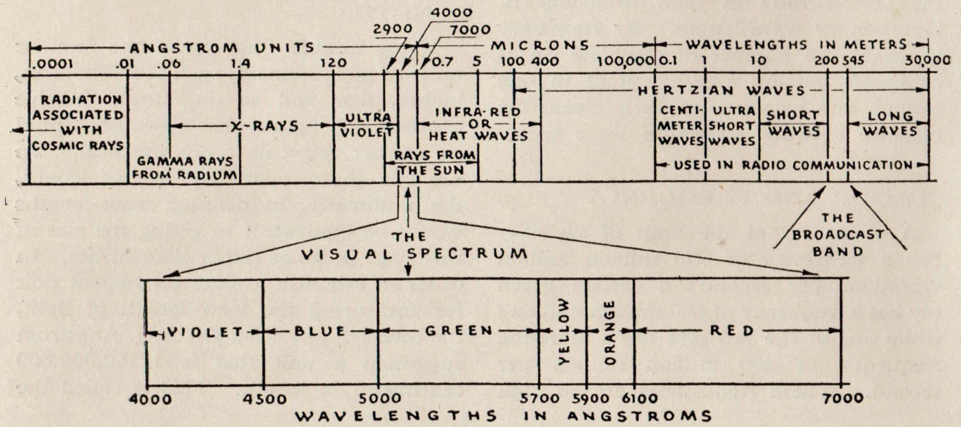
From this it is obvious that the Angstrom Unit scale is considerably more practical for measuring wave-lengths of visible light than any of the other common units. Accordingly, the visible spectrum is thus scaled in the accompanying illustrations. The infra-red or heat waves are shown scaled in microns. The radio waves are shown measured (according to early practice) in metres. Radio waves now are,

LIGHT MEASUREMENT UNITS CONVERSION TABLE

1 millimetre	=	0.1 centimetre	=	0.03937 in.	=	1000 micron
1 micron	=	.0001 cm.	=	.00003937 in.	=	1000 millimicron
1 millimicron	=	.0000001 cm.	=	.00000003937 in.	=	10 A.U.
1 A.U.	=	.00000001 cm.	=	.000000003937 in.		

Another unit, which is ten times the length of the Angstrom Unit, also is widely used. This is called the *millimicron.* Microns and millimicrons are perhaps more convenient yardsticks for the longer wave-lengths such as heat ; and metres and centimetres for the still longer wave-lengths of radio. For light measurements, the Angstrom Unit is commonly preferred.

The accompanying table sets forth the comparison of these different units of measurement. It also shows that the of course, more commonly scaled in frequencies than wave-length. Light similarly can be scaled in frequencies. It has been noted above that violet light at the edge of the ultra-violet has a frequency of 750 million million vibrations per second (750 mega mega cycles) and also a wave-length of 4000 A.U., and that both of these statements mean exactly the same thing. It is obvious that the A.U. is the more convenient unit to use for light, just as kilocycles and megacycles are most convenient for radio.



Electro Magnetic Spectrum as Measured in Angstroms, Microns and Wavelengths

Newton's Rings:

Yardsticks of Optical Science *

Scientific Bureau Bausch & Lomb Optical Co.

IN THE irridescence of an oil film on a wet city pavement and in the colours of a soap bubble in the sunlight, science and industry have the key to the most precise and delicate direct measuring method known.

"It has been observed by others, that transparent substances, such as glass, water, air, etc., when made very thin by being blown into plates, do exhibit various colours, according to their various thinness, although at a greater thickness they appear very clear and colourless." So wrote Sir Isaac Newton in the last quarter of the 17th Century, and then he sets about describing a series of experiments in what we now call physical optics which have not been surpassed in ingenuity to date. Considering the crudity of his apparatus, the accuracy of his results is amazing.

Incredible Precision Required

The dimensioning of mechanical parts for high-grade optical apparatus is very precise. For instance, the lens separations in a modern microscope objective are specified in thousandths of a millimetre, or microns, one of which equals 0.00004″. But for gauging optical surfaces on lenses, prisms, and reflectors, the micron, small as it is, is still too large. Here recourse must be taken to fractions of the wave-length of light.

The optical engineer assumes and the skilled optical craftsman attains in routine production accuracies of curve to 0.000006″ and can exceed in fineness 0.0000008″ when instrumental applications require.

How can optical work be measured confidently with such delicacy? "It's very simple," says the experienced lens grinder and polisher. "I measured it by Newton's Rings and it's within a quarter or a tenth or a thirtieth of a wave-length." In the colour phenomena of thin wedge films he has a means for measuring the accuracy of transmitting and reflecting surfaces in units which, though real, are so small as to be almost inconceivable.

Newton's Pioneer Calculations

Each time such a measurement is made, the classical experiments of Newton are duplicated. Newton was not the first to observe the formation of coloured areas in the thin film of air between two polished plates, or in thin layers of water as in soap bubbles, or thin plates of glass, mica or pitch. Nor was he the first to propose an explanation. Robert Boyle and Hooke, the microscopist, both preceded him. Neither one, however provided an explanation on a definite quantitative basis.

"To observe more nicely the colours" under controlled conditions, Newton placed the plane surface of a plano-convex objective from a 14-foot telescope on the convex surface of a bi-convex objective from a telescope of about 50-foot focus, thereby forming a thin film of air which gradually increased in thickness from zero.

Upon observing this arrangement by reflected light, at the centre where the surfaces were in contact he saw a black circular spot about which was a series of bright and dark concentric circles. In white light the bright rings were coloured. In red light the rings were larger than when viewed in blue light. By calculating the distance between the glass surfaces he was able to determine the air film thickness responsible for each colour.

Ingenious as was Newton's Corpuscular Theory, it finally lost ground in the face of the Wave Theory as sponsored by Huygens, Young and Fresnel.

The modern explanation of Newton's Rings is based upon the assumption that light consists of periodic disturbances which, regardless of their frequency, travel at the same speed in any homogeneous medium.

It can be visualized somewhat imperfectly by the mechanical analogy of water waves which would be formed by touching a tuning fork or vibrating reed to a liquid surface. With such a set-up ripples would radiate in all directions from the point of contact.

If the fork was of low note, fewer waves would be radiated per second than if a higher note fork were used. The distance between the crest of one wave to the crest of the next would be the wave-length in either case. Obviously the low note fork would produce the longer wave.

Using two forks of identical vibration rate, it would be possible to find a position where the waves from one fork would dampen out or nullify the waves from the other. Another position could be found where the waves from one fork would accentuate the waves from the other. In the first case the waves would be out of

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step or phase. In the second case the waves would be in step or phase.

Formation of Newton's Rings

With light we have a condition somewhat similar. A body giving out visual light radiates energy in wave-form, in which the distance from crest to crest ranges from about 0.0004 to 0.0008 mm and which travels at the rate of approximately 300,000,000 metres p.s. in air.

It should be noted that interference of light waves emanating from different sources has not been demonstrated experimentally, possibly due to the extremely high frequency making synchronization very unlikely. However, light waves from the same source can be made to interfere under certain conditions, one of which is that responsible for the formation of Newton's Rings.

Let us assume that we have the same experimental arrangement as set up by Newton, namely a convex surface of very long radius and a plane surface enclosing a very thin film of air. As an illuminant we will use a source radiating light of one wave-length.

On looking at the enclosed air film from above we will see a central dark spot surrounded by alternate bright and dark circles. If we looked through the air film, we would see just the opposite a central bright round area surrounded by alternate dark and bright circles.

Path of Reflected Rays

Due to the very slight difference in curvature, the air film at any point can be considered as essentially plane parallel. We neglect all reflections except those at the enclosed air film-to-glass surfaces. These conditions are diagrammed in Fig.1.

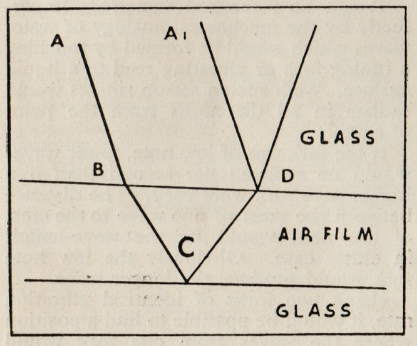

Fig. 1

A portion of the ray of light coming from A nearly normal to the film is refracted at point B, where it leaves the glass on entering the air film to point C where it is reflected back through the film to point D, where it is refracted along the same path as that portion of a ray coming from A1 is reflected at point D.

If the length of the path BCD is such that the light waves in the light following the path BCD are out of step one-half wave-length, they will interfere with or nullify those reflected at point D, and no light would be reflected from the film.

When the length of the path BCD is such that the refracted and reflected portions are in step, they augment each other and increased reflection occurs.

It would seem that the centre area, where the glass surfaces are practically in contact, should appear bright because here the film thickness is very small compared with the wave-length, and sufficient lag to cause interference would not occur. The apparent discrepancy is explained as follows :

Reflection at C occurs in air and there is a lag in the reflected light of one-half wave-length. Reflection at D occurs in glass with no retardation. Accordingly, no light is reflected at the centre nor when BCD is equal to any whole number of wave-lengths.

Taking into account the change of phase or reflection mentioned, film thicknesses corresponding to odd multiples of one-quarter wave-lengths will give increased reflection or "bright rings," and those corresponding to even multiples will give decreased reflection or "dark rings."

Heretofore we have considered the conditions for light of only one wave-length. When white light is used, the colours seen are those remaining after interference. It is interesting that light interferences as shown in Newton's Rings also forms the basis of surface treatment of lenses to prevent a loss of light by reflection.

From the foregoing it can be seen that in the thickness of an air film the skilled optical worker has a means of extreme delicacy and accuracy for proving his work. It is surpassed by no other precise physical determination. It provides its own unchanging standard.

When he checks his work by simply noting the shape, colour, and number of rings or bands that appear when he places the work in hand in contact with the master gauge, he can determine differences in curve or flatness in any desired fraction of the wave-length of the light employed. By using this test he can arrive at such perfection of surface that molecular cohesion results when two such surfaces are brought together.

TECHNICAL INFORMATION
for Projectionists

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Heat, Light and Screen Illumination *

by **A. S. Pratt, M.B.K.S.,** *Chief Designer, British Acoustic Films Ltd.*

THE history of the development of cinematograph equipment shows that one limiting factor after another operates to determine the maximum performance that can be obtained. For example, in the early days, the power of the illuminating system set a limit to the picture brightness. Subsequent development of light sources and larger aperture projection lenses continued until the heat at the gate became the limiting factor.

The next step was to move the shutter from the front of the machine to behind the gate, thus at one step reducing to approximately 50 per cent the amount of light and heat reaching the film, without altering the amount of light reaching the screen. Further development of light sources followed until today the film itself is again the limiting factor.

To understand why the film is the limiting factor it is necessary to consider the nature of the radiation falling upon the film in the gate. It must be realised that all radiation is a form of energy and that when radiation is absorbed the energy of the radiation is converted into heat with a consequent rise in temperature of the body which absorbs the radiation.

Contrary to what is often implied it makes no difference to the heating effect whether the radiation is in the infra-red, the visible, or the ultra-violet regions of the spectrum. The fact that the human eye responds to radiation of certain wavelengths is a characteristic of the eye, not of the radiation, and does not in the least affect the energy-carrying ability and hence the heating effect of the wavelengths concerned.

RADIATION CHARACTERISTICS

It is a characteristic of the radiation produced by a high intensity carbon arc, that approximately 50% of the radiated energy is in the visible portion of the spectrum, (1) whereas only about 12% of the energy radiated by a tungsten filament projector lamp (2) is in the visible region.

It is often suggested that heat filters can be used to remove heat from a beam of light and produce what is sometimes termed "cold light." This, of course, is quite untrue. A given quantity of energy in the visible region will, if absorbed, produce just the same temperature rise as the same quantity of energy in the invisible regions of the spectrum.

What a filter can do is to absorb some of the invisible energy from a beam of radiation without very greatly affecting the visible part, consequently the total energy in the transmitted beam can be reduced to a greater extent than the

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illuminating power. The filtered beam of light will not be " cold " however, because its heating effect is always proportional to the total energy it contains. For a given illuminating power, the heating effect can be reduced by an amount that depends upon the characteristics of the filter and the spectral distribution of the energy in the original beam. The results that can be expected from the use of heat filters in cinematograph projection equipment will be discussed later.

BEHAVIOUR OF THE FILM

It is interesting to try to visualise just what happens to the film during the short time it is exposed to the beam of radiant energy concentrated upon the gate aperture. The film base and the clear parts of the image have such a high transmission that they absorb a negligible amount of energy. The silver in the other parts of the image (3) (or the dyes in the case of colour film)(4) absorbs very strongly throughout most of the spectrum, and the energy which is absorbed is converted into heat in the very thin layer in the emulsion in which the detail of the picture resides. The emulsion layer can lose this heat by re-radiation, by conduction to the film base and to the metal parts of the gate, and by conduction to the surrounding air.

The time of exposure is very short. With a normal projector having two cut-offs per frame, each frame of the film is exposed twice, and each exposure has a duration of approximately 0.01 second. During this short time the emulsion layer cannot lose much of the heat because its temperature is too low for appreciable re-radiation to occur, the thermal conductivity of the emulsion and the base is too low for much to be lost by conduction, and the amount that can be lost to the air adjacent to the emulsion is small unless the air is moving very rapidly. Air cooling has in fact been tried (3), but it has been found that air velocities around 400 miles per hour have to be used to be effective. Slow moving air is quite useless for cooling purposes and it is clear that air directed on to the base side of the film would also be ineffective. Consequently the temperature of the emulsion layer must rise rapidly during the time that it is exposed to the radiation, and the extent of the temperature rise will be determined by the intensity of the radiation.

If this temperature rise is appreciable it can be expected that the emulsion layer will expand and that the film will be deformed. If the deformation is excessive focus trouble can be expected.

It is of interest to note that the dyes used in some colour films are comparatively transparent to parts of the infra-red spectrum (5), and consequently these colour films might be expected to have a slightly lower temperature rise than black and white films.

Immediately after exposure the film passes down through the gate and through the projector and during this time the heat will be dissipated by the various means mentioned above, which, though ineffective during the short exposure time, will of course operate to cool the emulsion layer during a greater period of time. A few inches after leaving the aperture the film can be expected to have attained approximately uniform temperature throughout its thickness.

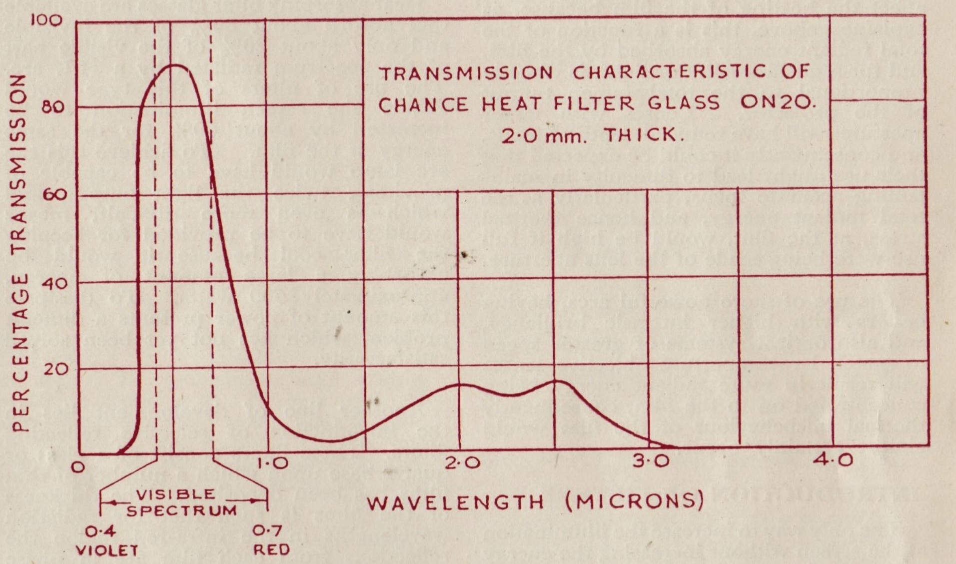
PROJECTOR CHARACTERISTICS

It will be apparent that, in order to obtain the maximum light on the screen with the minimum heating of the film, only that radiation which contributes to the illumination of the screen should be allowed to fall upon the film, and all other useless radiation should in some way be prevented from reaching it. It should be noted that useless radiation covers both non-visible radiation and also any visible radiation, incident upon the film, which does not reach the screen, *i.e.*, which is not passed on by the projection lens.

A most important feature of a projector is the amount of light which it projects on to the screen. The light output is measured in lumens, and the total lumen output is equal to the screen area in square feet multiplied by the average illumination intensity at the surface of the screen measured in foot candles (alternatively the area in square meters may be used multiplied by the average intensity of illumination measured in lux). The figure for the total light output in lumens is a most important criterion of the performance of projection equipment. The more efficient the projector is the more lumens will it project on to the screen for a given power in the arc lamp.

Modern projection equipment burning about 65 amps in a mirror arc will project about 7,000 lumens on to the screen and experience indicates that this represents the limit above which trouble with the film is likely to occur.

In any case this represents about the maximum amount of light that can be obtained from equipment of this type. Increased current in a carbon trim designed to burn at 65 amps will lead to increased carbon consumption rates and to generally unsatisfactory operation without appreciable increase in light output and the use of larger carbons with higher current may even result in less light on the screen because the larger carbon may operate with a crater having a lower intrinsic brilliancy.



If 10% is allowed for the loss in the projection ports and if the reflectivity of the screen is assumed to be 75%, a value which should be easily obtainable, it will be possible, with a light output of 7,000 lumens, to obtain a picture 20 feet wide having an average screen brightness of 16 foot-lambets, and a picture 28 feet wide with an average brightness of 8 foot-lambets. These are the maximum and minimum British Standard values for screen brightness (6).

It will be seen that picture sizes can be obtained that are quite adequate for most requirements, but it is of interest to consider what possiblities exist to get greater light output should the need arise.

FACTORS AFFECTING LIGHT OUTPUT

The light output of cinematograph projection equipment depends upon a number of factors :—

(1) The efficiency of the projector shutter system.

(2) The aperture ratio (f. no.) and the efficiency of the projection lens.

(It is here assumed that the arc lamp and the projection optics are properly matched so that the projection lens is completely filled with light and operating to best advantage.)

(3) The intrinsic brilliancy of the arc crater.

It is obvious that the efficiency of the projector shutter controls the light output and it is easy to see why modern projectors with high efficiency shutters produce a greater amount of film and gate temperature rise for a given arc current than do older machines with less efficient shutters.. The high efficiency shutters pass more total radiation, *i.e.* heat and light together, to the film, and hence to the screen, producing, for a given arc current, a brighter picture. It follows, therefore, that when discussing film and gate temperatures the criterion is screen illumination, and not arc current. Considerable improvement in shutter efficiency has taken place during the past few years, and it is difficult to see how any further significant improvement can be made.

It is possible that projection lenses may become available with apertures larger than those in current use. The use of such lenses would increase the optical speed of the equipment but would not affect the heating of the film because, as explained above, this is a function of the total radiant energy absorbed by the film, and for a given quality of light, is directly proportional to the total lumen output of the projector. Lenses with larger apertures will have reduced depth of focus, and consequently it could be expected that their use might lead to difficulty in maintaining accurate focus, particularly as the total radiant energy, and hence thermal stress, at the film, would be high if full use were being made of the lens aperture.

The use of more powerful arcs, having craters with higher intrinsic brilliancy, and also optical systems of greater speed to match larger aperture objective lenses will result in more radiant energy being concentrated on to the film, consequently thermal misbehaviour of the film would almost certainly occur.

INTRODUCTION OF FILTERS

The only way to increase the illumination at the screen without increasing the energy at the film is to use heat filters between the arc and the film. In this connection the term filter is used to mean a device that acts differentially as between visible and non-visible radiation, that is, a heat filter is one which transmits, more or less without alteration, the visible part of the spectrum and either absorbs or reflects most of the unwanted or invisible radiation.

As mentioned above, approximately 50% of the radiation from the high intensity carbon arc is in the visible part of the spectrum. It is, therefore, quite clear that there is a limit to the increase in screen illumination that can be achieved even with a theoretically perfect filter. If the intensity of radiation at the film is to be kept constant and if a perfect filter could be used, *i.e.*, one which removes all the invisible radiation without absorbing any of the visible, it would be possible approximately to double the screen illumination.

CHARACTERISTICS OF FILTERS

Practical filters absorb both light and heat and the limits indicated by consideration of theoretically perfect filters can never be reached. Ordinary glass absorbs about equal amounts of both visible and invisible radiation and hence the introduction of such glass into the optical system would effect no real improvement. A more powerful light source would be required to bring the screen illumination back to its original value and the total energy at the film gate would remain the same as before.

Heat absorbing filter glasses are available that absorb about 80% of the invisible and only about 20% of the visible part of the spectrum radiated by a H.I. arc. The use of filters of this type would enable the screen illumination to be increased by about 60% for the same energy at the film. To achieve this the arc lamp would have to be capable of providing twice the light output, and which is even more difficult, means would have to be provided for keeping the filter cool because it would be absorbing a large amount of energy, approximately 500 watts. To dissipate this amount of power presents a difficult problem which has not yet been solved satisfactorily.

Another line of development lies in the introduction of selective reflecting filters. These filters consist of a glass or quartz base upon which a number of thin films has been deposited. The thickness of the films is such that for radiation wavelengths in the infra-red region the reflections from each film are in phase with each other, hence the combination produces high reflection. For other wavelengths, and in particular for the visible part of the spectrum, the component reflections are out of phase, which results in low reflection and high transmission. The filters can be made so that approximately 80% of the energy in the visible region is transmitted, and a large part of the remaining energy is reflected. By virtue of the fact that these filters reflect the unwanted radiation and transmit most of the visible radiation they absorb very little energy and consequently have only a small temperature rise. They do not, therefore, need cooling. They are, however, not so efficient in removing all the unwanted energy as are absorption filters, because the correct phase relationship between the reflections at the various surfaces can only occur in a comparatively narrow band, and, therefore, more or less complete reflection will only occur in this band.

It is unlikely that filters of this type will ever be produced with a transmission efficiency of much more than 80% for the visible part of the spectrum. This means that with normal projection equipment the use of such filters would reduce the screen illumination to about 80% of its present value and, as indicated above, modern projection equipment gives a maximum light output when burning about 65 amps and there are no simple means available for increasing the light output. To get a significant increase in light output it will be necessary to use much more powerful and elaborate arc lamps of the rotating positive type. These would consume 4 or 5 times the power and after making the necessary allowance for the loss in the filter would produce a net increase of about 15% in the screen illumination.

SOME EXAMPLES

These figures are based on published data (7) which gives, for 80% side to centre distribution, an output of 13,000 lumens for 8 mm " Suprex " and 7 mm " Orotip " C carbons at 70 amps 40v in a lamp with a 14 in. f2.3 mirror and a projector with a 5 in. E.F. f2.0 coated projection lens. 13.6 mm " National " H.I. and ½ in. " Orotip " carbons at 150 amps, 78 volts in a lamp with a condenser working at f2.0 and with the same projection lens give 16,000 lumens for 80% distribution. 13.6 mm "National" H.I. and ½ in. H.D. "Orotip" at 170 amps 75 volts, under the same conditions give 18,500 lumens. The new " Hitex " super high intensity carbon (8), at 180 amps 74 volts, gives 19,300 lumens under the same conditions. These are figures for no shutter ; with a 50% shutter the screen lumens would be 6,500, 8,000, 9,250, and 9,650 respectively. After allowing 20% for the light loss in a heat filter, which is about the least that can be expected, the relationship between arc current, arc power, and screen illumination is :—

Arc Amps	*Arc Kilowatts*	*Screen Lumens.*	*% Screen Lumens.*
70	2.8	6500	100
150	11.7	6400	98.5
170	12.75	7400	114
180	13.3	7700	118

This really is the crux of the whole matter. With non-rotating carbon high intensity lamps it is possible to obtain really adequate screen illumination for all but the very largest picture sizes without running into trouble with the film To obtain any increase in light output above this value it is necessary to have very much more powerful lamps and then to introduce heat filters to prevent film damage and as a consequence of the inevitable loss of light caused by the introduction of the heat filters the nett gain in screen illumination is so small as hardly to be worth while.

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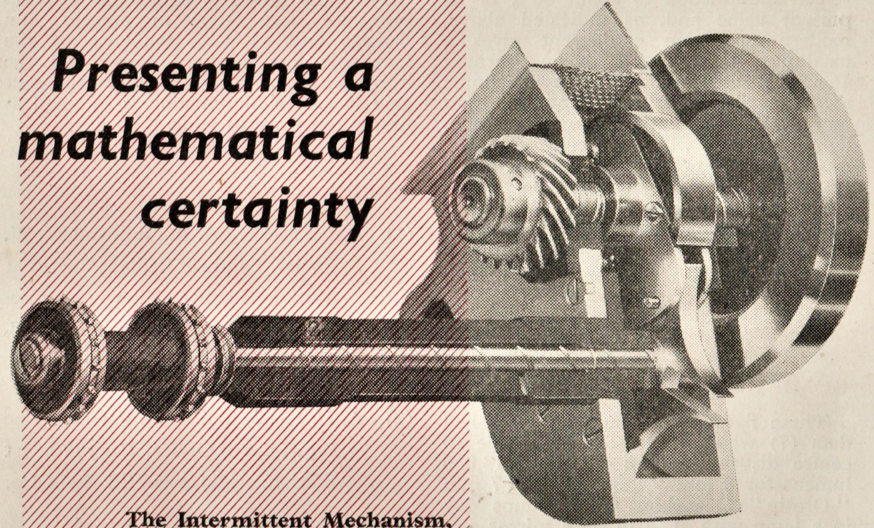

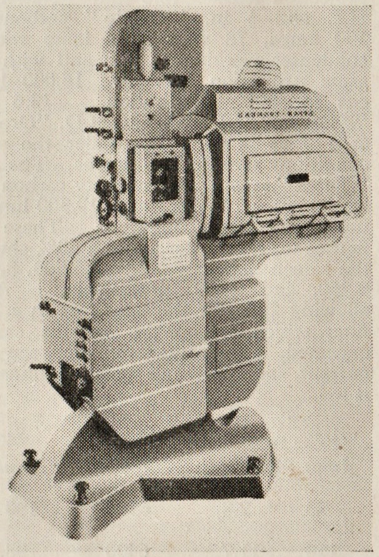
GAUMONT-KALEE

TECHNICAL INFORMATION

for Projectionists

Published by **G.B-KALEE LTD.** **No. 10**

Why 3-D Requires Precision in Equipment and Operation*

By GIO GAGLIARDI

PROJECTION of 3-D films has developed an entire set of new and somewhat different problems for the projection room. Mainly these arise from the necessity of operating two projectors simultaneously to project two disparate pictures superimposed upon the screen.

We are now dealing with *stereoscopic* projection, and the problems involved are indelibly related to all the complicated theories and phenomena of stereoscopic photography. (The word *stereoscopy* is derived from two Greek bases—*stereos*, meaning solid; and *skopos*, meaning to see. Thus stereoscopy means *to see solid.*)

Fundamentally, stereoscopy is based upon what seems to be rather simple principles. The human being has two eyes which are separated from 2½ to 2⅝ inches. This is called the *interocular distance* and is one of the most important factors in the entire theory. Because of this separation, each eye has a separate and different point of view for any object within the line of sight. These two views—slightly different—supply the brain with information which it uses in forming a conception of depth (perspective).

When two photographs are *made* of the same object or scene, with two cameras separated by a distance virtually similar to that between the eyes, these two photographs will correspond to the visual images of the two eyes. Now if these two photographs are *viewed* in such a manner that each eye sees its own picture and not the other, then conditions comparable to direct binocular vision are established and the two photographs will fuse into one stereoscopic or three-dimensional picture.

STEREOSCOPIC PRINCIPLES

The problem then involves two principal and fundamental steps. Two photographs must be taken from two different points of view. These two photographs must be viewed simultaneously; but each eye must only see its own picture. Let us examine the principles of the stereoscopic projection system where these two dissimilar images are projected on a screen.

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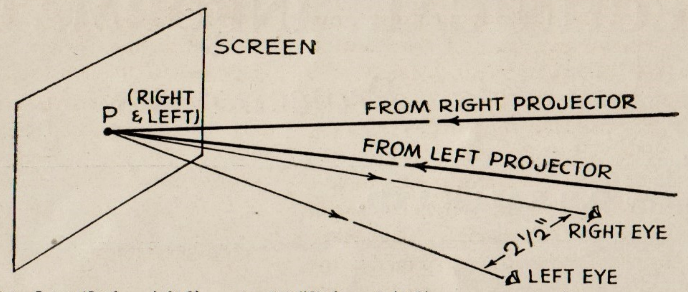

FIGURE 1—Point "P" from left film and point "P" from right film converge at point "P" on screen. Left and right eyes converge on point "P" at screen. Film parallax is zero. Screen parallax is zero.

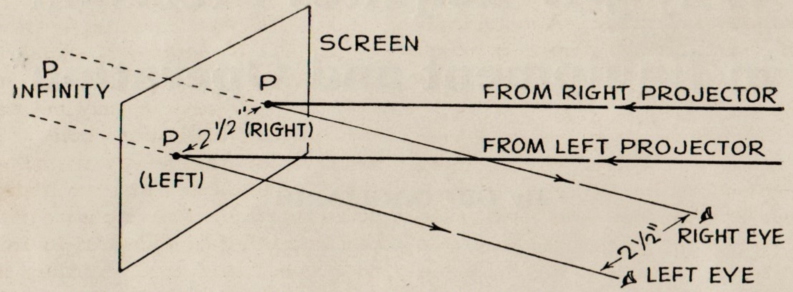

FIGURE 2—Point "P" from left film, and point "P" from right film are separated 2½ inches at screen. Left and right eye converge Point "P" at infinity behind screen. Screen parallax is + 2½ inches. Film parallax is 2½ inches divided by magnification between film and screen picture.

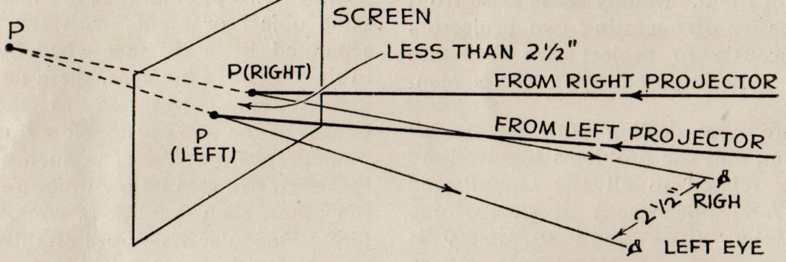

FIGURE 3—Point "P" from left film and point "P" from right film are separated less than 2½ inches at screen. Left and right eye looking at "P" (left) and "P" (right) separately converge at fused image "P" behind screen. Screen parallax is less than + 2½ inches. Film parallax equals above value divided by magnification.

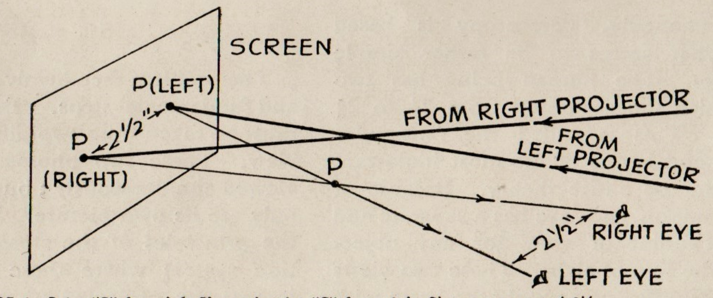

FIGURE 4—Point "P" from left film and point "P" from right film are separated 2½ inches at the screen but are reversed in position. Left and right eye looking at "P" (left) and "P" (right) separately converge sharply and fuse image "P" in front of screen. Screen parallax is—2½ inches. Film parallax is — 2½ inches divided by magnification.

Simple sketches embodying these principles are shown in *Figures* 1, 2, 3 and 4. In each case a spectator is located at a distance (*V*) from the picture screen, on to which are projected the images from the left and right films of a stereoscopic pair. Let us say that the spectator's eyes have a separation of 2½ inches, which is about the average interocular spacing. By means of the selective (polarizing) spectacles, the viewer's eyes are able to see every single point of detail of each picture very much like the scanning beam of two synchronized cathode ray tubes. Automatically each eye will select any similar point on each picture and resolve it into an image in space.

Let us examine *Figure* 1 : A point *P* from the *left projector* is focused on the screen and is seen only by the *left eye*. An identical point *P* from the *right projector* is also focused on the screen and it is seen by the *right eye*. But *both* of these *points* are superimposed exactly on the screen plane, therefore the brain locates them only as one point at the screen surface. This is a case similar to the condition that would be produced by using only *one film* and *one projector* in standard two dimensional projection.

Now examine *Figure* 2 : Here the point *P* from the *left projector* seen by the *left eye* is separated from the identical point *P* of the *right projector*, which is seen by the *right eye*, by a distance of 2½ inches. Each eye is looking at its *own* point *P*, and the axes of both eyes are parallel, therefore the brain will fuse the images of the two points at a distance equal to infinity (far, far away) *behind* the screen.

Now take *Figure* 3 : Here the distance between the images of point *P* (left) and point *P* (right) is *less* than 2½ inches. Each eye looking at its own point *P* will converge and the brain will establish the location of *P* some distance *behind* the screen, between the plane of the screen and infinity.

In *Figure* 4 the images of point *P* are again projected on the screen with a separation of 2½ inches, but this time the position is completely reversed: *the projection rays cross before they reach the screen.* Again, since each eye will only see its own proper point, the visual axis of each eye will cross *in front of the screen* and the brain will locate the image of *P* somewhere at the point of *convergence* in front of the screen.

THE SCREEN PARALLAX

The distance between the screen images of point *P* (left) and point *P* (right) is called the *screen parallax for stereoscopic projection.* By looking at the sketches in the following order—2-3-1-4—you will note that the point *P* may be moved by the brain's imagination from a position away out at infinity—up to the screen—then through it and into the centre of the auditorium. If the point were the picture of a baseball, it could be thrown from deep centre field and come hurtling into the spectator's lap. Of course, the above example is an exaggerated case, though used in "trick" stereoscopic photography.

It is common practice to designate the screen parallax (separation of corresponding points in the two pictures) as positive, or +2½ inches, when the fused image is at infinity *behind* the screen, as in *Figure* 2. The parallax is zero when the points converge at the screen, as in *Figure* 1. And the parallax is —2½ inches when the points converge *in front* of the screen half way between the screen and the spectator.

You will note that there is only a maximum allowable limit of 2½ inches in order to place the complete depth of any scene between the screen frame and infinity, and *this limit is fixed regardless of the size of the picture screen.*

Let us assume that we have to fill a screen 24 feet wide with a standard 35mm film frame having a width of 0.825-inch. The magnification from the film to the screen in this case is 350 times. Therefore the maximum separation of 2½ inches between points in the two images on the screen can only be an infinitely small amount on the two films. In other words the *printed separation*, or *parallax on the left and right hand films* of the stereoscopic pair, will be 2½ divided by 350, which equals 0.007 inches. This means that those *two points* would appear on the films as if each were printed off centre by 0.0035-inch.

The ability of the human eye to see stereoscopically depends upon the distance between the observer and the object. The farther away an object is located, the less perception will the observer have of its depth, or third dimension.

LIMITING DISTANCE VARIES

This limiting distance varies for different persons. Let us assume that objects beyond a distance of 600 feet do *not* produce any stereoscopic effect; in other words, that everything beyond 600 feet is at infinity to the eyes. Then a parallax of 2½ inches at the screen will represent points *starting at* 600 *feet and everything beyond* in depth behind the screen.

Since most of the action in any scene should take place near the observer, let us say that this action ranges over an *apparent* space of 60 feet behind the screen (plane of the screen itself). This principal zone then will be covered by only 1/10 of the total permissible screen positive parallax of +2.5 inches, and that is +0.25 inches. On the film this smaller quantity will be reduced to a parallax separation of little less than 0.001 of an inch.

This means that in order to maintain the exact relationship between all points on the two projected images so as *not to distort* the original shapes and the curves of depth, the two films should be exposed, printed and projected in machines with *zero error* of registration and with a *zero amount of lateral motion.*

It has been determined that about 70% of our theatres have screens ranging from 16 to 25 feet wide and averaging a magnification of 300 times, which is very close to the example used above. The necessity for extreme accuracy in film stock manufacture, and absolute precision in camera and processing equipment cannot be overemphasized if the infinitely small film parallaxes are to be maintained in order to achieve maximum stereoscopic resolution.

The startling effects of trick stereo photography can be produced easily and require the minimum amount of equipment accuracy; but these tricks in themselves will not sustain public demand. The real beauty and artistic appeal of true stereoscopic pictures which will maintain a public for the motion picture can only be obtained by *reproducing accurately* all the scales of minute differences stored in the stereoscopic pairs of films in the projection room.

The new well made three-dimensional films may only be fully exploited if the theatre projection equipment is the best available. It must be remembered that two projectors are operating simultaneously to deliver two pictures on the theatre screen.

The eyes of the spectator are trying to focus on each picture individually and to converge every detail into a fused three-dimensional image. The slightest relative vertical displacement of the two pictures will force the viewer's eyes to twist; the slightest lateral change in spacing of the two films will cause the eyes to change their picture-fusing, or to change the location of the points of convergence. Loss of focus in either projector, or excessive difference in brightness between pictures, will impair the three-dimensional effect!

All the above defects which can result from slightly worn, defective, or old-style projection equipment will not only produce picture distortion, but will cause excessive eye strain and fatigue to such an extent that patrons may lose all interest in stereoscopic motion pictures.

Only rock-steady, accurate projectors, correctly aligned, and properly operated will reproduce faithfully all the small differences of stereoscopic parallax which can give such true details in well made three-dimensional pictures.

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TECHNICAL INFORMATION

for Projectionists

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Relating Picture Size To Seating Pattern*

We are reprinting only the third article of the series "Theatres and the New Techniques" written by Mr. Ben Schlanger, as it is of the greatest interest since the development of Wide-Screen and CinemaScope.

SIZING THE wider picture is again our subject in this article. The preceding discussion of "wide-screen" picture dimensions offered a selection of procedures as might be advised by specific circumstances, and went into the factors of aspect ratio and structural conditions affecting choice. Now we deal with the expanded performance area as an essentially permanent installation—in its basic specifications, at any rate.

The projected picture, regardless of size or proportions, is fundamentally related to the seating pattern. As we increase its dimensions, this relationship becomes increasingly critical. The question of picture size in the past has been simpler than now, not merely because of its relative smallness, but also because of cinematographic practice which the traditional scale and shape advised. "Wide-screen" technique includes increase in the volume of pictorial material as well as extension of the space which it occupies.

Other qualities of the screen image are changed. The very expansion of width to twice as much as before, even more in some instances, makes any distortions the more apparent. Visual acuity is sharpened by magnitude alone, so that regardless of whether projection and screen specularity produce a brighter picture than before, perception is more sensitive to perspective and all the other factors of realism.

Whether it is wise to provide for "wide-screen" productions in some more or less temporary manner, depends upon circumstances of each situation. We cannot ignore, however, the natural relationship between picture size and seating pattern, and the fact that it is more critical in "wide-screen" technique than ever before. Why that is so is explained in this article, and we offer a simple method of determining picture size according to seating pattern.

VISION AS A BASIS

The efficiency of a seating plan is measured by the percentage of desirable viewing positions in it; hence all conditions affecting viewing of the picture should be determined on the basis of an ideal viewing location at the centre of the *seating mass.* Since a normal seating pattern is narrower toward the front than it is elsewhere, the centre of the seating mass is normally more than halfway back from the screen. When the seating plan includes a balcony, then we have still more seating toward the rear of the auditorium, which pulls the centre of the seating mass (centre of seating gravity, as it were) yet farther back.

* Reprinted from "MOTION PICTURE HERALD BETTER THEATRES," November 7th, 1953, by kind permission of the Editor

This centre is that point along a line perpendicular to the centre of the screen at which half of the seating is forward of it, and half of it to the rear of it. If we then establish a picture size which is the most desirable for viewing a screen performance in the new "big picture" technique (bearing in mind the cinematographic values of that technique), we shall have the best size for the greatest part of the seating capacity. For convenience in reference, let us call that picture size *optimum*.

In dealing in the preceding article with screen dimensions more in terms of immediate expedients than we are approaching them here, we used the factor of maximum viewing distance (*W*). This has served for many years as a reference for determining a minimum size of a picture in order to give the majority of patrons effective perception of screen image details. With cinematographic practices developing from the fact that the picture was almost square and typically small relative to the auditorium—using, that is to say, the "close-up" more and more—it was found by persons trying to arrive at some sort of competent guidance in the matter that the need to perceive detail—*visual acuity*—was adequately satisfied, on the average, if the picture was no smaller than a trifle over one-fifth the distance from the screen to the last row (a maximum viewing distance approximately five times the screen width, or 5W).

But "wide-screen" technique is a horse of another colour. With it, the *value* of the close-up can be retained, but with other (environmental) material included; moreover, an important advantage of the "big picture" is the exploitation of scenic and spectacular material, requiring long- and wide-angle shots. All the relationships of picture size to seating pattern now become more critical than they were. This article therefore submits a formula that recognizes the conditions introduced by "wide-screen" technique from studio to theatre.

It doubtless may be assumed that exhibitors want to take the fullest possible advantage of this new technique of cinematography and projection; we therefore do not want to lose any of the effect of "presence" that it can give the screen performance, nor minimize any of the pictorial conditions which help the mind to construct a realistic image.

AS THE CAMERA SEES IT

Consider the camera as a witness of the scene. (And that is the point of view of the director who is creating and judging the action and composition of the scene.) Obviously, the ideal point from which to view the projected scene would be one comparable in angle and distance to the relative position of the camera itself.

Only a few members of an audience could enjoy such a favourable location; however, going to a larger picture does move that position to the centre of a greater number of seats than has been typically the case. If the centre of the seating mass is one from which the picture is viewed with greatest visual ease, and with such ideal conditions of perception that there is a minimum of distortion of *perspective* (depth sense), then it does express the relationship between the focal length of the camera lens and the focal length of the *projector* lens.

This is illustrated in accompany drawings. Widening of the picture with the use of shorter focal length lenses in both cinematography can—and in the product made with "wide-screen" technique, actually does—move this point of superior perception closer to the centre of the typical seating mass—for some scenes, in fact, placing both at about the same position.

We shall deal with this condition of viewing further in this article, in illustrating the application of the method here submitted for determining picture size in accordance with the seating pattern. But first the method itself:

The method is illustrated in the three drawings accompanying this article. In *Figures* A-1 and A-2 describe a seating pattern that may be taken as typical, since it is based on the survey of pertinent conditions in existing American theatres recently conducted by the Society of Motion Picture and Television Engineers.

The pattern of *Figure* A-1 includes a balcony; that of A-2 is of single-floor seating.

The schemes here are worked out on the basis of a maximum viewing distance of plan flares out continuously toward the rear in a wedge shape, which it rarely does. As for the extremely wide auditoriums (relative to depth), the abundance of architectural forms that these introduce

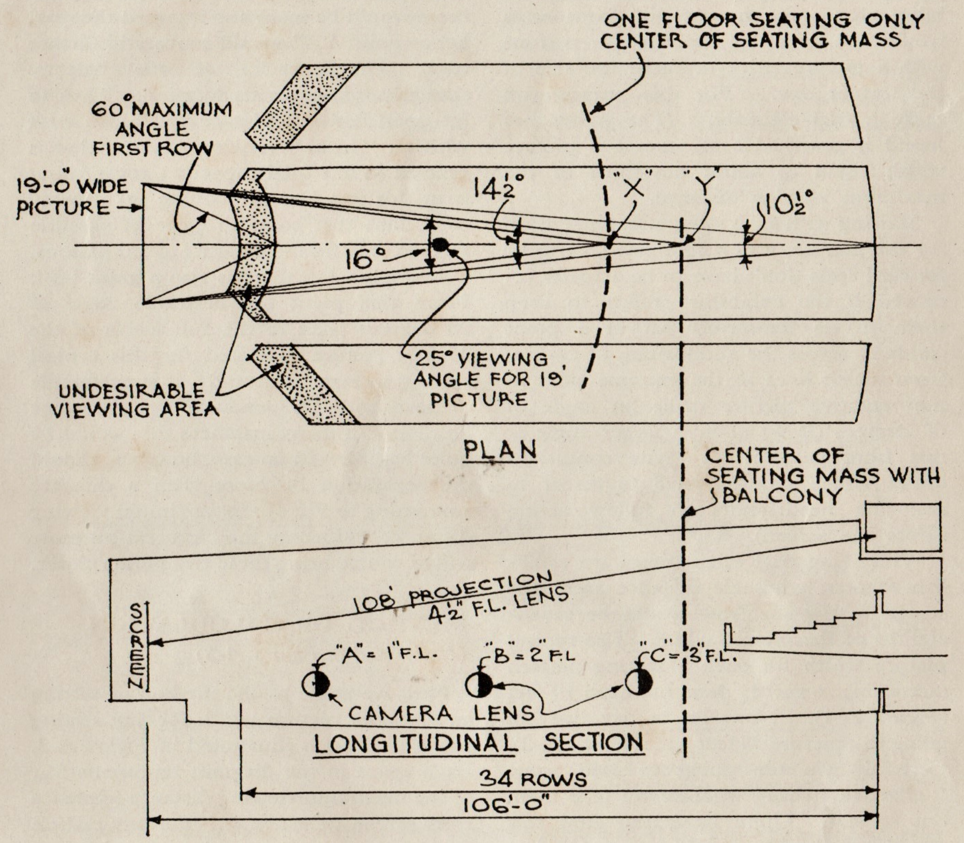


FIGURE A-1 : Plan of one-floor seating pattern relative to screen, and section drawing of a balcony seating pattern of same capacity, both representing typical conditions of existing theatres as established by a recent survey by the Society of Motion Picture and Television Engineers. The screen here (prior to enlargement) is 19 feet wide, according to the survey average, and the plan drawing shows angles of vision which that picture width subtends at various depths. In the section drawing preferred viewing positions are related to camera lenses. Dotted line "X" in the plan is the centre of seating mass of the one-floor pattern ; line "Y" is the centre for the pattern including a balcony. For more details see text.

106 feet, which the SMPTE survey found to be typical. While there are many theatres with wider patterns for such depth, greater relative width does not affect the calculation *unless* he seating at the screen end present another kind of problem; they should be modified so that they do not compete with the performance in audience attention upon the picture.

CENTRE OF SEATING MASS

Now in the typical one-floor pattern of *Figure* A-2, it was first necessary to determine the seating capacity we would have to deal with, considering the probability that some number of front seats would not be at all desirable to patrons with a picture twice or more the size of the former one. For this purpose we make a trial estimate. The writer has found it practicable to assume a picture width equal to about one-third of the maximum viewing distance.

Starting with such a tentative dimension for the picture, a new first row (the more forward seats don't have to be actually removed if the exhibitor prefers to keep them in) is tentatively set at a point (midway across the auditorium, of course) from which lines to the extreme sides of the tentative picture make an angle of 60 degrees (if we allow a larger angle at this front position we invite conditions under which patrons have to resort to annoying head shifts to follow action across the screen).

With these trial calculations, we establish that an advisable distance from the screen to the first row would be seven-eighths of the picture width. The typical picture width for such a seating pattern (according to survey data) has been 19 feet (*Figure* A-1). Now, let us say, we are going to a picture 35 feet wide (*Figure* A-2). Certainly we are going to lose some "effective" seats, whether we take them out or not. Quite likely our first row was too close to the screen with the 19-foot picture. Let us say that we should ignore the 120 seats in the front rows in order to establish an "effective" seating mass. If our total capacity is 1,100, our seating mass (new "effective" capacity) becomes 980, half of which is 490. The point (midway across the auditorium) at which 490 seats are in front, and 490 seats to the rear, is the centre.

A total of 490 seats are to the front and rear, respectively, regardless of whether they all are on one floor or on two floors. Balcony seating is part of the 490. Thus, as you can note in *Figure* A-1, the centre for a balcony house ("Y") is farther from the screen than the centre ("X") for a one-floor theatre. In *Figure* A-2 the centre ("Z") is shown for a seating mass including a balcony with the picture enlarged to 35 feet. If this seating pattern were wider toward the rear (wedge-shaped), there would be more seats toward the rear, hence point "Z" would move still farther back. The capacity of the balcony similarly influences its location. Thus to hit upon the best picture width, we start with an "ideal" viewing position that is centred in our total capacity; going about it in this way, we are setting up viewing conditions that come as close as possible to good ones for the majority of our patrons.

In *Figure* A-2 there is also a point "S". From this point the desirable angle of 25 degrees takes in the full width of the 35-foot picture indicated for this typical seating pattern. Naturally, it is preferable to have both "S" and "Z" at the same location. In many instances this would be quite feasible. In no case, however, should the separation be more than a distance amounting to 5% of the maximum viewing distance. Widening the picture a bit more will of course bring these two points closer.

METHOD OF CALCULATION

(Illustrated in Figure A-3)

Now we come to the method of setting an *optimum* picture width for any seating pattern. This is illustrated in *Figure* A-3. Each space in the diagram represents 5% of the maximum viewing distance (distance from screen to last row). For any picture width, the viewing angle at which the entire width can be comfortably seen (without conscious movement of the head from side to side) becomes smaller as the viewing position moves back; for that reason, the picture can be made wider as the centre of the seating mass moves back.

One possible centre of seating mass is indicated at a distance from the screen amounting to 55% of the maximum viewing distance. For such a centre, a viewing angle of 30 degrees is recommended. All of the viewing angles indicated in the diagram were chosen to avoid objectionable extremes in either the more forward or more rearward rows of seating, extremes which make adjustments and compromises in the nearer and farther seating more difficult. Angles of from 30 to 25 degrees are indicated for viewing distances of from 55% to 80% of the maximum, which are the distances from the screen of seating mass centres in most theatres.

Adjustment can be made, of course, for centres at less than 55%, or more than 80% of the maximum viewing distance. To do this, allow one degree of change in the viewing angle for each 5% reduction or increase, as the case may be, in the percentage of maximum viewing distance.

The different picture widths at different centres and angles in *Figure* A-3 merely indicate how the picture can grow as the centre of the seating mass moves back. To compute the actual width of the picture for the centre of seating mass of any particular theatre, a simple arithmetic method is as follows:

For an angle of 30 degrees, multiply the distance from the screen to the centre of seating mass (centre of screen to point "Z") by 0.26795. This calculation will give you one-half of the picture width in feet and fraction thereof. Multiply this by two and you have the full width of the picture best adapted to good presentation for the majority of your patrons.

For example, if the maximum viewing distance (screen to last row) in your theatre were 106 feet, and the centre of the seating mass were at 55% of that maximum, the centre would be 58.3 feet from the screen. Multiplying 58.3 by 0.26795 gives 15.621485, and twice that result is 31.242970 or about 31.2 feet for the picture width.

Multipliers for the angles of *Figure* A-3 are: 25 degrees—0.22169; 26 degrees—0.23087; 27 degrees—0.24008; 28 degrees—0.24933; 29 degrees—0.25862; 30 degrees—0.26795.

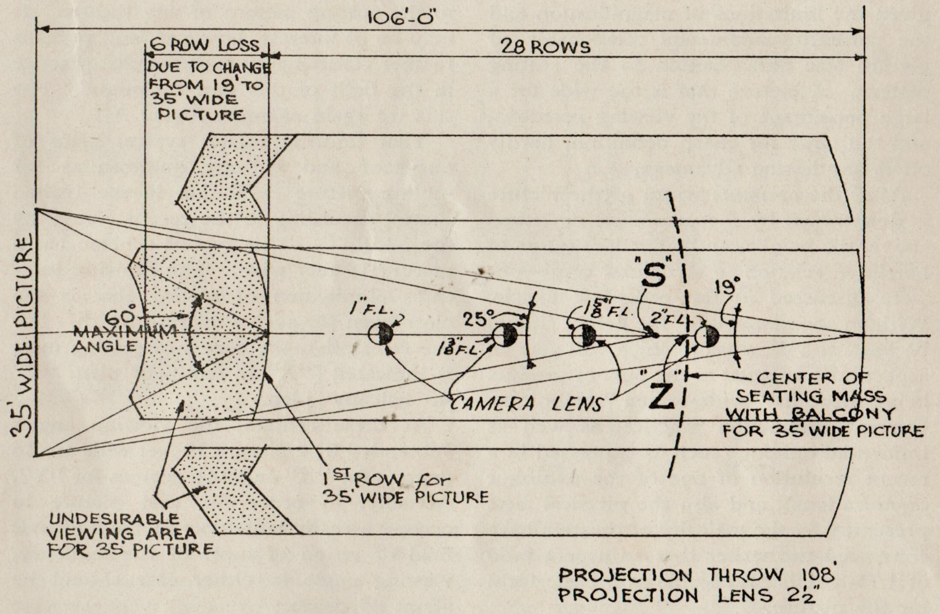


FIGURE A-2: Typical seating pattern with picture widened to 35 ft., showing new preferred viewing positions created by new picture width (also by use of wide-angle camera lenses).

These recommendations have been developed, on the basis of survey data and direct observation, to provide projection and visual conditions for the most effective "wide-screen" presentation possible in the majority of existing theatres. A specific local situation may advise some "interim" installation, for which we presented procedure in the preceding article. To provide for the kind of cinematography and performance area which can make "wide-screen" an authentic advance in motion picture technique, recognition must be given the limitations of magnification and the natural, fundamental relationship of picture size and position to the seating pattern. A picture that is too wide for a large percentage of the viewing positions, and too large for sharp definition, hardly offers any lasting advantage.

After the *optimum* width of the picture is determined by the procedure described above, the height can be fixed. Factors of height in relation to structural conditions were discussed in the preceding article. With an *optimum* width, the height should be fixed at a dimension which will give an aspect ratio adapted to the bulk of product being made in "wide-screen" technique. Current production practice, as well as influential opinion (such as expressed in a recent resolution of one of the exhibitor organizations), and also the physical facts presented by the majority of theatres have convinced the writer that an aspect ratio of 1.75-to-1 is practicable as a basic form for the picture.

Proportions of 1.7-to-1 would be better for product in the 1.33-to-1 ratio yet to be played; however, these will soon become of less and less concern, whereas the new "wide-screen" product is being produced with camera warning lines allowing for 1.66, 1.75 and even 1.85-to-1.

As for proportions of 2-to-1 and up—especially those considerably more—a strip of masking across the *bottom* of the screen, which is only 2 inches above the platform, would provide for reduction of height without appearing to shrink the picture from size otherwise used, since the bottom area of a screen image is always subject to visual obstruction and the lower edge conventionally has been around 2 feet above the stage. How much the height would need to be reduced on these occasions would depend on the amount of pictorial material at the extreme sides that might be feasibly masked off in the aperture.

CONVENTIONAL PRACTICE

In the paragraphs above we have given the essentials of the method by which the expanded picture can be properly related to the seating pattern of any theatre. It may be of interest, however, and perhaps further clarifying, to examine past practice in the light of this new technique. For this we again examine *Figure* A-1.

That drawing relates typical plans of one-floor and balcony auditoriums for motion picture exhibition in the United States, according to the recent survey by the SMPTE. This typical scheme has a picture 19 feet wide. The drawing indicates elimination of seating that is too close even for such a picture width. For the remainder, the centre of seating mass is indicated ("X" in one-floor plan, "Y" in balcony plan.)

At these centres, the viewing angles subtended by a picture 19 feet wide are 16 degrees for "X" and 14½ degrees for "Y". Actually, in order for that picture to occupy a really large part of the audience field of vision of most of the audience, viewing angle in either case should be about 25 degrees.

We have previously referred to the relationship of picture size to camera lens focal length as well as to projector lens focal length, which bears upon the location of the best viewing position. (For those who are interested, the formula is : *Projection distance multiplied by the ratio of camera lens focal length to projector lens focal length*). Now in *Figure* A-1 we may note that point "C" is closest to the seating mass centre ("X" and "Y"). Point "C" is where a picture 19 feet wide subtends the angle of a lens having a focal length of 3 inches. A 3-inch lens is used for close-ups. The seating patterns and projection systems that developed from the early days of the art (that growed up, as it were, like Topsy) called for predominant use of the close-up for most effective narration on a relatively small screen.

In *Figure* A-1 are also points "A" and "B". These represent camera lenses of shorter focal length for middle and long shots. Note how far these two points are from the centre of the seating mass. Moreover, the point at which the 19-foot picture subtends the advantageous angle of 25 degrees is far forward of the centre of the seating mass. It should be moved back as close to the centre as possible.

A viewing angle in the vicinity of 25 degrees is advantageous because of the size of the 35mm film frame, which cannot be "blown up" to just any dimensions without damage to the screen image. This angle also finds recommendation in cinematographic practice. The closer the centre of the seating mass is to the point at which the picture width subtends an angle of 25 to 30 degrees, the greater the number of viewing positions with desirable angles.

Under some circumstances these *optimum* angles could well be increased, as in the case of larger film width, along with greater available projection light. They could also be increased for theatres of considerably smaller maximum viewing distance than that of the typical patterns in *Figure* A-1, provided a picture of 35 feet or so could be properly accommodated.

But in a broad middle range of theatres, a position in the 25-30-degree are (*Figure* A-3) can be located, by adjustment of picture width, effectively close to the centre of the seating mass. This is particularly true of one-floor seating, where the centre normally is closer to the screen than it is in a balcony auditorium. And any increase in viewing angle subtended by the picture enhances "presence" by being favourable to the use of shorter focal length lenses. For the 19-foot picture in *Figure* A-1, the positions representing 1-inch and 1⅜-inch (wide-angle) camera lenses are too far forward in the pattern.

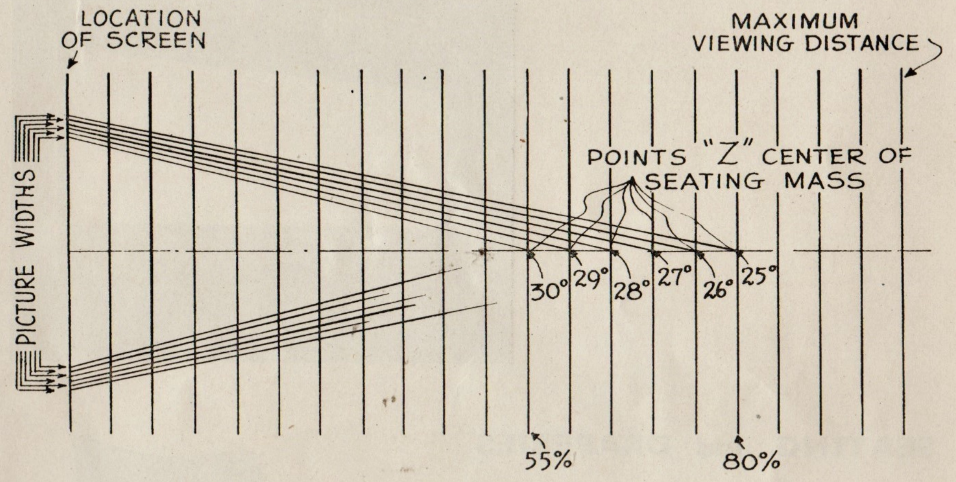
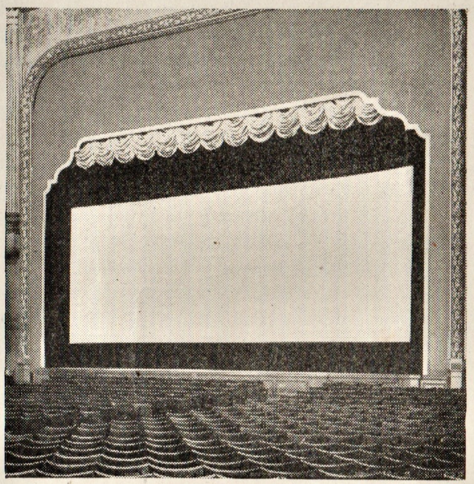
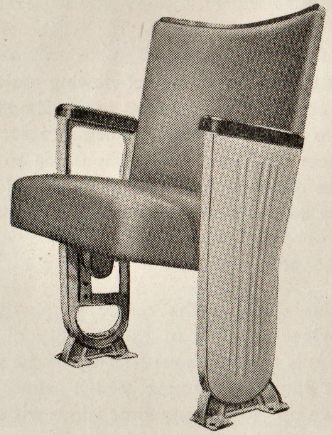


FIGURE A-3 : Diagram of viewing positions relative to screen showing viewing angles as referred to in text explaining a simple mathematical method of determining picture size for "wide-screen" projection according to seating pattern. Vertical lines mark off distances from the screen amounting to 5% of the maximum viewing distance. For the various distances at which the centre of the seating mass is located, picture width can be readily determined by applying one of the mathematical factors that are given in the text.





TECHNICAL INFORMATION
for Projectionists

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Setting Up a Scheme for Conversion to Wide Pictures*

By GIO GAGLIARDI

HAVING ARRIVED at a decision to convert his theatre to wide-screen presentation, the exhibitor owes it to himself and to the art which he exploits to consider every possible factor and to anticipate a solution to every apparent problem. Each theatre presents its own problems to some degree, both in projection and in sound.

Each theatre therefore must be treated individually in order to obtain the best results ; however, certain general concepts and methods of procedure should be followed in order to prevent costly mistakes.

First, we must realize that to make such conversions involves more than just the purchase of a new set of lenses or a larger screen. If we are to spend money for equipment with the hope that this equipment may find use for a substantial period of time, we must try to anticipate to some extent later developments in motion picture presentation.

Within the last year we have had 3-D ; stereophonic sound on separate film ; four-track stereophonic sound on CinemaScope film ; anamorphic projection with one optical track ; non-anamorphic wide-screen projection with various aspect ratios ; Perspecta sound from one optical track ; and the promise of anamorphic prints in a compression ratio different from that of CinemaScope.

All of the processes available are competing with one another for spectator appeal, and so far the public has not seemed to show any sharp-cut preference generally. It is even possible that other innovations may come along in the near future. We must not exclude the possible resurgence of 3-D on single Vectograph film, which may be shown on large screens with anamorphic attachments ; or the eventual change in film specifications to permit larger film gate areas.

The new techniques have served to stimulate new public interest in motion pictures, with an associated increase in attendance. It is up to us to maintain this stimulation and to keep the public convinced that the motion picture theatre still offers the latest and the best form of dramatic entertainment.

CHOOSING A SCREEN SIZE

Before the theatre operator begins to order equipment he should revise all his old concepts of screen sizes *versus* theatre size. During the last twenty years the technical societies of the industry made extensive surveys of the relationship between picture size and auditorium viewing distances. From these developed the recommendation that the width of the picture should not be less than approximately one-fifth of the

*This article from "MOTION PICTURE HERALD" is reprinted by kind permission of the Editor greatest viewing distance (in a large number of theatres the width was—and still is—much less than that).

Thus, where the last row of seating was 100 feet from the screen, the picture was given a width of about 20 feet. And that was a liberal allowance ! With such viewing conditions, long and even middle shots lost impact and "presence" and the close-up was more and more relied upon to bring "intimacy" and special details to the audience.

A close-up, of course, excludes much—often all—of the surroundings, the setting which helps to produce realism. (This condition is a flagrant deficiency of the restricted television screen.) Cinerama spectacularly accomplished the feat of making every middle-shot a "close-up," of including tremendous volume of beautiful detail in panoramic views. CinemaScope productions, and to some extent the cropped pictures, have a similar objective. By using a wider screen, it is possible to bring to a theatre audience a much more realistic and beautiful representation of what its members would have seen if they were located in the position of the camera.

SELECTING THE EQUIPMENT

Having noted these principles, we can now approach the task of selecting the equipment for converting projection in the theatre to such presentation. *Regardless of the size of the auditorium*, and *wherever it is physically and economically possible*—

1. The new picture should be made large enough so that small objects and details become fully visible to persons seated at maximum distances. This should apply for *all* types of picture shots.

2. The new picture should cover the greater part of the auditorium width ; it should have the effect of filling the viewing field of the audience and should not appear bounded by any confining and invasive frame-work.

3. The new pictures should be bright enough to bring out the best colour balance and tones.

4. The new pictures should be rock-steady and sharply focused.

For a long time, product will alternate between standard and anamorphic projection with a variety of aspect ratios. The pictures should have, if possible, the same height, however, changes in ratio being made by expanding and contracting the width.

It has been authoritatively found that in order for the spectator to be able to resolve the smallest details in the new type of picture, his distance from the screen should not be greater than three times the width of the picture. This means that the picture should have a *width equal to at least one-third the distance from the screen to the last row.*

The minimum distance between front rows and the screen is a subject for discussion. I have viewed pictures from a distance *less than the screen width* without any discomfort or eye-strain, and it may be possible that with the new CinemaScope camera lenses and VistaVision methods, picture definition can be improved to the point where even closer seating will be acceptable.

Many of the newer theatres have been built without definitely marked stages, or with very wide arches and shallow screen platforms. In these cases, new screens may easily be installed inside the proscenium arch in sizes sufficient to meet, or even to surpass, minimum requirements.

However, there are a great number of older theatres where the proscenium arches are too narrow to contain screens of sufficient width to do the new pictures justice. In these cases the new screens should be relocated *in front* of the proscenium arch.

The improvement in appearance, the effect of modernization of an auditorium, when such a change is made, is almost unbelievable. The confining framework of old-fashioned massive arches and surrounding decorative plaster can be eliminated and the whole forward area of the auditorium will seem to open up and give dynamic "presence" to the wide-screen pictures.

ADAPTATION TO STRUCTURE

New screens and frames should be sized in proper proportions to allow for the presentation of all present and future product. Each theatre must be carefully surveyed to determine which of its sight-lines will impose primary limitations.

The height of the picture may be limited by low balcony soffits. From the rear seats in the orchestra, determine what height can be made visible. From the rear seats in the balcony determine if any main ceiling structure will limit the picture height. If the projection beam is lowered to bring the picture forward or down, determine whether standees in balcony seats will interfere with the picture. For one-floor houses, determine if persons entering or leaving forward rows can cause any interference.

The width of the picture may be limited by old-style boxes, organ-lofts and air-conditioning grille-work, and possibly by fire-exit doors. In any such case, careful consideration must be given to the removal of such obstructions. Boxes are obsolete, and should have been removed long ago. Very few theatres now have organs in use and blanking out the grilles should not create any difficulties.

The worst obstacles are fire exits when they are located on either side of the stage. By checking with the municipal building department it may be found possible to eliminate them, to build over them, or to move them to another location.

SETTING UP A PLAN

Having determined what the final limiting factors will be for the picture, whether it be the height or width, a set of data should be worked out for the new projection throw similar to those in *Figure* 1. Here a throw of 120 feet was selected and picture sizes were computed for several different picture heights such as are most common, ranging from 14 to 24 feet.

In each group the widths are indicated for all the common aspect ratios, from 1.33-to-1 up to 2-to-1 ; and also for the anamorphic aspect ratios of CinemaScope and VistaVision. The lens size corresponding to the proper aspect ratio at a projection throw of 120 feet are also indicated.

Bear in mind that since projection lenses at present are made in only $\frac{1}{4}$-inch steps, the actual picture sizes are more or less approximate, and in order to match picture masking height and width, it may be necessary to file several aperture plate sets.

This operation has been found tedious ; it must be undertaken with painstaking care, however, in order to get the various types of picture to fit their correct masking frames. Let us assume that the limiting factor for a theatre with a throw of 120 feet is the height and *that this is* 18 *feet.* In *Figure* 1 we note that the width of such a picture may range from 24 feet for the old aspect ratio of 1.33, up to width of 46 feet for the CinemaScope full ratio of 2.55.

FIGURE 1 — Comparison of picture size and lens focal length for equal picture heights using all aspect ratios. Calculated for 120-foot throw.

Aspect Ratio	Picture Size	Lens F. L.	Picture Size	Lens F. L.	Picture Size	Lens F. L.	Picture Size	Lens F. L.	Picture Size	Lens F. L.	Picture Size	Lens F. L.
1.33	24 x 32	3.00	22 x 29	3.25	20 x 26	3.75	18 x 24	4.00	16 x 21	4.75	14 x 19	5.25
1.66	24 x 40	2.50	22 x 36	2.75	20 x 33	3.00	18 x 30	3.25	16 x 27	3.75	14 x 23	4.25
1.75	24 x 42	—	22 x 38	—	20 x 35	2.75	18 x 32	—	16 x 28	3.50	14 x 25	4.00
1.85	24 x 44	2.25	22 x 40	2.50	20 x 37	—	18 x 34	3.00	16 x 30	3.25	14 x 26	3.75
2.00	24 x 48	2.00	22 x 44	2.25	20 x 40	2.50	18 x 36	2.75	16 x 32	3.00	14 x 28	3.50
ANAMORPHIC :												
2.00	24 x 48	3.00	22 x 44	3.25	20 x 40	3.75	18 x 36	4.00	16 x 32	4.75	14 x 28	5.25
2.35	24 x 56	3.50	22 x 51	3.75	20 x 47	4.25	18 x 42	4.75	16 x 36	5.75	14 x 33	6.00
2.55	24 x 61	3.50	22 x 56	3.75	20 x 51	4.25	18 x 46	4.75	16 x 38	5.75	14 x 36	6.00

Let us assume that the front end of the auditorium can be rearranged to take a picture 18 by 46 feet; then a screen 19 by 47 feet and its proper frame should be installed. On this screen it will be possible to project a 1.66 ratio picture equal to 18 by 30 feet, or a 1.85 ratio picture equal to 18 by 33 feet.

When VistaVision is available, it will be possible to project a picture 18 by 36 using either a simple short focal length lens of 2.75 inches; or if squeezed prints are available, using a 4-inch lens and a $1\frac{1}{2}$ anamorphic attachment.

With four-track stereophonic CinemaScope prints, and 4.75-inch lenses, a 46-foot picture may be obtained. If a single-track CinemaScope print is used, then for the same projection lenses a picture 18 by 42 feet can be projected.

All of the above procedure can be performed rather simply by using fixed top and bottom masking for the screen, since a height of 18 feet is maintained at all times; and by moving side masking to selected positions for each type of picture.

PROJECTION LIGHT SOURCES

Now what projection lighting equipment must we have in order to make these new pictures bright enough for proper presentation? The new metallic screens give a considerable *brightness gain* when compared with "white" screens. This gain will vary from two to three times when the screen is viewed from the centre, but it will drop to less than one when the screen is viewed from the extreme sides (angles of 45°).

Since this reflectivity will drop as the surfaces age and become soiled, it has been found necessary to demand a light intensity at the centre of the screen of about 10 to 12-foot candles.

When we go from a 20- to a 40-foot picture, the magnification of all details is increased four times. For that reason the mechanical effect of film motion is also aggravated tremendously; therefore projector mechanisms, lens mountings and focusing must be held to very close tolerances. *It is of the utmost importance that good projection equipment be used* and that it be kept always in perfect alignment and repair.

TECHNICAL INFORMATION
for Projectionists

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THE CINEMA SCREEN*

By **R. ROBERTSON,** B.Sc., M.I.Mech.E., M.B.K.S. *of British Optical & Precision Engineers Ltd*

This paper discusses the measurement and control of screen characteristics with particular reference to modern metallised screens and the requirements of present-day large picture presentation.

IN CINEMA PROJECTION, each point of the projected image is illuminated by the very narrow pencil of light rays converging to it from the projection lens. The function of the screen is to scatter this illumination so that sufficient light from each image point is directed toward every viewing point to present a picture of satisfactory luminosity.

Luminosity is a subjective phenomenon which arises in the eye of the beholder, being a sensation evoked by the retinal image and proportional to its intensity. Since the area of this image and the amount of light by which it is formed both vary inversely as the square of the distance, its intensity and hence the resulting luminosity sensation are independent of distance.

Luminosity does, however, depend upon the visual sensitivity of the individual, which varies appreciably with conditions of seeing and slightly from one person to another, and is accordingly an elusive and unstable thing to measure. To avoid this difficulty, we define and measure a quantity called Luminance which is a characteristic of the luminous surface and corresponds to the luminosity which would be ascribed to it by an agreed standard observer. This somewhat arbitrary individual is defined by international agreement on a basis which provides that measurements are consistent with appearances for normal observers under conditions of good visibility.

This condition applies over the range within which the luminosity of a cinema screen is of interest, and accordingly the distinction between the luminosity which we see and the luminance which we measure is not here of sufficient practical importance to justify insistence upon this precise terminology in preference to the more widely understood and inclusive term " Brightness".

The practical unit in which Luminance is measured is the Foot-Lambert. This is the luminance of an idealised surface, uniformly bright in every direction and radiating 1 lumen per square foot. Since an illumination of 1 foot-candle intensity represents an incidence of 1 lumen per square foot, the luminance in foot-lamberts of a perfect diffusing surface is numerically equal to its illumination in foot-candles.

For many purposes, however, it is more convenient to measure luminance in candles per unit area when the effective candle power of a small surface element in any direction is given by the product of its luminance in that direction by its corresponding area. A surface of uniform luminance of, say, B candles per square foot radiates πB lumens per square foot corresponding to a luminance of πB foot-lamberts.

The luminance at any point of a luminous surface in general varies with the direction of view. In order to visualise simultaneously the luminances in all directions,

*This article is reprinted by kind permission of the British Kinematograph Society we can represent them by a solid centred about the point of radius in any direction proportional to the corresponding luminance. In the special case of uniform brightness in all directions, the radii are all equal and the solid is a hemisphere. In general, it is some bulbous shape which varies with the obliquity and vergence of the incident illumination.

The illumination at any point of a cinema screen is by sensibly parallel light rays of no very great obliquity when for practical purposes we can treat the solid as of fixed shape, determined by the surface alone but variable in direction, this following the ordinary laws of reflection and of linear dimensions proportional to the total amount of light reflected per unit area of surface.

For any particular surface, this reflected light is a constant proportion of the incident illumination known as the "Total Reflectance" of the surface. Thus, the luminance in foot-lamberts per foot-candle of a uniformly bright surface is numerically equal to its total reflectance, while that in any particular direction of a directional surface equals the product of its total reflectance by the ratio of its luminance in that direction to that of a uniformly bright surface of the same total reflectance, or, what comes to the same thing, reflecting the same amount of light per unit area.

We shall call this ratio the "Gain" of the surface in this direction. It follows the shape of the luminance solid and can be represented by a precisely similar solid, having the superiority that its size is fixed and independent of variations in incident illumination or total reflectance.

The gain of a surface has previously been defined as the maximum value of this ratio (1) and also as the ratio of the actual brightness to that of an idealised uniformly bright surface reflecting the same amount of light as that incident upon the actual surface (2). This ratio equals the product of the gain (as defined above) and the total reflectance, and is sometimes called the "Effective Gain", "Apparent Reflectance" or preferably, following I.C.I. recommendation, the "Luminance Factor".

While the luminance factor is of great practical interest as giving an inclusive measure of screen overall performance which is all that really interests the user, it is not so useful in understanding and controlling screen performance as the separation of reflectance and distribution as independent factors which follows our preferred definition of gain.

Total reflectance is an intrinsic characteristic of the material and quality of the surface. It can be nearly 100% for very highly polished silver or aluminium surfaces, and since it takes into account all the reflected light irrespective of direction, can be equally high for a very good matt white surface. It is not, however, practicable to attain or maintain such high values under everyday conditions on large surfaces such as a cinema screen which also is inevitably exposed to soiling by dirt and especially by tarry matters in the atmosphere.

A cinema screen must be perforated for satisfactory transmission of sound from the speakers behind it. These perforations represent a loss of useful reflecting surface, and hence of light, of about 8%, and in practice a total reflectance of around 60% to 70% is about as high as one can reasonably expect.

In this respect, there is little difference between present commercial metallised screens and a good matt white screen. Indeed, the white screen has commonly a somewhat better total reflectance when new, but soils more rapidly.

The gain of a surface is determined by its texture. Recalling our preferred definition of gain as the ratio between the actual brightness in any direction to that of an idealised surface uniformly bright in every direction and reflecting the same amount of light, it is evident that the gain of any uniformly bright surface must *ipso facto* be 1 in every direction. Also that an increase of brightness and hence of gain in any direction requires an increase of light going out in that direction and is only possible at cost of a compensating reduction elsewhere.

Thus, while we can always realise a high gain in a particular direction by concentrating up to all the reflected light into a corresponding narrow cone, this high gain is always necessarily associated with a correspondingly restricted directionality, and an overall advantage is quite impossible. For example, a particular screen may have a gain stated as 2. This refers to the maximum gain and means that at the most favourable direction of view it appears twice as bright as a matt screen of the same total reflectance (in practice, as a matt screen), but as both distribute the same amount of light, the matt screen must be brighter in some directions, and is probably so at angles of view greater than about 40°, which, however, are of minor importance to a cinema audience.

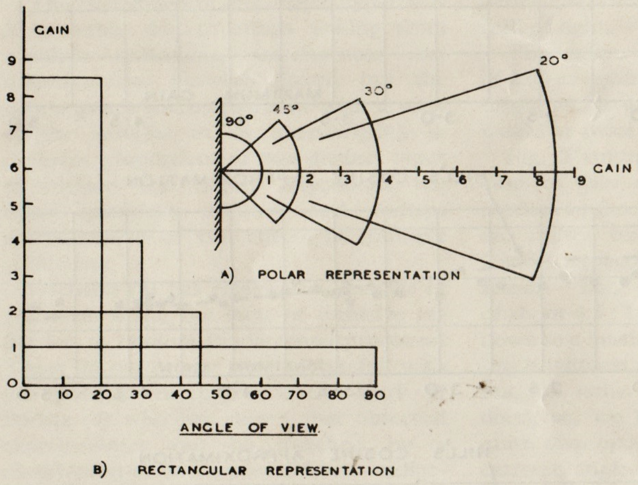

Fig. 1. The relationship between gain and directionality.

Figure 1 illustrates the practical consequences of this inevitable relationship between gain and directionality for the simple case of a surface formed to concentrate all the incident light into a specified cone so that brightness is uniform within this cone and zero outside, the gains corresponding to cones of various semi-angles being as follows :-

Semi-angle	20°	30°	45°	90°
Gain	8.5	4.0	2.0	1.0

'a' of this figure is a polar representation in which the gain is shown directly in the corresponding direction and is, in fact, a section of the representative solid already discussed. 'b' is an equivalent rectangular representation which, while less direct, is often more convenient.

It will be recalled that within moderate obliquities of illumination, the solid of which 'a' is a section, is of fixed shape but varies in direction, following the ordinary laws of reflection. By defining the viewing angle as that between the line of sight and the direction of direct reflection, this variation is compensated for, the gain at any angle so defined being independent of the angle of illumination.

Except for the special case of a "beaded screen", the angle of direct reflection is equal and opposite to that of incidence, both being measured from the normal to the surface. The surface of a beaded screen has a "cats eye" effect, the direction of direct reflectance being back along the direction of incidence.

Figure 2 illustrates the gain distributions typical of modern metallised screens having an aluminised surface.

Aluminium can be a very good reflector, the total reflectance of vacuum deposited aluminium films approaching 90%. The aluminium content of aluminium paint is not an ordinary powder, which is granular and dark, but is in the form of very fine but quite definite polished flakes, like microscopic confetti, prepared by milling

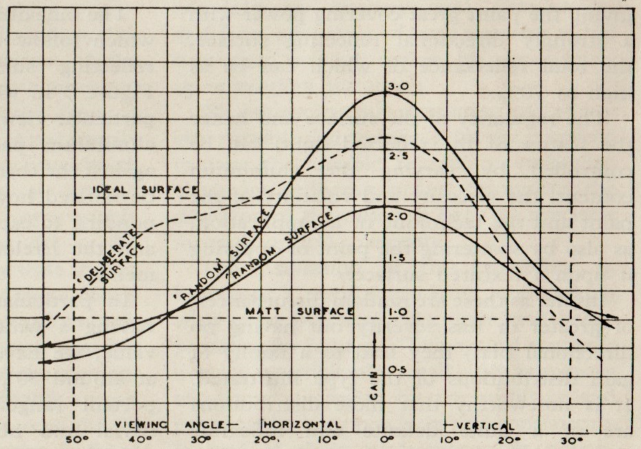

Fig. 2. Gain distributions of some actual surfaces.

aluminium foil with a lubricant. On account of their shape and slight greasiness, these flakes tend to float in the surface of the paint film like leaves on a pond, thus giving the paint great covering power with a strongly directional reflecting surface, the total reflectance of which can be as high as 70%.

The regularity of the surface and hence the scatter of the reflected light, can be controlled by varying the aluminium content, the viscosity and volatility of the paint and the technique of its application, as also by spattering the paint or applying it upon a textured surface.

Insofar as these are random disturbances, of greater or less severity but having no directional bias, they lead to a family of gain distributions of the type illustrated. It is noteworthy that these distributions are of a quite definite and inflexible characteristic shape, any particular maximum always corresponding to a quite definite and predictable distribution, evidently determined by the laws of probability and not by the particular manner in which it has been realised.

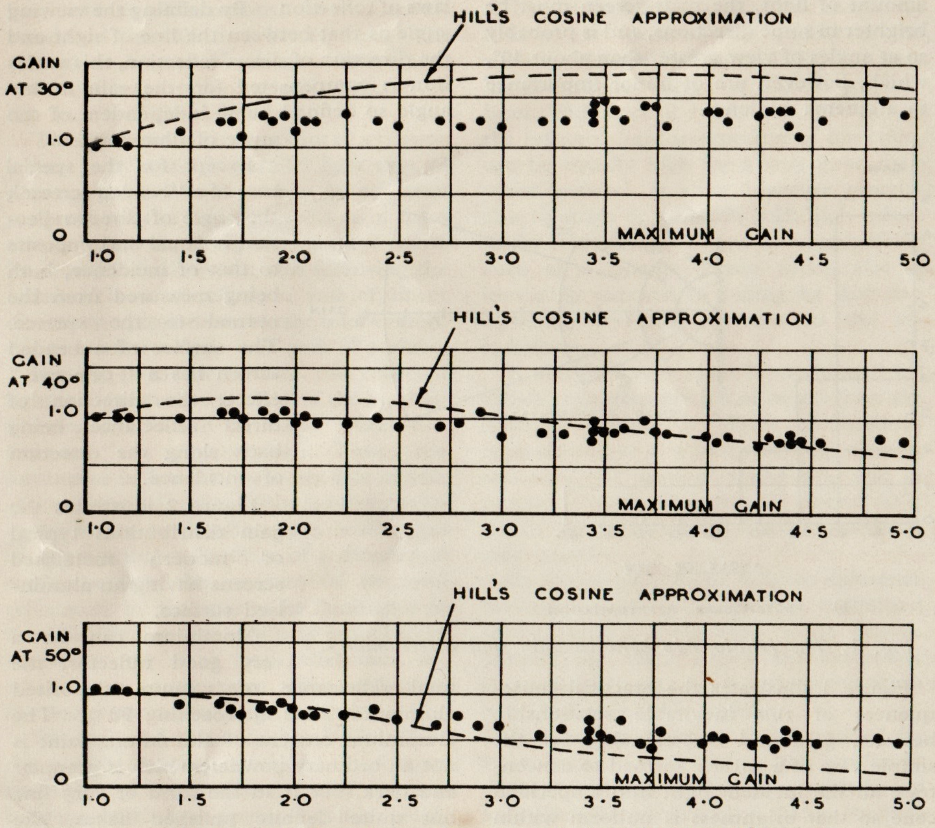

Fig. 3. *Gain of random surfaces at particular viewing angles.*

The inflexibility of the gain distributions which follow random disturbance of the reflecting surface is demonstrated by Figure 3 in which the gains measured at particular viewing angles for a diversity of aluminium painted surfaces are plotted against the corresponding maxima. It will be noticed how closely the points corresponding to each angle of view are aligned and the irrelevance of the various treatments.

In particular, it is evident that while having a wide choice of the maximum value, we have no control over the gain at around 30°, and very little in the important range between 30° and 50°, a trivial and bounded improvement here requiring a quite disproportionate sacrifice of maximum brightness.

While this distribution is doubtless shaped by the laws of probability, it does not appear possible to relate it to any likely probability distribution of singly reflecting mirror facets. It is indeed quite simple to determine a distribution of such facets to yield any possible gain characteristic, but the required distributions appear very artificial.

The inadequacy of this simple hypothesis is probably due to effects arising from multiple reflections, interferences and discontinuities between facets, but the data appears more consistent with a view of the surfaces as an intermingling in different proportions of two distinct types of surface—one highly directional, the other essentially diffusive and perhaps representative of the effects of multiple reflections.

Harrison (3) has reviewed a number of efforts to relate the facts of diffusive reflection to random fundamental processes. These do not appear very successful, with the possible exception of the work of Barkas (4) who has shown that observed characteristics can be matched by a distribution of two types of facets—reflective and diffusive respectively. Hill (5) has, however, proposed a very simple and successful empirical approximation equivalent to :-

$$G(V) = G(O) \cos^{n} V$$

where $n = 2\,(G(O)—1)$, G(V) denotes the gain at viewing angle V, and the relationship between n and G(O) is necessary to satisfy the condition that the distribution disposes of exactly all the light.

This formula gives a family of mathematically consistent distributions of the right sort of shape, and is very convenient for calculation. Loci calculated from it are included in Figure 3. It is necessarily exact at $V = 0°$ and, for the gains considered, is evidently quite accurate at around $V = 40°$. It however gives appreciably inflated values for V between 0° — 40° at cost of too low values at very wide angles.

We turn to consideration of these distributions in the light of theatre requirements. The attainment of the greatest possible brightness requires direction of the incident light into the minimum acceptable spread of viewing angle, and ideally a screen should be tailored so that its distribution is fitted to local requirements. This is hardly practicable, but it is found that in the great majority of theatres the viewing angles can be kept within about 50° horizontally and 30° vertically by suitably curving and tilting the screen.

Accordingly, a useful criterion of performance is the brightness possible to an idealised screen uniformly bright for angles of view within the rectangular pyramid defined by these limits and with no overspill of light.

This screen would have a uniform gain of 2.05 as against 1.7 for a screen uniformly bright within a cone of 50° semi-angle, and would be twice as efficient as a matt screen.

Fig. 2 contrasts this criterion with the kind of gain distribution resulting from random surfaces. Two typical distributions are shown corresponding to maxima of 2 and 3 respectively. The latter is evidently rather " hot," having a brightness ratio of about 4.5 : 1, and it is necessary to come down to a maximum of 2 in order to reduce this brightness range to the more reasonable but still rather wide ratio of 2.4 : 1. In doing so, we have obtained a slight but quite disproportionate increase in gain at extreme angles of view, and in effect are forced to keep the central gain down to avoid too great a brightness ratio, but are unable to benefit from this at wide angles of view on account of the particular geometry of this type of distribution.

While our convenient criterion of uniform brightness within the angles of interest may not be the best possible utilisation of the light at our disposal, it is certainly an unexceptional distribution, and from any point of view superior to the best that we can realise by dependence upon random scattering.

We can escape this restriction and secure any possible distribution if we are prepared to take the trouble to replace controlled chaos by deliberate order, controlling the direction of the reflected light by precisely formed optical elements.

The realisation of this possibility is, however, a very formidable undertaking with great practical difficulties and heavy penalties for failure. The optical elements must be sufficiently small and numerous to escape resolution by the audience and yet must be very precisely and consistently formed if their performance is not to relapse to that of random scatterers. Of necessity, they must be regularly arranged which introduces a lot of hazards, since while the eye is tolerant of chaos, it is very critical of trifling irregularities in uniformity and especially sensitive to any kind of systematic or repetitive error.

In practice, the screen surface must be formed by some kind of embossing roller with the difficulty that any error in the consistency of its pattern, as also any out of truth or other systematic irregularity in its action, repeats at every revolution with the consequence that individually insignificant errors build up into painfully obvious streaks, bars or chequered patterns.

A closely related hazard is the risk of moiré patterns following superposition of one regular pattern upon another, as by the superposition of a regular pattern of the perforations necessary for sound transmission upon a regular pattern of optical elements. Fig. 4 illustrates this

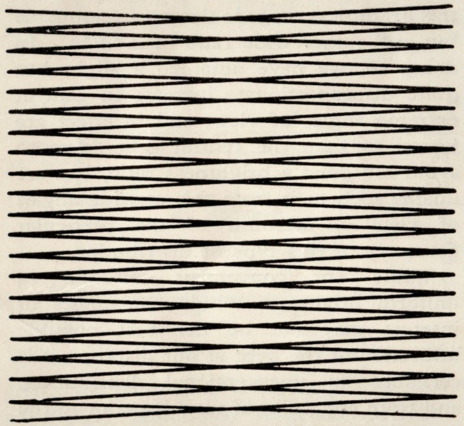

Fig. 4. Moiré patterns due to two sets of bars

effect for the simple case of two sets of bass slightly out of alignment, and one can see plenty of everyday examples, as, for example, the very bold and shifting patterns seen when a nylon stocking is held up or a net curtain folded upon itself.

A further practical problem is that a cinema screen, certainly one of the sizes of interest today, must almost of necessity be fabricated from material made and perforated in rolls of workable width, then joined together into a sheet of the required size. It is everyday experience that even quite gross irregularities of a matt surface are inconspicuous, due to the circumstance that changes of angle do not bring changes of brightness, whereas a quite trifling blemish in a polished surface is very apparent due to rapid change of brightness with angle. Thus it is easy to make an inconspicuous joint in matt material and not very difficult in smooth surfaced material which can be welded together, especially when the sheet is later sprayed, but much more troublesome in the case of a patterned surface, since any mutilation of the pattern or disturbance of continuity may advertise itself as a stripe, darker or brighter than its background according to the view point.

The juxtaposition of successive panels introduces further hazards of contrast and periodicity, certain to emphasize any otherwise insignificant variations in surface quality between one panel and the next, across the width of the panel material, or following any slight buckling of the panels in consequence of tensions across the joint.

These difficulties can, however, be overcome by taking sufficient pains, as evidenced by the practical success of the "Miracle Mirror" screen. This has a deliberately engineered surface and is the outcome of many years' development work requiring infinite care and patience, by the Research Division of 20th Century-Fox Film Corporation, by kind permission of whom I am allowed to describe something of the ingenious methods employed.

Its gain distribution is as indicated in Figure 2. This is not sharply rectangular in order to avoid practical objections to an abrupt change in brightness and to provide some overspill of light to positions outside the intended viewing angles. Within these, the gain is everywhere well maintained in relation to what is theoretically possible and does not fall below that of a matt surface, the brightness range being kept to about 2 : 1.

The pattern comprises a repetition of accurately formed optical elements. There is great economy in initial highly skilled labour in having these as large as possible, but they must not be so large that they can be seen by the audience. Their size is 0.050″ x 0.025″, chosen because this cannot be resolved at a distance of 12 ft.

There are 800 of these elements to every square inch of surface, 115,000 to every square foot—say 100 to 150 million in the surface of a typical large screen, and for reasons already discussed, all must be precisely alike. All are precise reproductions of a single master carefully shaped to give exactly the required light distribution. This is a hardened punch, the end of which is cautiously ground and polished by direct cut and try methods until its performance is correct.

The method of testing this is very practical. An impression made in bright aluminium foil is illuminated in a special "camera," and the reflected splash of light recorded on a sheet of printing paper accurately placed to receive it. The spread and brightness variation of the light patch, recorded as darkening of the paper, is a direct indication of the light distribution due to the shape, and a guide to any necessary modification.

Figure 5 shows a reproduction of two

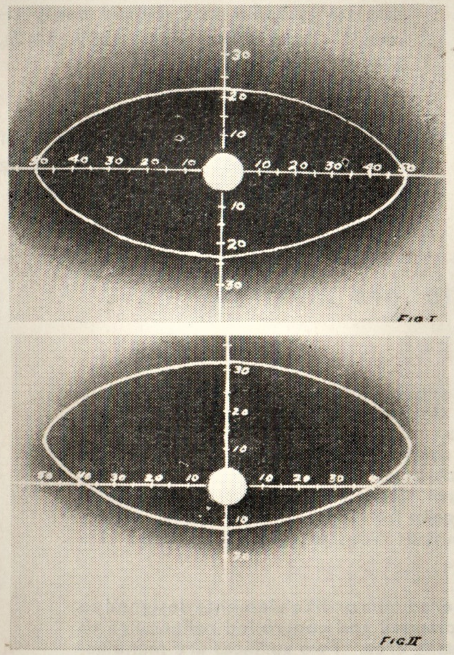

Fig. 5. Light distribution of 'Miracle Mirror' elements.

such records.—" I " relates to a " head-on " screen in which the light distribution is symmetrical about the normal. " II " demonstrates the very important possibility by deliberate control to bias the direction of principal reflection, and relates to a " tilted " pattern. As evident from the distribution, this results in a screen having an in-built bias equivalent but preferable to a corresponding tilt of the screen as a whole.

Following a very laborious and exacting series of operations, the proved master form is precisely duplicated all over the surface of a roller employed to pattern the screen material. This is made as a web of metallised plastic supported and strengthened by an integral fabric base, its surface fully finished. After perforation, it is cut into lengths which are finally joined together into a screen.

The nature of the material with its fully finished surface requires a sewn seam. 'A' of Figure 6 shows diagrammatically an ordinary sewn seam and the local buckling

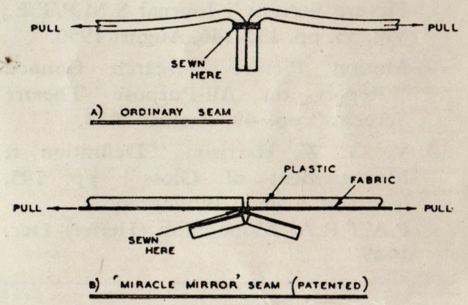

Fig. 6. Comparison of sewn seams.

and distortion of the surface which inevitably accompanies the bending over of sensibly thick and stiff material. As earlier pointed out, this disturbance is not serious in the case of a matt surface, but intolerable in a high-gain surface due to its necessarily directional character.

'B' of Figure 6 shows the very ingenious patented method developed to overcome this difficulty. Instead of turning the full thickness of both pieces of material against each other, the relatively thick and stiff plastic is scored through down to the strong but thin and flexible fabric base. The stitching is done through the score so that the seam is in the fabric and draws the undistorted surface layers together, end butting to end, and presenting an undisturbed reflecting surface.

The achievement of a satisfactory random surface is not, however, without its own attendant problems. Fig. 7 shows the spraying of a large screen at the factory of Andrew Smith Harkness Ltd. It is hardly possible to overestimate the skill and experience necessary to maintain sufficient uniformity of finish over such large areas, the difficulties of which are enhanced by the great sensitivity of the surface to slight variations and the searching examination to which it is exposed when illuminated in a cinema.

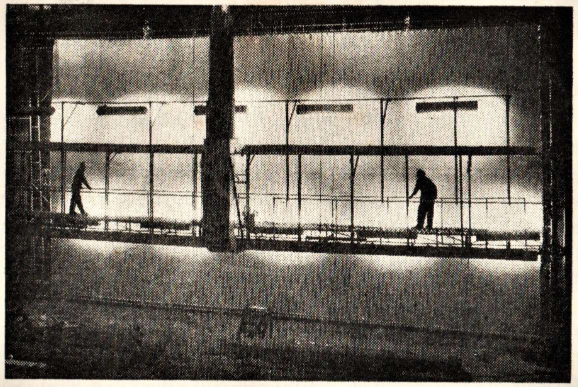

Fig. 7. Spraying a large screen.

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TECHNICAL INFORMATION

for Projectionists

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Recent Developments in Anamorphotic Systems*

By **G. H. COOK** Taylor, Taylor and Hobson Ltd.

Read to a meeting of the Theatre Division, British Kinematograph Society on December 15, 1954.

AT THE PRESENT TIME the cinema industry is in the midst of changes which are almost as revolutionary as the introduction of talking pictures in the 1920's.

Anamorphotic optical systems are playing an important part in these changes and this paper will endeavour to describe the reasons for their presence and the types of system which are being adopted.

The term anamorphosis as applied to optical systems implies an arrangement in which image formation occurs on different scales in the vertical and horizontal directions. There is therefore, at some stage between camera and theatre screen, deliberate distortion of the original scene which must be compensated for before the picture can be viewed in the theatre.

The use of anamorphotic systems in itself does not provide any startling change to the appearance of screen pictures. It is a means of providing wide screen pictures of the so-called panoramic type whilst avoiding some of the practical difficulties which prevent conventional systems from providing an adequate standard of performance.

The limitations on the dimensions of large screen are set by the width available within the architecture of the theatre and for height by sight lines from the rear of the stalls seats past the overhang of the balcony. These limitations, and to a smaller degree the desirability of avoiding extreme picture height for viewers near the screen, have resulted in the adoption of picture formats whose aspect ratio, width to height, is up to twice the conventional ratio of $1\frac{1}{3}$ to 1 which has been a standard for many years on small screens.

The sponsors of wide aspect ratios argue that they permit the composition of a more interesting picture, especially if the scale of the image detail on the screen is maintained near its normal value by the use of wider angle camera lenses embracing more extensive fields of view. The claim that the panoramic screen gives an illusion of depth is not substantiated by any optical characteristic of the screen image and can only be due to what has been called extra " audience participation " within the scope of a more extensive picture.

Difficulties of Wide Screen Projection

When an attempt is made to produce these large, wide aspect, screen pictures by conventional means and by standard projectors, two serious difficulties are encountered. One is due to the fact that the

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extra screen width has to be provided by shorter focal length projection lenses ; that is, the optical magnification between the film and the screen is increased and imperfections due to the presence of emulsion grain or lack of definition on the film are exaggerated.

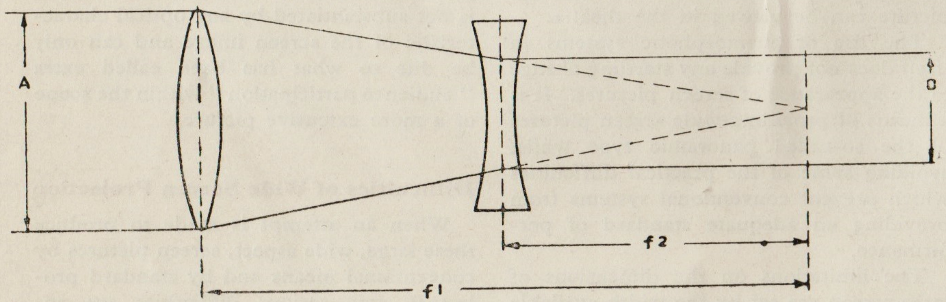
The second difficulty is due to the fact that the projector picture aperture has to be cropped, top and bottom, to provide the wider picture aspect ratio and there is therefore less light passing through this smaller aperture to illuminate a larger screen.

The visibility of the screen picture depends on a number of factors but, assuming adequate illumination, and the use of a perfect projection lens, it depends mostly on the information stored on the film. The presence of grain in the film either direct or reproduced from negative grain, plus the presence of camera lens aberrations and depth of field considerations has the effect of limiting the amount of picture information that can be stored on the film. Taking an average resolving power of 50 lines and spaces per mm. for the camera lens and film combination, we can consider the film image as a mosaic in which there are 100 individual picture elements per mm. When this is projected at a magnification of 500 times on to a 35ft. wide screen the screen picture is a mosaic where the size of each individual picture element is about one-quarter of an inch. The visual acuity of the human eye is sufficient to discern this degree of softness of the image at distances up to about 35ft. from the screen.

The brightness of the screen image for any constant screen area is directly proportional to the total luminous flux passing through the projector gate. If the area of the gate were reduced by cropping top and bottom, the total luminous flux passing through it from the same arc lamp would be reduced proportionately and, if this illuminated the same or a larger screen area, screen brightness would be reduced.

Both these types of difficulties relating to grain size, definition and illumination can be reduced by the use of anamorphotic projection systems. The variation of optical magnification in vertical and horizontal directions permits the projection of wide aspect ratio pictures from projector gates whose dimensions make good use of the picture area available on standard positive 35mm. film. The largest area that can be recorded on the film and projected by a standard projector has an aspect ratio of about $1\frac{1}{4}$ to 1. If all this area is to be projected on a screen having the CinemaScope aspect ratio of $2\frac{1}{2}$ to 1, the optical projection magnification must be twice as great horizontally as it is vertically.

To maintain correct geometrical reproduction of the original scene, the image on the positive film must be unnaturally compressed so that its scale horizontally is half its scale vertically. Thus, if the original object seen by the camera was a circle, then the image on the positive film must be an ellipse, with its horizontal axis half its vertical axis. This ellipse on the positive film will be projected on to the screen as a circle.



Telescopic Power $\frac{f_1}{f_2} = \frac{A}{B}$

Fig. 1. Simple telescope system.

Anamorphotic Reduction of Negative Grain

[A slide was used to demonstrate in an approximate manner the anamorphotic reduction of the effects of negative grain and definition. These effects can be simulated by breaking up the image into a mosaic where the individual picture elements correspond to the maximum storage capacity of the film. These projected images are enlarged considerably and should be considered as very small detail within a large screen picture. On the left of the slide was the image which would be produced by straightforward projection at high magnification from a cropped positive picture area, and the coarse picture mosaic was seen to have equal vertical and horizontal pitch. On the right of the slide was the image which would be produced by anamorphotic projection on to the same screen and the horizontal magnification was therefore the same as for the left hand image. The vertical magnification from a maximum area projector gate, and thus from a large film area, had been halved and in the vertical direction there were therefore twice as many elements per unit height. The overall effect of the right hand image showed an improvement in apparent definition.]

Increased Luminance

[Increased screen brightness with anamorphotic projection was demonstrated by first projecting a wide aspect ratio screen area from a top-and-tailed projector gate, and then by projecting a similar screen area anamorphotically from a normal gate having twice the height. A considerable increase in brightness was observed.

Having described the basic reasons for the use of anamorphotic systems we can consider the various systems that are available for this purpose.]

Available Anamorphotic Systems

Since the screen picture has to be increased in width it is convenient to use supplementary wide angle attachments in front of conventional projection lenses. To achieve the desired anamorphotic effects the attachment must have telescopic

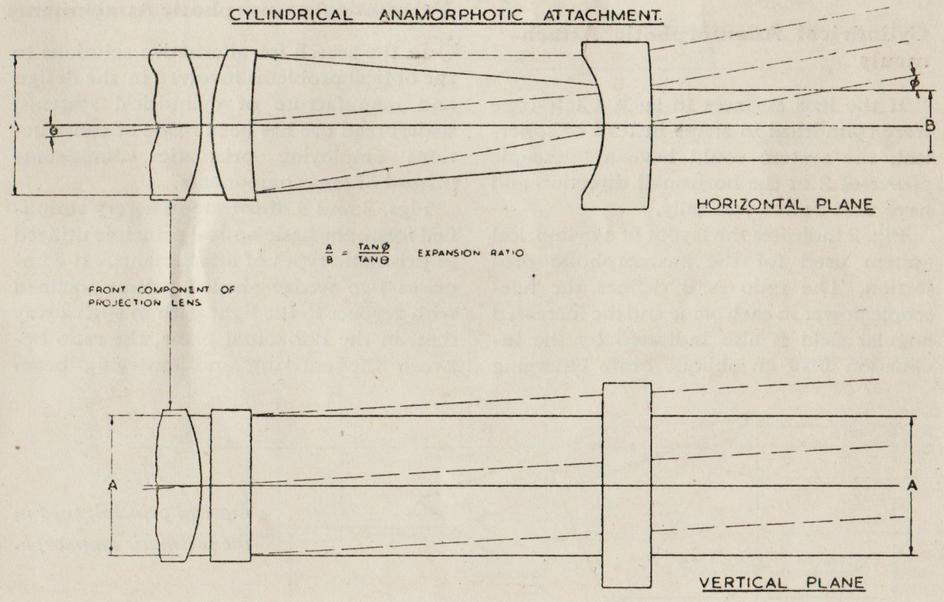


Fig. 2. Layout of cylindrical system used for anamorphotic projection.

power horizontally and no telescopic power vertically.

Consider a simple telescope system such as that used in opera glasses. When the separation between the collective and dispersive components is equal to the difference between the focal lengths of the two components, parallel light entering at one end emerges from the other as parallel light. The telescopic power is then defined by the ratio of the two focal lengths f_1/f_2 and considering the geometry of this arrangement it can be shown that telescopic power can also be defined by the ratio of the entrance and exit beam diameters A/B., see Fig. 1.

If such a system has a telescopic power of 2 and it is positioned in front of a conventional camera or projection lens with its collective component near the lens, it will reduce the focal length of the combination by a factor 2 and double its angular field of view. Although the beam width is reduced according to the telescopic power, the focal length of the combination is reduced by the same factor and there is therefore no change in relative aperture or f/number.

Cylindrical Anamorphotic Attachments

If the lens surfaces in such a telescope were cylindrical in shape instead of spherical, the system could have a telescopic power of 2 in the horizontal direction and have unit power vertically.

Fig. 2 indicates the layout of a cylindrical system used for the anamorphotic projection. The ratio A/B defines the telescopic power in each plane and the increased angular field is also indicated by the inclination θ of an oblique beam emerging from the projection lens and the inclination φ of the same beam emerging from the cylindrical attachment. The ratio $\tan\varphi/\tan\theta$ is equal to A/B. In a vertical plane the lens surfaces are straight and parallel. A equals B and φ equals θ and there is therefore no change of focal length or angular field.

The optical design of this type of system requires just as much attention as the design of normal camera or projection lenses and the adequate correction of all aberrations can be achieved by the use of complex lens constructions comprising more than one lens element in each of the front and rear components.

The advantages of cylindrical anamorphotic attachments for cinema projection were first proposed and demonstrated by Professor Chrétien in France some 25 years ago. The recent adoption of the method on a large scale has encouraged the development of a variety of cylindrical constructions by manufacturers in many countries.

[The type of performance provided by a cylindrical anamorphotic attachment was demonstrated.]

Prismatic Anamorphotic Attachments

In the search for alternative solutions to the optical problems involved in the design and manufacture of cylindrical systems, widespread use has been made of constructions employing prismatic components instead of lens components.

Figs. 3 and 4. illustrate in a very simplified form, the basic optical principle utilized in prismatic types of attachments. It comprises two wedge shaped prisms inclined with respect to the light path in such a way that, in the horizontal plane, the ratio between the entering and emerging beam widths fulfils the requirements for telescopic power as defined previously. By suitably inclining the two prisms in opposite directions, the emergent beam can be made parallel to the entrant beam, see Fig. 4. In the vertical plane the flat polished surfaces of the prism are parallel to one another and therefore have no effect.

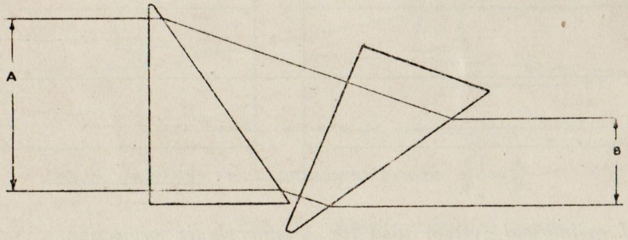


Fig. 3.

Optical principle used in the prismatic anamorph.

Prismatic attachments have one big advantage over all other types. They are readily adaptable to a form wherein the inclinations of both prisms may be adjusted to provide a range of telescopic power and thus varying degrees of picture expansion. This form will be of use to the exhibitor when he has to project different degrees of image compression. He thus avoids the necessity of using a number of different attachments each providing one fixed expansion ratio.

Although the opposed inclinations of two prisms provide correction for primary colour aberrations, higher order colour aberrations are excessive and such simple systems cannot yield useful results. Furthermore, as a result of other aberrations the telescopic power varies across the field of view and results in distortion of the image.

Adequate correction of distortion and colour aberrations can be obtained by replacing the simple prisms by more complex forms.

The arrangement shown in Fig. 6 can be considered as the simplest construction to give an adequate performance at a fixed expansion ratio of about 2. This diagram also indicates a somewhat more complicated variable form which provides the same standard of performance over a small range of expansion ratios.

[The prismatic developments thus illustrated were demonstrated first by the projection of a test object through simple uncorrected prisms. The colour aberration was excessive and it was explained that had the projection been over a wider screen a variation of expansion across it would have

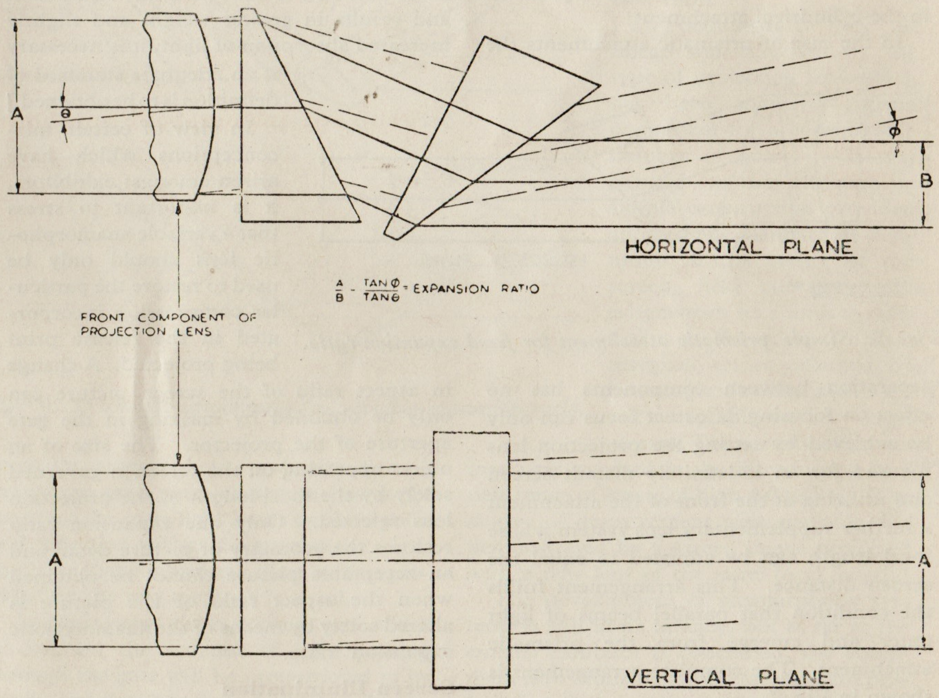


Fig. 4. The prismatic anamorphotic attachment.

been noticeable as a distortion of the image. The correction of these two errors was shown by projection through a standard prismatic attachment whose expansion ratio was fixed at the factor 2 required for CinemaScope. Using the variable type, the performance was maintained over a range of expansion ratios from about 1.4 to 2, see Fig. 6.]

Focusing varying screen distances

One important feature arising from the use of all types of anamorphotic systems is the means adopted for focusing different screen distances. The combined system of projection lens and attachment has different focal lengths in the vertical and horizontal planes. Since focusing movement of a lens is a function of its focal length, no single movement of the projection lens alone can focus simultaneously vertical and horizontal lines on the screen. In the case of cylindrical systems two adjustments are necessary, one to the projection lens in the normal manner and the other to the component separation in the cylindrical attachment.

In the case of prismatic attachments the separation between components has no effect on focusing. Correct focus can only be achieved by setting the projection lens focused for an indefinitely distant screen and utilizing at the front of the attachment a further supplementary lens system whose focal length can be adjusted to equal the screen distance. This arrangement fulfils the condition that parallel beams of light enter and emerge from the prismatic attachment. The complete arrangement is shown in Fig. 7.

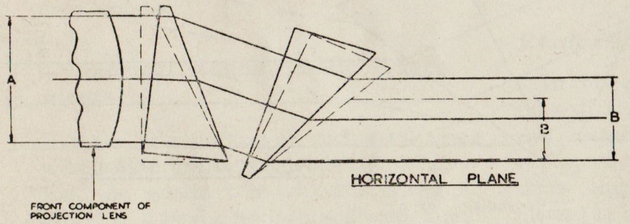


Fig. 5. Simple prismatic attachment for fixed expansion ratio.

Some variable prismatic attachments being made in other parts of the world do not include supplementary focusing lenses. The errors of focusing which result are only dependent on the ratio of the two focal lengths and thus the expansion ratio. The actual form adopted for the prismatic components can have no influence on this effect.

[To illustrate the necessity of providing suitable focusing means, an image was projected through a variable attachment correctly focused for the screen distance in the theatre at Film House. The equal definition on vertical and horizontal lines was noted, and it was also observed that both horizontal and vertical lines went in and out of focus simultaneously. Then an image was projected through an identical system whose supplementary focusing arrangement had been removed. It was seen to be impossible to achieve simultaneous focus for vertical and horizontal lines, and that the errors increased with the increased expansion ratio. The demonstration clearly proved that whilst the focusing arrangement does add to the cost of the equipment and results in greater weight and slightly increased absorption of light, it is necessary if an adequate standard of definition is to be obtained.]

In view of certain misconceptions which have arisen amongst exhibitors, it is important to stress that a variable anamorphotic lens should only be used to restore the particular compression incorporated in the release print being projected. A change in aspect ratio of the screen picture can only be obtained by masking in the gate aperture of the projector. The size of an object appearing on the screen is governed solely by the focal length of the projection lens selected. Only one expansion ratio restores the geometry of picture detail and an acceptable picture cannot be obtained when the aspect ratio of the picture is altered solely by means of the anamorphotic expansion ratio.

Screen Illumination

At the beginning of this discussion it was stated that anamorphotic projection permitted the use of larger projector gate apertures and resulted in improved definition and illumination. The improvement in definition exists at all expansion ratios but the gain in screen illumination is most apparent at large expansion ratios such as the factor 2 used for CinemaScope.

In comparing the illumination on the same screen area provided, firstly, by normal projection from a cropped gate and secondly, anamorphotic projection from a maximum area gate, allowance has to be made for the extra light losses by absorption and reflection within the attachment. It is useful to know where the illumination provided by the two methods is equal.

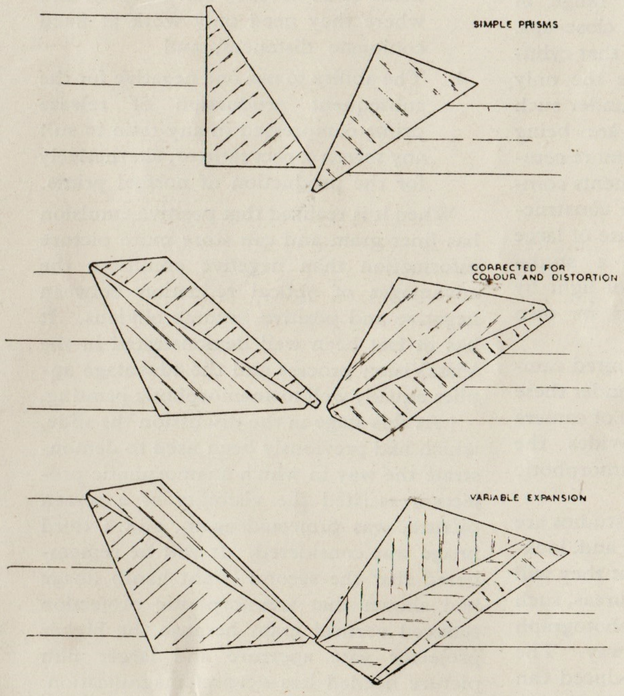


Fig. 6. Prismatic attachment for variable expansion ratio.

Assuming that the maximum gate width is constant the amount of light passing through the gate will be proportional to its height and thus inversely proportional to its aspect ratio.

If the gate for anamorphotic projection has maximum height its aspect ratio will be about 1.25 to 1. It can be shown that the two methods will give equal screen illumination when the screen aspect ratio is 1.25 divided by K where K is the proportional light transmission in the attachment. Prismatic attachments transmit about seven-tenths of the available light so that the two methods give equal illumination at screen aspect ratios of 1.25 divided by .7, i.e. about 1.8 to 1. Above this ratio anamorphotic projection gives brighter screens.

The Projection Lens

This discussion would not be complete without reference to the projection lens itself. Poor definition arising from poorly corrected projection lenses is magnified by the anamorphotic attachment in the same proportion as the expansion ratio.

[To demonstrate this, an image was screened by the type of projection lens which has been standard cinema equipment for a considerable number of years. It was pointed out that although its simple construction provided an adequate standard of definition in the centre of the screen, field curvature and astigmatism set a limit to definition at the edges. Such marginal errors enlarged by anamorphotic attachments are not acceptable on very large screens. The need for improvement has resulted in the introduction of a new range of lenses of high definition. The degree of improvement now available was demonstrated by a screen image projected with a new lens of the same focal length.]

The development of anamorphotic systems is still in its infancy, but as far as the cinema exhibitor is concerned, the equipment now available for use on standard projectors will be adequate for a number of years.

Release Prints

The most severe optical problems occur in the processes used to produce release prints. When attachments which function in the described manner are used at the camera stage to record on the negative a compressed picture, they have to provide angular fields of view considerably greater than those required in cinema projection. To add to the difficulties, the camera attachment is also required to give good definition over a considerable range of object distances from infinity to close-ups. At the present time it is thought that cylindrical types of attachments are the only constructions that can perform under such extreme conditions and they are being developed in forms which utilize more complex and more numerous components compared with the relatively simple constructions used for projection. The use of large anamorphotic attachments on a studio camera and the associated loss of light by absorption and scatter presents its own problems.

The small studio may have limited camera and processing facilities and under these conditions it appears that the use of camera anamorphotic attachments provides the easiest method of producing anamorphotic prints.

On the other hand, the larger studios are not always limited in this manner and, looking into the future, it may be that they will use cameras with larger negative areas, such as the VistaVision camera, to photograph wide-angle scenes in the usual way. The straightforward negatives so produced can then be compressed at an optical printing stage to provide compressed release prints for cinema projection. The advantages of such a process would be :

1. The use of normal type camera lenses avoiding the light losses, definition losses and extra bulk arising from anamorphotic attachments.
2. The use of larger negative areas whose grain and definition is improved by reduction printing.
3. The use of anamorphotic systems at the printing stage where the angular fields to be covered can be small and where they need only work at fixed conjugate distances, and
4. The ability to use one negative for the subsequent production of release prints compressed in any ratio to suit any screen aspect ratio or, alternatively for the production of normal prints.

When it is realized that positive emulsion has finer grain and can store more picture information than negative emulsion, the advantages of optical reduction between negative and positive become obvious. It has in fact been well demonstrated in the VistaVision process and the advantage applies equally well to anamorphotic printing.

[At this stage in the discussion the slide, which had previously been used to demonstrate the way in which anamorphotic projection assisted the visibility of a screen picture, was projected again, and a third image was considered. It will be remembered that the second (right hand) image had shown that anamorphotic projection reduced vertical grain because the higher projector gate aperture and larger film picture needed less vertical magnification. The third image was obtained by a large straightforward negative having been compressed horizontally at the printing stage, and the resultant positive projected anamorphotically.

It was seen that the horizontal printing compression reduced the horizontal grain so that grain was reduced in all directions to give a further improvement in picture visibility.]

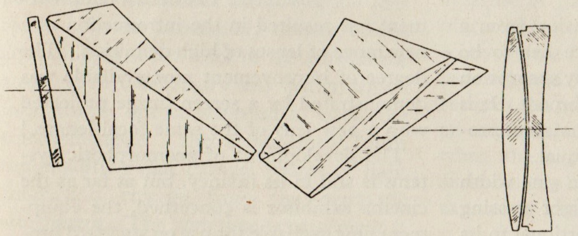


Fig. 7. Arrangement of prismatic projection attachment.

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TECHNICAL INFORMATION
for Projectionists

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Projecting a Big Picture with Small Image Quality*

By GIO GAGLIARDI

Wide-screen technique is stymied in its objectives by lack of sharp definition. The attack underway on this problem points to further basic change in the art.

LARGE SCREEN projection has been with us for two years or thereabouts, and although the "big picture" is definitely established as a new format, the technique of achieving it is still in ferment, and experience with it has increased interest in the efficacy of a much larger, especially wider, film photograph.

The tremendous impact which Cinerama seems to have had on the public, led to the success of CinemaScope. In the relatively short period of two years, over ten thousand theatres have been equipped for the presentation of CinemaScope pictures on relatively large screens, which are being employed for the projection of standard prints in somewhat greater size than previously. These latter are of course magnified proportionately in both width and height, and to an extreme degree that lowers screen image quality.

Up to the time of wide screen technique, the average picture size in the United States (SMPTE surveys) was a little less than 20 feet wide by 16 feet high. A 24 x 18-foot picture was considered to be just about the limit for good illumination and resolution. When CinemaScope and wide-screen projection of "cropped" standard films came along, picture sizes went up and up until standard prints were being enlarged to 40 feet in width, and in some cases even more.

The effect on image quality should be noted here because this constitutes the experience which has sent research in the direction of a larger film photograph. First, as a remedy, older lamps were "boosted"; then new higher powered lamps were developed, while specular aluminium screen surfaces were resorted to for more efficient use of available light. "Cropped" standard prints required lenses of shorter focal lengths than previously manufactured, until now high-speed lenses are now available even in focal lengths below 2 inches.

Resolution Degraded

Nevertheless, these larger pictures, when *viewed from the best seating areas of our theatres*, have not been clear or sharp enough. In other words, the picture quality, or resolution, has been degraded from that *available* with traditional practice.

The physical quality of a picture depends upon the number of fine details which can be perceived. The greater the visible de-

*Reprinted from "MOTION PICTURE HERALD BETTER THEATRES" August 6th 1955 by kind permission of the Editor.

tails, the more convincing the image as a representation. If these details are blurred, or are enlarged to such a point that they lose form and tone, then the picture looks shallow, fuzzy, false.

Under traditional practice, good or acceptable resolution has been obtainable at a distance from the screen between two and five times the screen width. This means that for a 20-foot picture, the closest seats

FIGURE 1 — Comparison of magnification rates prior to wide-screen technique with those of CinemaScope in a relatively small picture width.

	Projection Systems	*Aperture Dimensions*	*Projected Film Area*	*Picture Dimensions*	*Linear Magnif'n*	*Enlarge-ment†*
Item 1	Old Style Projection for 20′ Picture	.825″ x .600″	.495 sq. in.	20′ x 15′ 300 sq. ft.	290 times	88,000 Times
Item 2	Old Style Projection for 24′ Picture	.825″ x .600″	.495 sq. in.	24′ x 18′ 432 sq. ft.	350 Times	125,000 Times
Item 3	Cinema-Scope Projection for 88,000 Times Enlargement	·912″ x .715″	.652 sq. in.	32′ x 12.5′ 400 sq. ft.	420 Ts. hor. 210 Ts. ver.	88,000 Times

†*Picture size relative to film area.*

Three factors mainly influence screen image quality. One is the grain of the film itself. Each grain, after having undergone chemical treatment, cannot be broken down into smaller values of picture information. The finer the grain and the better the chemical process, the more detailed the information that can be crammed into each tiny part of the film photograph.

The second factor is the amount of magnification given the picture on the film. This means the amount of enlargement between aperture and screen.

The third factor is the viewing distance —that is, the area in the auditorium from where the picture on the screen has the best resolution. This is an area in which the spectator should be able to see the smallest details in their true colour and he should not be conscious of any space or bleeding of colour between them.

compatible with good resolution were 40 feet from the screen. If this *same picture* were magnified to a width of 50 feet, the closest acceptable seats would be 100 feet from the screen.

These conditions are of course prohibitive in auditoriums of commercial theatres. We must seat people much closer than that, and there are other conditions which make it highly desirable to seat them nearer. The fact remains, however, that our wide-screen pictures often have poor resolution for the majority of patrons, seem fuzzy, lack detail except in close-ups.

Magnification Rates

Let us have a closer look at this matter of magnification. *Figures* 1 and 2 contain data comparing the physical area and magnification ratios involved in most of the known projection systems. *Item* 1, in *Figure* 1, shows that the standard aperture dimensions of .825″ x .600″, when projected to give a picture 20 feet wide by 15 feet high, results in a *linear* magnification of 290 times, and an *area* enlargement of 88,000 times. In other words, the picture area of the film in the projector gate, which is approximately one half of a square inch, is enlarged 88,000 times in being projected to a size of 20 x 15 feet on the screen !

This tremendous enlargement of the film frame also magnifies the photographic, chemical and mechanical imperfections inherent in the manufacture and processing of black and white and coloured negative and positive film. However, these imperfections did not interfere with proper resolution if seen from a point no nearer the screen than twice the width of the picture —in our example, 40 feet.

Now let us see what happened when we began projecting much larger pictures. *Item* 4, in *Figure* 2, takes into consideration the same 35mm film, using the same size aperture (.825″ x .600″) but in this case the picture on the screen has been increased to a width of 44 feet. The film area of .5-inch has been blown up to a picture area of 1500 square feet, an enlargement of 430,000 times, while the *linear* magnification has become 640 times.

This tremendous change in picture size has also magnified the imperfections proportionately, so that in order to maintain the same picture resolving quality the spectator should not view the picture at a distance smaller than twice the *new* width, or 88 feet from the screen. This of course is an impossibility ; few usable seats would be left in the theatre. Therefore the minimum viewing distance must be reduced.

Effect on " Presence "

A much smaller minimum viewing distance is desirable also to heighten the effect of " presence." In a case represented by *Item* 4 of *Figure* 2, however, this could be done only by reducing the picture quality for a large percentage of the audience—all of it seated closer than 88 feet from the screen. *Items* 4, 5 and 6 are all of similar character, and they typify the conditions caused when the standard 35mm film frame is enlarged to the new picture widths.

Picture aspect ratios now vary from the old 1.33 through 1.66 and to the 1.85-to-1. In the accompanying tables a picture area of 1500 square feet has been maintained in all cases in order to make comparisons with other systems. If we use a 1.85-to-1 aspect ratio (as in *Item* 6) for a 53-foot picture, the area enlargement is 590,000 times. This represents an increase in picture enlargement of six times over the former average under traditional practice given in *Item* 1.

It is pretty definite that the physical quality of such a picture is a burden on the industry's efforts to advance the art, to give a screen performance the greatest possible conviction. Engineers and producers have been striving energetically for a solution of this problem. If wide-angle large pictures are to be maintained, which of the three factors effecting screen image quality could be more readily improved ? Considering the size and shape of most existing theatre auditoriums, the present viewing distances cannot be altered very much. That leaves the problem one of improving the grain and die quality of 33mm film, or *to decrease the required picture enlargement by increasing the effective area of the film in the projector gate.*

Wide-frame Methods

Both of these sources of a solution are now being explored in various ways. Cinerama got around the limitations of 35mm film at the outset by combining three strips in projection. You will see in *Item* 10 that the actual film area in each Cinerama projector gate is approximately 1 square inch, and since three projectors are operating at the same time, the *projected film area* is equal to 3 square inches.

FIGURE 2 — Comparison of magnfiication rates according to projection systems, using 1500 square feet as basis of picture size.

	Projection Systems	*Aperture Dimensions*	*Projected Film Area*	*Picture Dimensions*	*Linear Magnif'n*	*Enlargement†*
Item 4	" Standard " 1.33-to-1	.825″ x .600″	.495 sq. in.	44′ x 33′ 1500 sq. ft.	640 Times	430,000 Times
Item 5	" Cropped " 1.66-to-1	.825″ x .495″	.410 sq. in.	50′ x 30′ 1500 sq. ft.	720 Times	530,000 Times
Item 6	" Cropped " 1.85-to-1	.825″ x .445″	.367 sq. in.	53′ x 28′ 1500 sq. ft.	760 Times	590,000 Times
Item 7	C'Scope 35mm 2.55-to-1	.912″ x .715″	.650 sq. in.	60′ x 24′ 1440 sq. ft.	780 (width) 390 (ht.)	330,000 Times
Item 8	SuperScope 2-to-1	.715″ x .715″	.510 sq. in.	55′ x 27′ 1500 sq. ft.	920 (width) 460 (ht.)	420,000 Times
Item 9	VVis. horiz. 2-to-1	1.40″ x .720″	1.0 sq. in.	55′ x 27′ 1500 sq. ft.	470 Times	216,000 Times
Item 10	Cinerama	1.10″ x .93″ (Each proj.)	3.0 sq. in. (3 aperts.)	65′ x 23′ 1500 sq. ft.	260 Times	70,000 Times
Item 11	Todd-AO	2.0″ x .85″	1.70 sq. in.	60′ x 25′ 1500 sq. ft.	360 Times	127,000 Times
Item 12	C'Scope Wide Film	1.8″ x 1.4″	2.50 sq. in.	60′ x 24′ 1440 sq. ft.	400 (width) 200 (ht.)	86,000 Times
Item 13	MGM-Gotts. Wide Film	2.0″ x .85″	1.70 sq. in.	60′ x 25′ 1500 sq. ft.	360 Times	127,000 Times

†*Picture size relative to film area.*

Thus for a picture 65 × 23 feet (an area of 1500 square feet), the *linear* magnification is only 260 times, and the *area* enlargement is only 70,000 times. This is actually less magnification than in traditional practice as shown in *Item* 1! With Cinerama good picture resolution can be maintained for viewers seated even so close as 25 to 30 feet away from the screen.

CinemaScope (*Item* 7) enlarged the picture frame area of the regular 35mm film. Its projector aperture of .912 x .715-inch has an area of .650-square-inch, which is 75% larger than the 1.85-to-1 " cropped " aperture. However, even this increase in film area still required an enlargement of 330,000 times in order to produce a picture 60 feet wide, and this enlargement is over 3½ times greater than that of former practice (*Item* 1). This means that for desired resolution in a 60-foot picture the minimum viewing distance should not be less than about 70 feet.

Item 3, *Figure* 1, refers to a CinemaScope picture only 32 feet wide. Here the enlargement is 88,000 times or exactly the same amount as in *Item* 1. With a picture of that size, good resolution should be obtained at a viewing distance of 40 feet.

Improvement in film grain characteristics is the basic objective of Paramount's VistaVision process. The negative film, which is normal 35mm stock, is exposed in double frames (8 sprocket holes) in a horizontal camera. The size of the negative frame is 1.472-inch wide by .997-inch high. After development this large negative frame, with an area of 1.46-square inch, can be reduced optically in printing to a normal positive 35mm frame of about .45-square inch, thereby decreasing print film grain.

There is no doubt that the reduction in film grain thus accomplished permits better viewing conditions in the theatre. Recent announcements by Fox and MGM indicate that both of these companies contemplate using large negatives in their cameras, then reducing the film grain size by reduction printing to the standard size 35mm positive.

Twentieth Century-Fox will use a negative about 55mm wide with an eight sprocket hole pull down. This will give a negative film area of 2.5-square inches (see *Item* 12 in *Figure* 2), which will give a print-down reduction of 4-to-1 for optical track CinemaScope prints. It is believed that MGM will use the large Todd-AO frame (*Item* 13) on a negative 65mm wide. This will produce a negative area of approximately 1.7-square inches.

This form of reduction printing from large negative to standard size positive will minimize to some extent the flaws and resolution errors which have been inherent in the over-enlargement of the picture on the screen. The result should be the presentation of better defined screen images in every theatre. Such improvement does not entail any change of equipment in the field.

Ultimate accomplishment of the desired quality can really only come, however, when the *actual positive film-to-screen magnification* is reduced to the old-time minimum. As we said, Cinerama accomplished this by using triple prints in three projectors (*Item* 10). Todd-AO, with its single 65mm positive (*Item* 11) will have a total enlargement of 127,000 times, which is greater than Cinerama but should be comparable in quality to the old-time 24-foot picture (*Item* 2).

Paramount in special cases has released unreduced positives, printed directly from their large VistaVision negatives (*Item* 9). These 35mm prints were projected through special horizontal projectors and demonstrated that good picture quality can be brought back to the theatre on a large screen.

It is quite possible that Twentieth Century-Fox may release some of their new 55mm CinemaScope pictures on full-sized 55mm positive prints (*Item* 12). In this case a 60-foot picture should have the equivalent quality of the old-time 20-foot picture even when viewed from a distance of 40 feet.

The nature of film presentation has changed radically in the last two years. Producers and engineers have been trying to change the scope and dramatic range of the theatre screen. An attempt is being made to bring *dynamic reality to the theatre.*

Direction of Progress

Excellent picture quality, in combination with proper large picture size, are the two principal factors which will produce this realism. These two are only compatible if the film-to-image magnification does not destroy good seating arrangement. The efforts of the various producers to solve this problem are leading towards the use of large negatives first, then large positives as the final answer.

The trend for the future, at least for the larger theatres, seems to be towards the possible use of larger positive film. Cinerama started it with its sectional prints ; Paramount followed with its single double-frame horizontal projection ; Todd-AO is now getting ready for 65mm presentations ; 20th Century-Fox and MGM are developing wide-film processes. This means that engineers and manufacturers must be prepared to produce equipment capable of handling and projecting the new films. There is no doubt that this challenge will be met by producer, manufacturer and exhibitor in order to keep the motion picture industry the leader in the entertainment field.

TECHNICAL INFORMATION

for Projectionists

Published by **G.B-KALEE LTD.** **No. 16**

The Effect of Wide-Screen on Maintenance

THE GREATER magnification of wide-screen projection is accompanied by corresponding or even greater, magnification of the possible defects which are inherent in any projection system. The principle of motion picture projection calls for the reproduction of successive photographs which must register, one upon the other, exactly, without any variation whatsoever. The projector machanism attempts to accomplish this extremely difficult operation.

Absolutely perfect registration is not possible, due to unavoidable manufacturing tolerances ; however, a picture jump (poor vertical registration) of a tenth of an inch used to be considered the limit for good projection. At a magnification of 280 typical of former standard practice that acceptable jump represented a maximum permissible motion in the film gate of only four ten-thousandths of an inch. This extremely low tolerance was met by most projectors and was maintained by normal careful repairs.

Magnification Factors

Today, however, this condition has been aggravated severely. In order to obtain the wider pictures in the new aspect ratios, *without using anamorphic lenses*, the picture frame area has been cut off at top and bottom. This truncated frame is then enlarged tremendously to produce the new large pictures. For a 2-to-1 aspect ratio and a picture width of 40 feet, the magnification of the frame height and all *vertical* imperfections becomes almost 600 times. If we go to a width of 80 feet, this magnification is increased to 1200 times.

In order to maintain the same minimum of picture jump previously specified, the projector mechanism must meet much stricter machining tolerances. The permissible frame jump in the film aperture should be reduced to two ten-thousandths of an inch, and of course to a smaller amount, if possible.

Since picture jump is related to vertical magnification, anamorphic technique is a help. With a CinemaScope frame, which is .715-inch high, the magnification and the jump may be reduced by 40% over a standard 2-to-1 ratio picture frame, whose height is only .412-inch (assuming both pictures are maintained at the same height). However, the CinemaScope picture may suffer from an increased proportion of side, or lateral, film weave effect. This is due to the greater expanison of the image produced by the anamorphic lens in order that an aspect ratio of 2.55-to-1 can be maintained.

Other factors which are adversely affected by the over-magnification of wide-screen pictures are resolution, brightness, focus range, and break-up of emulsion grain. Some of these factors are closely related.

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More lamp power and illumination produces more heat on the film, which in turn causes more buckling and poorer focus over the full width of the projected picture.

Wide-angle projection lenses for larger pictures have shallower focus range, adding to the difficulty of keeping the film in focus. And over-magnification of emulsion grain reduces picture resolution.

The above list of projection troubles brought about by the new large pictures sounds formidable ; however, ways and means are being found to diminish their effect and to bring back the steady, sharp, crisp quality of projected pictures. Let us see how projection practices can help the situation.

Sprocket Conditions

Eccentric sprockets, lopsided sprocket rims, bent or sprung sprocket shafts produce a recurring and periodic jump in the picture. Since this jump occurs every fourth frame, and there are 24 frames per second, the jump repetition has a six-cycle period which is easily visible to the eye.

A selected projection test loop, made from the *SMPTE Jump and Weave* target film, should be projected and careful observation of the fully magnified pattern on the screen will indicate the amount of jump and its period of recurrence.

A close examination of the sprocket and sprocket teeth with a magnifying glass should reveal any deformity or excessive undercutting. If necessary the sprocket or intermittent should be changed. The loop should be run so see whether jump has been eliminated.

Film Guides and Pads

Worn film runners or tension pads may produce uneven or low pressure distribution on the film, causing the frames to overshoot the stopping point. This may generally be accompanied by erratic side-to-side weave. Again adjustment of pressure, or replacement of guides and pads, may remedy the trouble, which can be verified with the same test film as noted above.

Most projectors are equipped with edge-guiding film slides. These should be checked with a gauge for correct alignment and location. They should be examined for wear, and the tension on the edge of the film should be kept sufficient to prevent weave and lateral motion. Again, the same test loop will measure the results.

New or heavily waxed film may cause jumping. This motion is very erratic and can be detected by the noise produced, and possibly by the deposit of wax on the guides. This condition should be temporary and easily isolated by comparing the operation with a normal test loop.

Some of the picture jump, or side motion, may be due to inaccurate camera and printer registration during the film processing. This defect cannot be corrected in the projection room, but it can be isolated by making a comparison with the test loop, which has been carefully processed to minimize such inaccuracies.

Shutter Adjustment

With the larger pictures more light is needed. In some cases, projector shutter blades have been reduced in angle to a dangerous size. The slightest adjustment change, or least amount of gear back-lash, may produce travel ghost effects. To detect this trouble the *SMPTE Travel-Ghost Target* test reel should be used.

This reel will demonstrate the slightest amount of fringing, or ghost, and its direction. Adjustments or replacement should be made as required. If the shutters are not wide enough, a slight fringe or halo will occur on both sides of the bright sections on the screen and will give the effect of very bad focus. Lenses sometimes are blamed for this effect when actually the shutter and gear train are at fault.

Film Curvature and Flutter

Wide-angle, high-speed lenses transmit more light, but they are also much more critical in focusing. The permissible " depth of focus " becomes more shallow and the film should be held in one plane to close tolerances.

More light means more aperture heat, and tests have indicated that the amount of film curling, or " pin-cushioning," in the gate varies directly with the heat on the film.

Projection Lenses

Judging the quality of a lens in a theatre is a very difficult process. This is due to the fact that there are so many other variable factors involved. The physical quality of the film used may be questionable. The amount of film curl may be beyond the depth of field of the lens. The lens mounts or tubes may be vignetting. The light source may not be matched to the lens speed.

However, there are some field tests which may help in checking the operating quality of a lens. The lens holder should be perfectly strong and rigid to eliminate any spurious vibrations. The lens axis should centre and be perpendicular to the film picture frame.

The lens mount, extension tube, projector front should in no way extend into the light beam. The lamp optical system should be of the same speed as the lens, at least for the rays about the aperture centre.

To check for lens conditions, use a dummy aperture plate with many small perforations. The images of the perforations should be checked on the screen for overall sharpness. This aperture plate must be kept cool or it will bulge out of plane.

The SMPTE has a *Focus and Lens Aberration Target* test film which should then be used to check the field curvature and field depth.

If these tests are satisfactory, then a *Resolution Test Film* should be used to determine if the lens has equal resolving power for the sides and corners of the screen as well as for the centre.

Anamorphic Devices

Anamorphic lenses of the fixed (cylindrical and mirror), and variable prismatic type are now in use. Some of these devices are very large and quite heavy. It is absolutely necessary that proper mounts are provided to prevent dragging the backing lenses out of line, and to prevent any excessive vibration.

Because film product now varies in basic technical specifications, lenses must be changed more frequently than they used to be. Proper mounts, locking rings and stops should be provided to facilitate these changes and to insure correct re-establishment of picture size and focus.

Variable anamorphic lenses can go out of setting, especially where individual adjustments are available for right and left expansion. An anamorphic target test film should be used to check the proper picture size, the proper anamorphic expansion ratio, and the proper balance between right and left side of picture.

In these cases, a resolution test film would easily determine whether any resolving power is lost at the picture's sides.

For these reasons the engineer and projectionist must apply ingenuity, expertness and extreme care in handling all projection equipment.

Simplifying Projection Technique

ONE OF THE major factors of poor screen image quality is overenlargement of the film photograph. In the days before the large screen, enlargements of 80,000 to 100,000 times were seldom exceeded. That kept resolution well within the bounds of acceptability. Today that is no longer the case. With the new large pictures, area magnification of over 500,000 times has been attempted on many large indoor screens and the results have been extremely poor.

Some concept of our present problems and of a possible method for their solution may be obtained by examining and comparing the data collected in the accompanying table.

The assumption for this discussion is that the stage will permit a picture of 40 feet maximum width. The problem is to determine what picture sizes can be installed in such a theatre, what are the best magnification conditions, and what changes could be made in film and projection procedure to *give better conditions and to simplify actual operation.*

It is fairly obvious that the maximum projected film area, using 35mm. prints, is obtained with full-size CinemaScope, which has an aperture .912″ wide by .715″ high, representing an area of .652 square inches.

This case is shown as *Item* 6 in the table. This film, with an anamorphic compression ratio of 2-to-1, gives a picture 16 feet high by 40 feet wide at an enlargement of 141,000 times.

Let us assume that this theatre is *not* equipped with magnetic reproducers and insists on running with optical track CinemaScope prints, in which case the data in *Item* 1 will apply. Since this aperture is only .839″ x .715″, a proper lens should be chosen to give a picture 40 feet wide, *but the height will then be* 17 *feet.* For this case the enlargement will be 163,000 times. This condition is not as good as when the full CinemaScope frame is used.

Now let us see what happens to the cropped standard print pictures which should match the two cases shown above. *Items* 2 and 7 show what happens to standard film when a cropped aperture is used. For a picture aspect ratio of 2-to-1 the picture in *Item* 2 would be 17 feet high by 34 feet wide. The height would match *Item* 1, but the picture enlargement would be 246,000 as compared to 163,000 for CinemaScope of *Item* 1.

The case of *Item* 7 shows a similar relationship to the full-sized CinemaScope aperture and picture of *Item* 6. In both instances, even when the cropped standard picture is not made excessively large, the

	Projection System	*Anamorphic Ratio*	*Aspect Ratio*	*Aperture Size*	*Film Area*	*Picture Size*	*Enlargement*
1	C'Scope Opt.	2 to 1	2·35 to 1	·839″ x ·715″	·600 sq. in.	17′ x 40′ 680 sq. ft.	163,000 times
2	Crop. Stand.		2 to 1	·825″ x ·412″	·340 sq. in.	17′ x 34′ 580 sq. ft.	246,000 times
3	Anamor. System	1·7 to 1	2 to 1	·839″ x ·715″	·600 sq. in.	17′ x 34′ 580 sq. ft.	139,000 times
4	Crop. Stand.		1·75 to 1	·825″ x ·471″	·389 sq. in.	17′ x 30′ 510 sq. ft.	189,000 times
5	Anamor. System	1·5 to 1	1·75 to 1	·839″ x ·715″	·600 sq. in.	17′ x 30′ 510 sq. ft.	122,000 times
6	C'Scope Mag.	2 to 1	2·55 to 1	·912″ x ·715″	·652 sq. in.	16′ x 40′ 640 sq. ft.	141,000 times
7	Crop. Stand.		2 to 1	·825″ x ·412″	·340 sq. in.	16′ x 32′ 510 sq. ft.	216,000 times
8	Anamor. System	1·5 to 1	1·92 to 1	·912″ x ·715″	·652 sq. in.	16′ x 31′ 500 sq. ft.	110,000 times
9	Crop. Stand.		2 to 1	·825″ x ·412″	·340 sq. in.	20′ x 40′ 800 sq. ft.	340,000 times
10	Anamor. System	1·5 to 1	1·92 to 1	·912″ x ·715″	·652 sq. in.	21′ x 40′ 840 sq. ft.	185,000 times

TABLE OF MAGNIFICATION RATES FOR VARIOUS PROJECTION SYSTEMS

blown-up type of picture suffers considerably from over-magnification.

Now consider the case where an exhibitor insists upon showing a standard cropped picture so that it will fill the screen. *Item* 9 shows this condition. The picture is made 40 feet wide to compare with CinemaScope, so that with a 2-to-1 aspect ratio, the enlargement becomes 340,000 times. As a result, the picture has very poor definition and is seldom completely in focus.

Obviously a study of the table will show that the principal remedy which will bring back good screen image quality is the use of the largest possible film area in the projector gate that our present 35mm. stock will permit. When we crop the film frame and then blow it up excessively, we go completely against this sensible principle.

There are many persons in the industry who maintain that a picture aspect ratio of 2-to-1 is more desirable than the CinemaScope ratio of 2.35 or 2.55-to-1. This argument may have some justification ; *however, the loss of picture quality produced by cropping a standard aperture to obtain this aspect ratio only serves to defeat the process.*

Use of Maximum Area With Minimum Magnification

A method may be suggested which will use the maximum amount of film area and also confine magnification to a minimum. Let us first consider *Item* 8 in the table. Here we use the maximum picture frame size of .912″ x .715″ ; however, the picture on the film is compressed to an anamorphic ratio of 1.5-to-1, and when projected through a 1.5-to-1 anamorphic expander a picture 16 feet by 31 feet will be obtained. This will have an enlargement ratio of only 110,000 times. *Item* 7 shows a cropped picture of the same size which, however, has twice such enlargement (216,000 times).

The case shown in *Item* 5 is quite similar, but the picture area on the film is reduced to .839″ x .715″ to suit single-track optical sound. Even for the largest picture possible under the conditions of this discussion, *Item* 10 shows that a 21-foot by 40-foot picture projected with a 1.5-to-1 anamorphic system would have an enlargement factor of 185,000 times, which is far less than the 340,000 times produced by the cropped picture of *Item* 9.

If all pictures were photographed anamorphically in a proper ratio and released with the four-track magnetic CinemaScope print specifications (aperture size .912″ x .715″), both CinemaScope and 2-to-1 ratio pictures could be projected to a width of 40 feet with acceptable magnification. This would be especially true with print-down from larger negative frame. With the latter technique plus recent improvements in chemical reagents, the above proposals should insure extremely good picture quality even in the upper picture sizes.

If it were possible to have such procedure universally accepted, projection would be simplified considerably.

The height of the pictures would be the same and the centre lines of the pictures would coincide.

Full size apertures could be used, and the projectors would not have to be moved between pictures.

The same back-up lenses could be used in all cases.

This system would simplify motion picture projection among the majority of theatres everywhere without placing any burden on technical progress. To the contrary, it would enable the industry to realize more consistently the advances it has already achieved.

Speed in Projection Optics

THEATRE MANAGEMENT sometimes considers the purchase of new high-speed lenses without taking into consideration the slow speed of their lamphouse optics.

If the projection is *faster* than the lamphouse optics, the light at the centre of the screen will not be increased, but the light at the side and corners will be greater than before.

If the projection lens is *slower* than the speed of the lamphouse optics, a considerable amount of light efficiency is lost for *both* the centres and the sides of the screen. This effect will be noticed if faster lamps are installed without a change in the projection lenses.

It has been customary to classify projection lenses by their *F/number* and this procedure is now being followed for the mirror and condenser systems of lamphouses. This classification is valuable because it permits the proper matching of lamp and projector optics to obtain maximum output.

Speed Matching

A great deal of discussion has developed regarding the necessity and correctness of proper matching. Since the speed of projection optical systems is a function of the angle subtended by the *effective pupil* of the optical unit to any given point on the film in the projector aperture, it is obvious that the centre of the film is the only area where maximum system speeds may be obtained. For the sides and corners of the film frame, the speeds of the two systems will still be matched but will be considerably reduced.

Figure 1, shows a perfect optical match and *full utilization* of the speeds of a projection lens *AB* and a lamp condensing system *EG*. *Angle AOB* is equal to angle *EOG* and *both serve to fill the entire lens and reflector from point* 0 *on the projector film gate.*

Figure 2, shows the same lens and reflector condition for the *corner* of the film gate. Here the " equivalent " aperture of the lens *CB* is matched to the " equivalent " aperture of the reflector *IE*—but, as is evident, angle *CPB* is smaller than the original angle *AOB ;* therefore the speed of the lens, or of the reflector, for point *P* on the film gate is less than for the centre.

For the condition in *Figure* 2, it can be said that the reflector does not fill the entire lens, therefore it is acting as a stop to the full speed of the lens. This is one of the reasons why the side and corner light on the screen cannot be brought up to the same level as the centre of the screen.

Even when both the projector lens and the lamp optics are theoretically matched for optical speed, a few poor adjustments can very easily cut down on the total system speed.

If the lamphouse is out of correct alignment, if the *condensing system is in the wrong position,* if the *lamphouse front section is too small,* if the *projector rear shutter housing shields and shutter hub interfere with the full light ray, if projection lens tubes and extension shields are too long*—all of these items can cause a reduction of total optical speed.

At any of these points, the interference mentioned will actually serve to reduce the effective lens stop diameter and thus in effect increase the *F/number* of the projection lens.

Measuring " Aerial Image "

Accurate measurement of the lens stop diameter is a laboratory procedure ; however, it is possible to get an approximate indication of the projection system speed by observing and measuring the diameter of the " aerial image " in the light beam in front of the projection lens.

The aerial image in front of a lens is actually the image of the reflector, or the condenser, created by the lens. At this

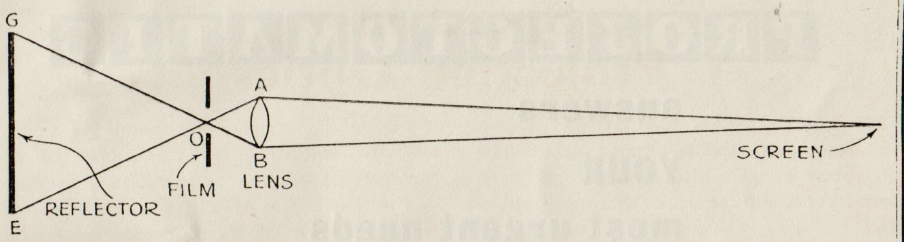

FIGURE 1: Matching of lens and reflector for center of film gate—maximum speed.

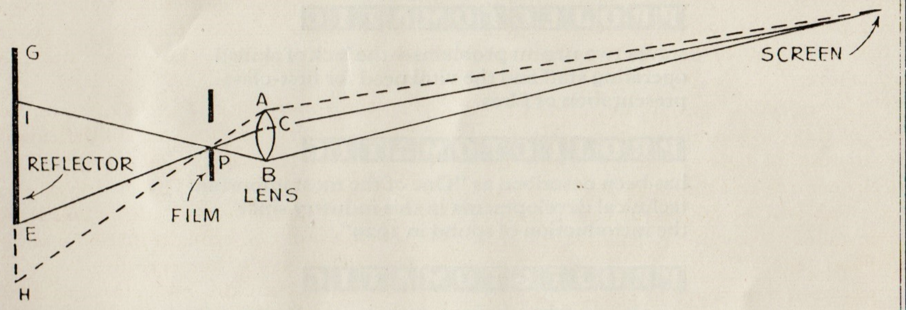

FIGURE 2: Matching of lens and reflector for corner of film gate—reduced speed.

point the optical " stop aperture " of the projection system may be measured. If the diameter of this image is smaller than the diameter of the last clear glass opening of the lens, then something in the system is " stopping " down the speed.

The speed of the projection lens is equal to the focal length divided by the *lens aperture* diameter. For a well-designed lens, the aperture diameter should be equal to the diameter of the last glass element. If the aerial picture in front of the lens is smaller in diameter than the last glass element, it is possible that the lamp optics (either reflector or condenser) are too small or out of proper position. The lamphouse optics are not filling the lens and are acting as a smaller " stop aperture " for it.

Testing System Speed

Let us assume that we are using a 4-inch focal length lens of f/2.0 speed. This lens " stop aperture " should be a minimum of 2 inches in diameter, therefore the aerial image in front of the lens should never be less than 2 inches in diameter.

If we hold a dark card in front of the lens and move it back and forth, there should be a spot where the image of the reflector or condenser is extremely sharp. At this point the image should not be less than 2 inches in diameter. If it is smaller, then the reflector or condenser is not filling the lens properly and is reducing the optical speed of the entire projection system.

Since a sharp image of the reflector, the reflector-holder and carbon guides may be obtained at this position, it is possible to see whether the reflector is filling the lens completely with light. Hold a graduated metal strip in front of the mirror face, from the rim towards the centre of the mirror (like a radius line).

Detecting the Speed

The image of this strip will be visible on the card in front of the lens. Cut notches in the metal strip every inch to coincide with the radius of the mirror. By counting the notches visible in the image it will be easy to determine exactly how much of the mirror is seen by the lens and if the lens is faster or slower than the reflector.

The effective speed of a complete projection train can be only as high as its slowest point. There are many locations where mechanical and optical stops, or restriction, will cause reductions in maximum speed. These faults should be located and, if possible, removed.

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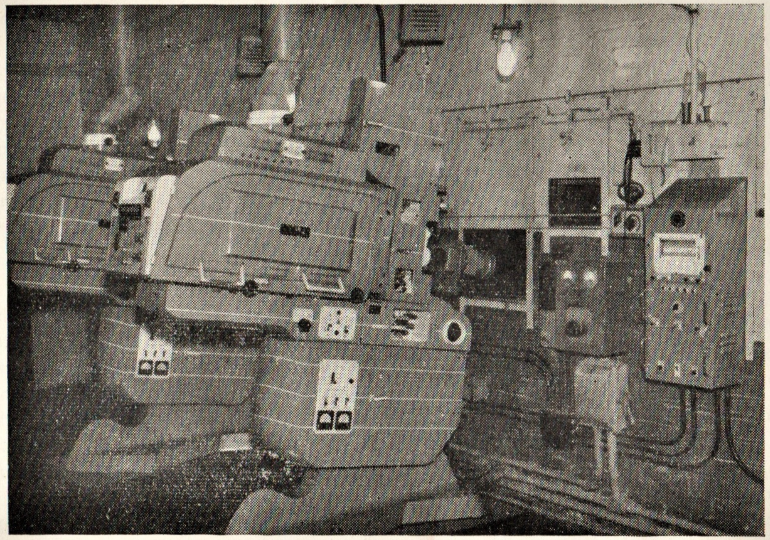

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TECHNICAL INFORMATION
for Projectionists

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How Projectomatic System Works

by **T. Robinson**
Inventor and Chief Engineer Essoldomatic Ltd.

WHEN considering technical developments in the cinema industry over the last 40 years the rapid progress made in many aspects is astonishing, but it is also astonishing to reflect that in that same period only one major change in the actual system of projection has been made. In the very early days a pause while the operator changed reels was taken for granted, but as features grew in length, the technique was evolved of using two projectors to show alternate reels, and the system of operating these changes from one projector to the other was developed to a fine art. Today that same system is still in operation, and although the projectors themselves have become modern streamlined equipments, these machines can still only present a performance as good as the crew which will operate them.

The growing shortage of man-power, coupled with the added complexities of variable masking for Cinemascope and other modern developments, led to increasing difficulties for the exhibitor of films on a commercial scale. The obvious answer to the problem was a system of automatic control to operate the change-over from one projector to another. Later this idea was extended to cover full automatic control over every part of the auditorium equipment, lights, curtains, music, etc. all being geared to one control, thus synchronising all these effects into one continuous operation, which would continue automatically from recorded music at the beginning of the programme, until the final rising of the houselights and the playing of the National Anthem.

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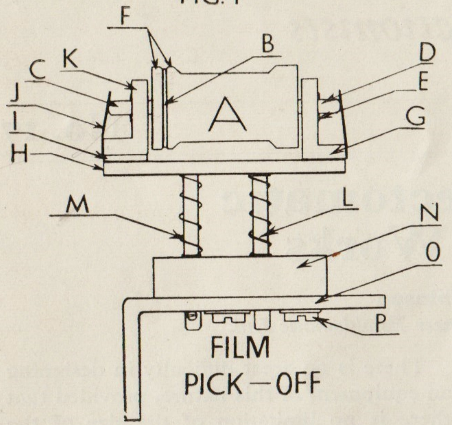
There is no great difficulty in designing an equipment of this nature, provided that there is no limitation of the size of the finished unit, or its complexity of operation, but as it was intended for use in projection boxes which are often very limited in size, and since it would then be used by operators who are untrained in the use of complicated electronic circuits, the problem soon became intensified. In addition, the design had to incorporate safety devices to provide for any emergency which might occur, so that the equipment was as safe or safer than manually operated projectors.

Bearing these facts in mind, I soon decided that the film itself should be made to operate the equipment, and the impulse derived from direct contact with the film should be picked off and transmitted to a control unit where it could be made to operate a relay system which would transmit power to the projectors as and when required.

The design did present certain technical problems and the first of these was to obtain a suitable signal from the film. The method finally found to be most reliable was to mark the film at predetermined places by means of paint, which has a carbon and graphite base with a low electrical resistance.

Other considerations which led to the choice of this method were, the simplicity of applying or removing paint from the film, the fact that no mutilation of the film is required, it is easy to standardise the system of marking employed, and, a last point, of major importance, it does not mechanically or electrically increase the chances of the film breaking or heating due to friction.

FIG. I



FILM PICK—OFF

Having confirmed that it was possible to obtain such a signal from the film, by means of paint, a pick-off mechanism was required to transmit the pulses thus received to the control unit and this you will see in Figure 1.

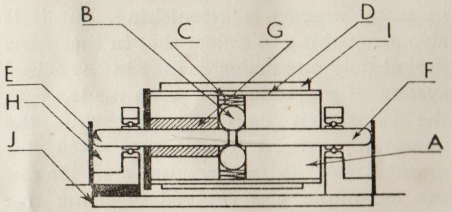
The pick-off mechanism comprises a brass roller A, one end of which is parted to insert an insulation strip B. The ends of the roller are drilled to insert two spindles C and D mounted on 2 ball races E. The whole is assembled on brackets K and G. These brackets are screwed to a brass carrier H. One bracket, K being insulated to isolate one end of the roller assembly at I. The spring contacts J are provided to ensure good continuity of contact between the spindles and connecting points.

The film passes over the entire surface of the roller, including the insulation strip, so when a mark of suitable conductivity is placed on the edge of the film, it will short circuit points F. making an electrical circuit between brackets K and G.

It is essential that the film should not be subject to any undue tension, and to enable it to run naturally over the roller assembly, it was mounted on two spring pillars L and M. These in turn are mounted on a block N fixed to the projector mounting bracket O. Two adjusting screws P are provided, enabling the whole pick-off assembly to be fitted to the majority of existing projectors.

The next problem to be encountered was to decide on a means of signalling a break in the film or a drop in projection speed. This safety device is a fundamental necessity, for as you know, great emphasis is laid on the safety aspect of all cinema and theatre equipment. On early models a method of using the static electricity generated by the film was used, but this was abandoned for a mechanical roller which you will see in Figure 2.

FIG. 2



STOP ROLLER

This is a roller A. drilled to take 4 ball bearings B. held in place by springs C, and the whole assembly is kept in position by a sleeve D. The spindles E. and F one of which is insulated G in a similar manner to the pick-off, are short circuited by the ball bearing B. the electrical circuit being completed between points F. and H. The film, passing over the neoprene sleeve I at a speed of 90 ft. per minute, will give a roller speed of 344 revolutions per minute approximately, and this is sufficient, due to centrifugal force, to keep the balls from making contact with the spindles, leaving them in the open circuit condition. If the film speed should fall to 70 feet per minute, or 270 revolutions per minute approximately, then the balls short circuit the cap between the spindles and thus a signal is obtained, both of a break in the film and of a drop in the speed of the projector.

A further safety device to be incorporated was a buzzer to sound immediately prior to starting the arc and motor of a projector, so warning the operator to stand clear.

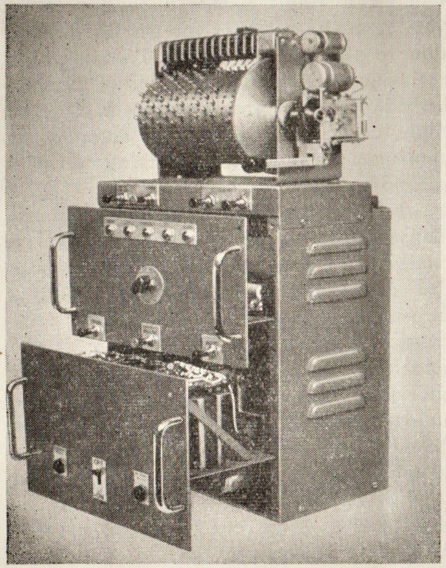
The next step was to design a control unit which would receive the signals from the pick-off assembly, and translate them into working impulses to carry out the various required operations.

Undoubtedly, the most satisfactory construction for ease of maintainance and reliability, was to separate the different functions of the unit into four parts. These are independently constructed and each part is removable, thus a high standard of efficiency is maintained, and if a fault should occur, the section concerned is removed as a whole, and a complete new section substituted : this only takes a minute or so and the fault can then be traced and repaired at leisure.

The instrument is divided into four parts like this, first the drum, then the case, next the Power Pack and lastly the Projector Control Unit.

Now, taking each part in detail, their main functions are :—

First the Drum. This is an aluminium cylinder mounted on ball bearings. It is drilled vertically and horizontally with rows of holes. For every pulse received from the film via the pick-off assembly, the drum steps round one horizontal row.



If pegs are inserted in these holes to protrude beyond the surface of the cylinder, as the Drum revolves the pegs will meet the chosen sets of contacts, and it is therefore obvious that by adjusting the positions and numbers of pegs, the pulses can be made to carry out any given operation. The standard model has 13 contacts, and looking at the Drum from left to right, these control :—

Arcs and projector motors
The light dowsers
Cinemascope masking
Normal masking
To open the screen curtains
To close the screen curtains
To switch on non-synchronous sound
Raise the footlights
Raise the houselights
For Automatic changeovers and lastly
Drum on self pulse.

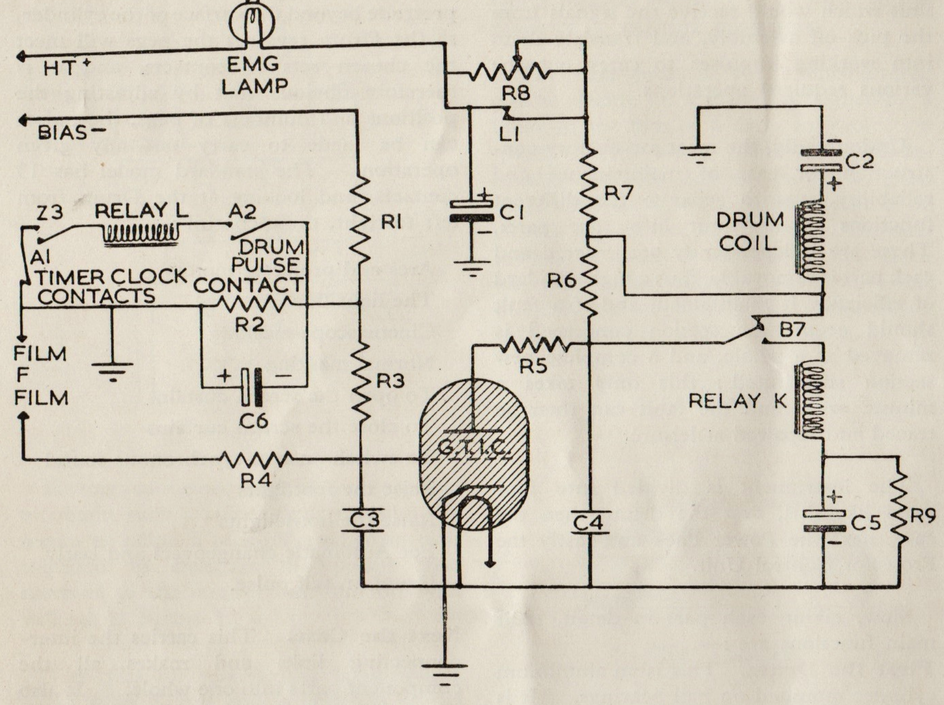
Next the Case. This carries the interconnecting links and makes all the component parts into one whole. It also carries the mains input, and all connections for the external secondary relays controlling the projectors, footlights, etc.

The Power Pack. This is of conventional design, having two double wound, screened primary mains transformers assisted by three rectifiers which convert the standard A.C. mains supply, 40-100 cycles, 200/250 volts, to the voltages required by the internal and external relay, circuits, the thyratron heater, anode, bias and indicator lamp supply. These transformers are thermostatically controlled to isolate themselves if their working temperature should rise excessively.

Lastly, the Projector control Unit. This contains six separate circuits which control :—

The heater supply.
The anode supply.
The bias voltage to the valve.
The internal primary relays.
The external secondary relays
And the indicator lamps.

FIG.3



It will only be confusing if I attempt to describe each of the circuits in detail. I have therefore only included the points which I think will be of interest.

First there is the method of interpreting the signal from the film by the use of a pulse circuit, showing how the signal operates either the drum control or the automatic changeover control which is shown in Figure 3.

The negative bias control voltage for the thyratron valve is obtained through resistance network R.1. R.2. and R.3. C.6 acting as a smoothing condenser. As R.1. and R.2. are of a relatively low value and there is no film trace across points F. there will be negative voltage on the grid through R.3. almost immediately the instrument is switched on.

The anode supply is taken through an emergency warning lamp P.1. which in the event of a breakdown of the main H.T. smoothing Condenser C.1. or any part of the anode circuit, indicates to the operator that a fault has occurred since the equipment was set in motion. The H.T. supply is required for charging the condensers to operate the drum impulse motor coil and the auto-change impulse Relay K. There will be a slight delay in the operating voltage at the anode of the gas-filled relay, due to the voltage dropped across high resistance R.7 by the drum coil of medium impedance, and the Condenser C.2. of high capacity: these two components causing a short circuit for a fraction of a second to the D.C. surge voltage. So it can be seen that when sufficient time has elapsed for the Condenser C.2. to be charged to the voltage required to operate the drum impulse motor coil, and a film-trace short circuits the pick-off contacts F. lowering the bias voltage at the grid and Condenser C.3. through Resistance R.4. then the condenser C.2. in the anode circuit will discharge through the drum impulse coil via the drum relay auto-contacts B.7. R.5. and the gas-filled relay. R.5. being of a low resistance, is only used as a current limiter to prevent damage to the valve.

Condenser C.3. is of small capacity to prevent the thyratron being tripped by any unwanted pulses from an external or internal source. Condenser C.4. is to ensure that the voltage at the anode of the thyratron is sufficiently low for the grid to regain control after the discharge of Condensers C.2. or C.5. As this is a chosen time circuit, only pulses of a given interval can operate either the drum coil, or Relay K when it is connected for the automatic changeover between two projectors. This takes care of any double pulse being received should a fault occur on the film marking, such as a trace becoming broken on passing through the projector.

To make the circuit self-pulsing at given time intervals, irrespective of the film pulses obtained from the projectors at F. a set of relay contacts A.2. and Z.3. are closed when in the drum operating position, connecting the grid bias voltage to a relay coil L. this will act as a resistance to drop the voltage at the grid to the required value, and at the same time open the contacts L.1. in the anode circuit so adding a variable resistance R.8 in series with R.7 to control the time taken to charge condenser C.2. to fire the thyratron.

It can therefore be seen that the circuit can be made to operate the impulse motor coil at a pre-determined setting of R.8 if a longer time is required, then contacts A.1. are operated by an external timer.

When a trace on the film is required to operate the primary relays controlling the arc. motor and the light dowser, it is necessary to excite the relay coil that changes the anode via changeover contacts B.7 from the drum coil to Relay K, and also to isolate Relay L from the grid circuit by opening contacts A.2 and Z.3. The same conditions then apply to Relay K as to the drum impulse motor coil, this time C.5. charging with a D.C. potential through R.6. and R.7. R.6 was added to the circuit to even out the difference of charging time required between drum control and automatic changeovers.

The Resistance R.9 is to ensure that C.5. will be fully discharged when the thyratron is in the drum control position as shown on the drawing. This is absolutely essential because, when a trace has been placed on the film for the purpose of operating the drum to start the sequence for automatic changeovers, if C.5 is not fully discharged, it will operate Relay K immediately the anode transfers and then C.5. would discharge through the gas-filled relay, thereby closing the master relay circuit on the incoming projector.

Looking now at Figures 4 and 5, it must be realised that the circuits shown in these Figures relate to one projector only. The Buzzer circuit and the dowser circuit being common to both projectors.

FIG. 4

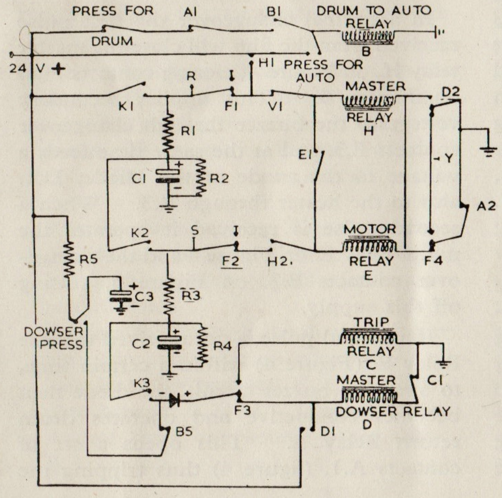


FIG.5

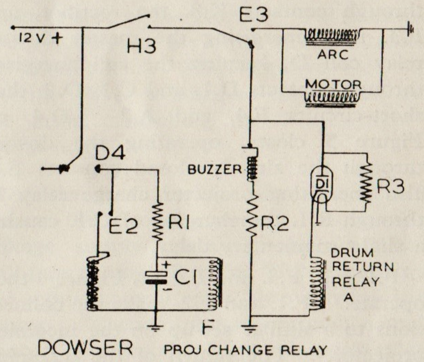


Figure 4 shows the primary relay circuitry for effecting automatic change-overs.

Figure 5 shows how the primary relays operate the secondary relays.

When control Relay K receives a pulse from the thyratron circuit as seen in Figure 3, it closes contacts K.1. K.2. and K.3. simultaneously. The 24 volt positive supply required to operate master relay H is then taken through K.1. F.1. and V.1.

Contacts H.1. and H.2. on Figure 4 close together with H.3. on Figure 5. The 12 volt supply is then taken through the now closed H.3. contacts, changeover contacts E.3 and limiting resistor R.2. The warning buzzer now sounds.

Relay H is maintained in the energised condition through H.1. V.1. F.4. and A.2. on Figure 4. The Condenser C.1. is then charged through R.1. On receipt of another pulse from the film, C.1. is discharged through contacts K.2. F.2. and the already closed H.2. to the primary coil of motor relay E. Contacts E.1, acting in an exactly similar manner keeping coil E. energised via H.1. V.1. F.4. and A.2.

Contacts E.3. on Figure 5 will change over, removing the supply from the buzzer on to the secondary relays controlling the motor and arc of the projector. Contacts E.2. also close, ready for the operation of the dowser. C.2. on Figure 4 then charges in conjunction with R.3. and again on receipt of another, C.2. will discharge through contacts K.3. the rectifier, and F.3. thus energising the master dowser relay coil D, keeping the coil energised through contacts D.1. and C.1. D.2. then short-circuits F.4. and A.2. D.4. on Figure 5 closes, operating the dowser through the already closed contacts E.2. also energising projector charge relay F. through R.1. the charging of C.1. causing a slight momentary delay.

F.1. F.2. F.3. and F.4. on Figure 4 then operate. F.1. and F.2. make the connections to a similar set-up on the incoming projector. The return of the incoming master and motor relays being taken to point Y on Figure 4. This completes the starting of one projector and the opening of the picture dowser, and it will now be explained how this is repeated on the opposite or incoming projector.

On receipt of a pulse from the outgoing projector, the master relay closes, sounding the warning buzzer. The second pulse closes the motor relay, operating the motor and arc on the incoming projector. The third pulse operates Relay C on Figure 4, this trips Relay D, changing contacts D.4. (figure 5) to open the dowser on the incoming machine, and closing the dowser on the outgoing machine, at the same time removing the energising voltage from the projector change Relay F. C.1. then discharges through Relay F. causing a lag in the change back again of F.1. F.2. F.3. and F.4. There are two reasons for this delay (a) the changeover contacts D.2. must open before the change of F.4. to trip the master and motor relays of the respective projectors. (b) to allow time for Condensers C.3. and C.2. to be fully discharged before the transfer of contacts F.3. to the energising position of relays C.

R.2. and R.4. are the usual Resistances to maintain Condensers C.1. and C.2. in a fully discharged condition.

This completes the sequence of automatic changeovers, and these will continue indefinitely for as many reels as are required to complete the feature.

At the end of the last reel it will be required to revert to drum control of the instrument. This is accomplished by the use of a Diode (D.1) in the following circuit on Figure 5.

In a normal changeover the first pulse received from the film will close the master relay H, on Figure 4, closing contacts H.3. on Figure 5. This applies secondary voltage to the buzzer through changeover contacts E.3. and at the same time feeds a voltage to the anode of the Diode, D.1. also to the heater through R.3. When a second pulse is received it operates the motor relay E. on Figure 4 and the changeover contacts E.3. on Figure 5, cutting off this supply.

If a second pulse is not received to close Relay E. (Figure 4) within a certain time, to open the buzzer circuit, the diode then becomes conductive and operates drum return Relay A. This opens a set of contacts A.1. (figure 4) thus tripping the drum-to-auto relay coil B . . . Co-incidentally with this A.2. opens, thus open-circuiting the master Relay H. (Figure 4) which in turn opens H.3. (Figure 5) cutting off the supply to the warning buzzer and diode, leaving the circuit open so that the next pulse received from the film will operate the drum.

Contacts H.2. on Figure 4 and E.2. on Figure 5 are inter-locking contacts to ensure that the secondary relays controlling the arc, motor and dowser, cannot be operated in the wrong order, for example, the motor must be running before the dowser can be opened. Therefore it is possible to energise the primary Relays C. and D. without operating the projector dowser.

When the instrument is switched on, all relays are in the position shown on the drawings ready to start one projector by injecting an impulse at " R " and " S," either manually or by the drum motor contacts. If it is required to start the opposite projector by the same method, that is, by injecting an impulse at " R " and " S," it is necessary to change D.4. on Figure 5, F.1., F.2., F.3., F.4. and D.2. on Figure 4. This can be done by discharging condenser C.3. into the master dowser relay D. D.1. holding the master dowser relay energised.

It will now be obvious that if the dowser alone is operated by any means independently, it will always stop the projector that is running and leave the primary relays set ready to start that same projector.

It follows that the automatic stop described in Figure 2 can be fed into this circuit so that if a film breaks it will stop the projector, and the primary relays will automatically be set to re-start, which is done manually by a press button.

R.5. is the charging Resistance for the dowser impulse Condenser C.3.
V.1. is the manually operated primary relay isolator.
Contact B.5. isolates the dowser circuit when on automatic changeovers.
The Rectifier between K.3. and F.3. is to prevent C.2. or C.3. obtaining a voltage from any source other than R.3. or R.5.

The manual button " press for auto " energises the drum-to-auto relay B. B.1. holding it energised. The " press-for-drum " de-energises the relay manually.

It may also be of interest if I give a brief description of the method used to couple the non-synchronous motor to the instrument.

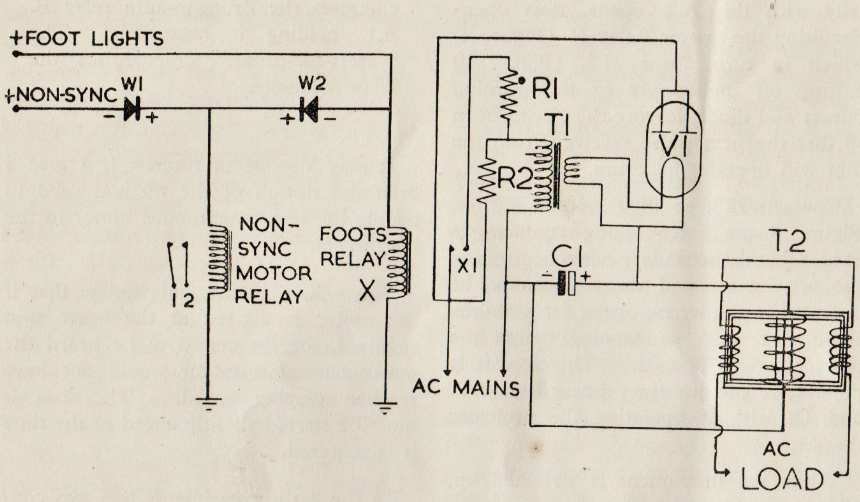
You will, of course, appreciate that if the motor is started at the exact spot required, for the sound to be heard the non-synchronous motor would not have reached playing speed. Therefore it must be started slightly ahead of the time it is required.

In the early experiments this was controlled by placing a peg in the drum, but since the introduction of wide-screen photography, necessitating the use of variable masking, the spare contact position on the drum which had hitherto been used, was now needed for controlling this masking. Without re-designing the whole instrument to provide extra contacts, which was not possible, owing to the limitation of size as already explained, the non-synchronous motor could no longer be started from a separate contact controlled by the drum. This was over-come by the circuit shown in Figure 6.

Contacts 1 and 2 are connected directly across the motor start switch. The negative side of the Rectifier W.2 is taken to the contact on the drum which controls the footlights. The negative side of Rectifier W.1. is taken to the contact on the drum controlling the " non-synch " sound relay.

As the footlights are always required before the non-synchronous sound, the voltage supply operating the footlights will pass through Rectifier W.2. energising the motor control relay, thus starting the motor. When the non-synchronous sound contact operates, this keeps the motor relay energised through Rectifier W.1. Therefore the blocking action of the Rectifiers restores independent action to two separate circuits.

FIG. 6



The footlights are controlled by a saturable re-actor as shown in Figure 6.

When the relay X is energised and contact X.1. closes, this feeds the live side of the A.C. mains into the valve heater transformer T.1. via the Thermistor R.1, the Thermistor acting as a variable resistance to control the rate of D.C. voltage feeding into the D.C. winding of the re-actor (T.2.) C.1. smoothing the A.C. ripple from the directly heated Rectifier. R.2. is to supply a small voltage to pre-heat the rectifier valve via the transformer T.1, and this will control the rate at which the D.C. voltage is removed from the control winding, when contacts X.1. open.

An exact replica of this circuit is also used to control the house-lighting, one or more re-actors being connected in parallel, depending on the lighting loads they have to control

There are some additional points which have not been described in detail . . .

(a) The arc is struck automatically by inserting a fusible pellet between the carbons.

(b) The arc may be started independently of the motor.

(c) All sequences can be controlled by one emergency push button should a fault develop in the valve or the film pick-off circuit while the projectors are running, so ensuring that the show remains uninterrupted.

(d) The drum is automatically isolated, so facilitating setting-up, when the instrument is set for automatic changeovers.

(e) In case of emergency the projectors can be stopped from either machine by means of press buttons, and if required to operate manually, they may be isolated from the instrument by a switch in place of contacts V.1. as previously described.

(f) The indicator lamps showing which of the circuits are in operation.

(g) Provision is made to control the footlights, either by a saturable re-actor or motorised control.

(h) The dowser is operated by a double wound solenoid, a heavy winding taking the initial surge, and a light winding to hold the shutter in the open position. This ensures that the shutters are fast operating.

(i) The sound from the film is operated by a relay, which is actuated by the same circuit used for the dowser.

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TECHNICAL INFORMATION
for Projectionists

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Hearing in the Cinema

by **J. Carson**
of Circuits Management Association Ltd.

THE cinema patron has gained a better appreciation of sound quality—largely due to listening to new radio receivers, television sound channels, V.H.F. radio receivers and long playing records which are now commonly obtainable. He hears them, usually, in fairly good " domestic acoustic conditions," which compare favourably with the acoustics of many cinemas.

Today, the public are " shopping " for their film entertainment. Cinemagoers are choosing the theatres which show the pictures they want to see, as against the " Cinemahabit." This includes the best in presentation, bright clear pictures on the screen, and sound which assures every patron of comfortable listening pleasure. The sound must at all times be intelligible, intimate, and a close approach to the original. It must be so closely related to the action and atmosphere, the artists and development of the plot, that the illusion is real and " the patron is in the picture." A film which achieves this gives the public what it wants. Good sound contributes substantially to the success of a good film. For it to do so the sound source must be capable of giving balanced response from 50 c.p.s. to 10,000 c.p.s. (or above), with freedom from distortion. All elements of the sound system must be the best possible, especially the loudspeaker assembly, it is the performance of the loudspeaker which can make the patron acutely aware of good sound. Apart from the broad frequency range it must reproduce faithfully, it must be capable of distributing sound without loss of tonal perfection to all seats in the auditorium—each person must enjoy " effortless listening " the sound should be " spoon fed " from the rear screen to each seat. Loudspeakers can these days be designed for use in any auditorium, be it a standard conventional theatre or one of the stadium type.

The public's goal is then—the cinema exhibitor's goal—this is one instance when we know what the public wants. The objective—from a quantitative and qualitative point of view—is the distribution of sound with proper tonal balance between all frequencies, so that the " intelligibility factor " is high—both for speech as well as music.

If engineering is still brought to bear and full use made of modern sound reproducer equipment available today, high quality reproduction from optical and magnetic recordings can be obtained.

Electro-Acoustics

The field of architectural acoustics as applied to the cinema, deals with the adjustment of auditoria to accept sound from a modern sound system, and if the " acoustical condition " is not corrected to meet exacting requirements then the final sound quality from good recorded film cannot be presented to the audience without introducing confusion in certain areas of the seating and destroying " good hearing."

Both the shape of the auditorium and the proper use of sound absorption material is necessary, also the loudness level of the direct sound should be such that it dominates the reflected or reverberant sound.

When considering shape the audience should be close to the loudspeaker, i.e., benefit from the direct sound. Fan-shaped auditoria enable this to be achieved, this shape has the added advantage of keeping troublesome long path reflections at a minimum and is acoustically superior to the rectangular shaped building, which can have all the acoustical vices. Even so, steps can be taken to introduce adequate sound absorption treatment. It is desirable in nearly all cinemas to control the reverberation time, i.e., the rate of decay of sound (see recommended optimum curve) and at the same time attain good tonal balance.

Reflections which have travelled over 60ft. longer than the initial direct sound, cause confused hearing, and in speech syllabic over-lap occurs and intelligibility is affected. Sound concentrations from curved walls and ceiling can cause echoes if the path exceeds 60 ft. A large variety of commercial absorbents are available in various forms, these consist of rock wool, fibre glass, asbestos and building board, and nearly all carry National Physical Laboratory absorption data certificates. A typical acoustic tile would have a co-efficient of absorption at 1,000 c.p.s. of about 75% (see typical absorption curve) and the application of tiles of this kind should not affect the aesthetic or decorated features of any auditoria. It is possible to arrive at a close approximation of the final hearing condition by dividing the total volume (in cubic feeet) by the total number of seats, and if this simple calculation shows a figure exceeding 130 cubic feet per seat—then acoustic treatment is needed to bring about optimum reverberation conditions.

When planning for good acoustics—it is always advisable to consider . . .

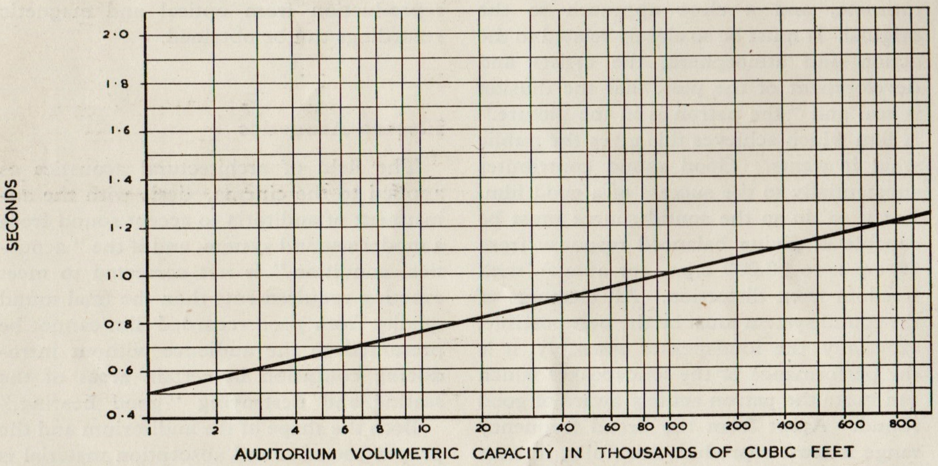
(*a*) Keeping the volumetric capacity as near 130 cu. ft. per seat as possible.

(*b*) Treating all curved wall areas, domes, curved ceilings and cove shapes with acoustic absorbent.

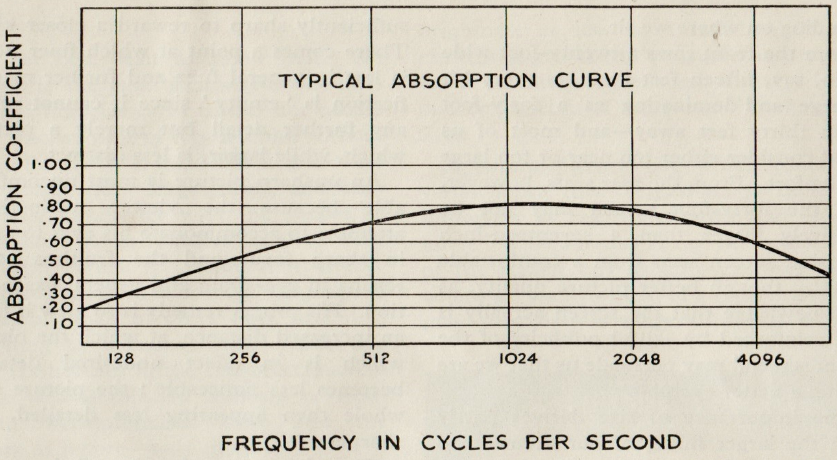
(*c*) Fixing absorption material to parallel side walls, which can cause sound flutter and confused hearing.

(*d*) Applying a high absorbent material to all rear walls to prevent long path reflections, which can destroy good hearing in the front stall seats.

An acoustical expert will provide an analysis showing the precise details with a full recommendation, which if followed out will give the condition required. The expert may suggest the introduction of absorption material to control the reverberant sound, and this would be necessary because the cinema theatre using amplified sound and presenting some 75% speech and 25% music subject matter generally requires a reverberation period lower than that for a concert hall used exclusively for musical entertainment.



A typical curve showing optimum reverberation times for various volumetric capacities (at 500 c.p.s.). The curve can be used for cinema auditoria using stereophonic sound reproducer equipment.

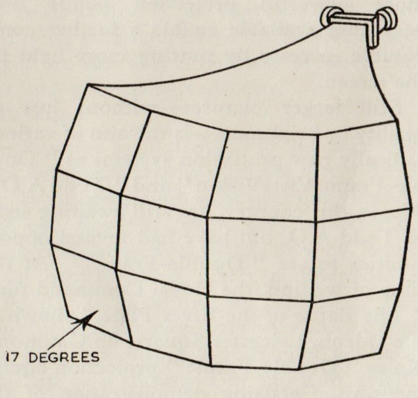


Curve data of various absorption materials will give a good indication of the co-efficient of absorption, and a material with an absorption closely resembling the typical curve shown here would be suitable for most situations.

Loudspeaker Assemblies

Speakers are built in two parts, one section reproduces the bass frequencies and the other the treble frequencies. Whilst both are important, it is the treble horn which provides those high frequencies so necessary for intelligibility, and this horn is designed in a cellular form to enable the high frequencies to be well distributed to all parts of the theatre seating. Each cell of the complete cellular mouth opening (see sketch) will provide a horizontal and vertical coverage of about 17 degrees, therefore horns can be built to any size to suit the dimensions of any auditorium.

The design of the bass section of the loudspeaker assembly is such that it will give satisfactory distribution of sound and the number of cone speakers employed in this section is determined by the seating capacity and volumetric capacity of the auditorium. Equipment manufacturers will always advise on the best speaker size and give the characteristics of their products. These enable the right assembly to be installed to meet all requirements.



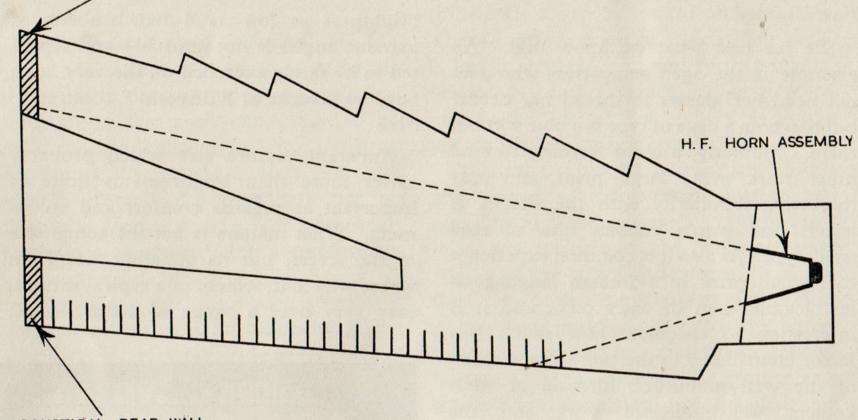
A 12 CELL H. F. HORN

The cellular H.F. Horn used with the bass section, can be supplied in sizes to suit the dimensions of any auditorium. Each cell will give a coverage of 17 degrees both vertically and horizontally and suitable horns fixed at the correct height will provide direct sound to all seats.

The Stage

Like the auditorium, the stage should receive close consideration when installing new loudspeakers, and its acoustical condition should be adjusted so that reverberation is kept at a low level and no stage echo effects are apparent.

Acoustic felt should be suspended at the rear of the loudspeakers (the full width of the stage) or alternatively, rock wool or fibre glass padding fixed and held in position by wire mesh on the rear wall. These absorbents will prevent reflections from the wall area and also reduce the stage time period.



Section shows H.F. Horn fixed at correct height to give direct sound distribution to rear stalls and rear balcony seating. In difficult theatres it is sometimes necessary to employ two H.F. Horns, one slung to feed the stalls seating and one positioned to feed the circle seating.

Two closely related variables now become evident :

(*a*) The response characteristic of the sound system as a whole.

(*b*) The acoustical condition of the auditorium.

If both are properly adjusted, vital, living sound with natural realism is achieved.

The cinema owner who intends to sell sound (and he *is* selling sound) will consider the performance of the installed reproducer set, and take the necessary steps to have it adjusted, modified or even replaced to conform to an agreed standard, such as that recommended by the Academy of Motion Picture Arts and Sciences.

From the sound track of the film to the final acoustics of the theatre, each element must accurately fit in place and play its part in creating a perfect high quality illusion. It remains however to " present the sound film " and by the judicious use of the volume/loudness control, some scenes can be emphasised, such as the roar of an earthquake, a battle scene or an explosion shot. Then again, the proper adjustment in loudness must be given to the exciting whisper. These sound cues should be listed and used for each presentation of the film programme. We know that in industrial areas the average cinema patron prefers fairly loud sound, but in the country districts the sound is usually maintained at a lower level. It is worth remembering that patrons in general appreciate less sound, but now demand better sound.

Good sound reproduction must be achieved, if the present-day critical audiences are to be satisfied, and the cinema is to continue to compete with growing competition from other sound entertainment sources.

Seeing in the Cinema

by **R. Robertson,** B.SC., M.I.MECH.E., M.B.K.S.
of Rank Precision Industries Ltd.

WE, the forty-five million British public, ' Went to the pictures ' more than a thousand million times last year. We went to see the picture, but the picture that we saw was seldom that actually shown us, but a much tidied up, embellished and generally improved version of it.

Our eyes are merely a link in a chain of complex physical and mental processes involved in the art of seeing. The visual impression of which we are conscious, an image constructed by our mind out of the data transmitted from our eyes, supplemented and edited in accordance with other knowledge and previous experiences.

Familiarity

We see best what we know best. An example is the aged sempstress who does not need her glasses to thread her needle but to whom a page of type is a blur without them. Similarly, a child learning to read must start with large print, and only increasing familiarity with the shapes of letters and words enables him to read small type. As also it is common experience that small print in a foreign language is less legible than in one's own, and it is interesting to speculate how much this factor contributes to the box-office success of the well-established formula of well-known, well-publicised stars and the mixture as before—only more so ?

A recognised thing tends to be ' seen ' as it is known or thought to be, regardless of how it is presented—unless the attention is deliberately directed to the presentation as such or this is disconcertingly novel.

This is especially true when the interest is so strongly held that emotions are aroused, as by a really exciting film, but irrespective of the quality of the film it is remarkable how readily and quickly we become oblivious to quite severe distortions when we pay our shillings to be entertained—distortions as ' keystone ' and bending arising from projection rake and screen curvature and fore-shortening arising from obliquity of view—as also how readily we adapt ourselves to the wide range in picture size and brightness between the best and poorest served seats.

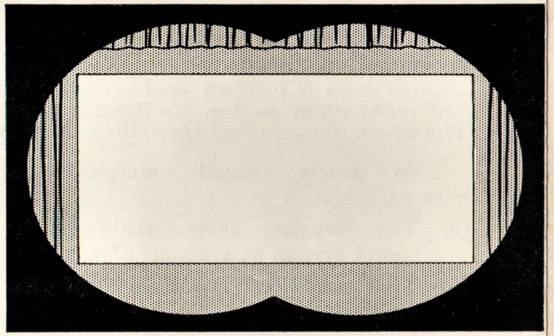
Brilliance

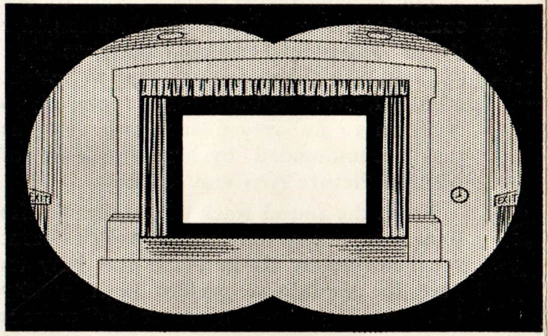
Brightness is unchanged by distance but does vary quite widely with the direction at which a modern high gain screen is viewed. The eye, however, while very sensitive to brightness differences within its view, is not at all critical when direct comparison is avoided. In reading, for example, the brightness of the page may vary from a few foot-lamberts only in a quite good artificial light up to a thousand or more in bright sunlight, and we are quite unappreciative of the magnitude of the brightness.

Attainable brightness of the cinema screen corresponds to that of a page seen in good artificial light. The B.S.I. recommend that the brightness of the centre of the screen, as seen from any seat, should lie between 8 and 16 foot-lamberts, but brightness as low as 4 foot-lamberts at extreme angles is not unusual—and reported to be rarely exceeded on the very large outdoor screens of " drive-in " theatres.

Size

Apparent picture size which probably varies more than brightness is quite as important as regards comfort and enjoyment. What matters is not the actual size of the screen but its apparent size from where we see it, which, in a typical theatre, may vary over a range of about 4-to-1, depending on where we sit.





Although the normal field of view of the human eye covers 180° by 120° we are not really aware of everything that occurs within these arcs. The upper picture shows what appears to be an ideal screen size within the field of view of the human eye, but this is a fantastic size and would not give good results for there comes a point of enlargement when detail is lost in ' fuzz.' The lower illustration shows a typical cinema screen as seen by the human eye. This is about the optimum size. The shaded portion is visible to the eye and anything of interest occurring or moving within this will attract attention away from the screen.

From the front rows a twenty-foot wide screen, say, fifteen feet away, is every bit as large and dominating as a forty-foot screen thirty feet away—and most of us would consider either too near or too large for comfort. From the rear seats, however, even the forty-foot screen may not be effectively larger than a seventeen-inch television screen seen from a comfortable distance, though better picture quality, as also knowledge that the screen actually is vast, reinforced by skilful publicity of the ' giant screen,' may persuade us that we are getting a better eyeful.

The importance of size derives partly from the larger filling of our accustomed visual field of view and partly from the greater wealth of detail which we can more readily distinguish.

This normal field of view encompasses roughly 180° horizontally by 120° vertically. We are only sharply aware of a very small region of this at a time, but remain sufficiently aware of what is visible in the rest for anything of interest to attract our attention and in normal seeing are continually shifting our attention, moving our eyes and head, to scan the scene before us.

The large area of our attention occupied by a large appearing screen involves correspondingly large scanning movement which contributes to enhanced feelings of reality, as also the more the eye is filled the less the likelihood of distraction by extraneous matters.

Contrast the same scene as seen in the ratio of magnification which obtains between the front and rear seats of a typical cinema. The greater wealth of detail evident in the enlarged view not only assists in holding attention by providing more for the eye to wander over, but, like the device of the " close-up", increases satisfaction by giving the viewer " bigger eyeful of what he wants to see more of."

Detail

This supposes that there is detail of interest in the projected picture which is sufficiently sharp to reward a closer view. There comes a point at which finer detail is lost in general fuzz and further magnification is ' empty ' since it cannot reveal any further detail but merely a picture which, while larger, is less distinct.

An unsharp picture is most uncomfortable because the viewer instinctively attempts to accommodate his eyes to see it in sharp focus and the fruitless effort results in eye-strain and general exasperation. His proper remedy is to view it from an increased distance, at which the blur—which is in effect undesired detail—becomes less noticeable ; the picture as a whole then appearing less detailed, but sharper.

Thus increasing the size of the screen may not bring any advantage to the front rows of seats, which can be—and probably already are—too close for comfort. It does, however, bring a better picture to the many more patrons behind, and it is the present experience of the industry that to do so is " good business."

The current trend of development in the cinema is all towards larger and still larger pictures. The white matt screen is, today, out-dated by the more effective directional screen since its preferential reflection towards the customers enables doubling the picture area without loss of brilliance, while more powerful projection lamps now becoming available enable a further comparable increase by putting more light on the screen.

Still larger pictures—without loss of quality or brightness—is the aim of various radically new projection systems as " Double-Frame VistaVision " and " Todd A.O." We, in this country, are still awaiting sight of Todd A.O. but have had several opportunities to see " Double-Frame." At the time of writing, the Royal Command film, " The Battle of the River Plate," shown at the Odeon, Leicester Square, on Gaumont-Kalee " Double-Frame " projection equipment, is a striking demonstration of the possibilities opened up by such systems.

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TECHNICAL INFORMATION
for Projectionists

Published by **G.B-KALEE LTD.** **No. 19**

Some Considerations on Siting a Cinema On Board a Passenger Ship

by **F. Evans,** A.M.I.E.E.
Superintendant Electrical Engineer, Canadian Pacific Steamship Co.

WHEN planning a cinema on board a ship the following considerations have to be borne in mind :— the number of potential cinema-goers is fundamentally 100% of the passenger complement. The shape, size and position of the cinema is governed by other architectural features.

The following describes the basic approach to the building of a vessel, and in particular of a cinema of the new Canadian Pacific vessels, s.s. " Empress of England " and s.s. " Empress of Britain " (passenger liners).

First of all the anticipated traffic on the route under consideration is estimated — and this estimate, to be of any real value must cover the next 25 years. From the known present volume of passenger traffic, trends in industrial developments in both terminal countries, immigration schemes etc., it is possible to assess the flow of passenger traffic. Having arrived at the estimated passenger traffic over the ensuing 25 years, one has to decide what degree of comfort these passengers will expect to travel in and what facilities they will expect.

The first move is made by the Catering Department, who suggest that cabin accommodation for First Class passengers be so many sq. feet of cabin accommodation and for Second Class passengers, be so many sq. feet of cabin accommodation. From this information the minimum superficial area of cabin accommodation is arrived at. Now in order to get the passengers to and from their cabins, corridor space must be provided, also staircases and perhaps elevators. The superficial areas for cabin accommodation can now be assessed.

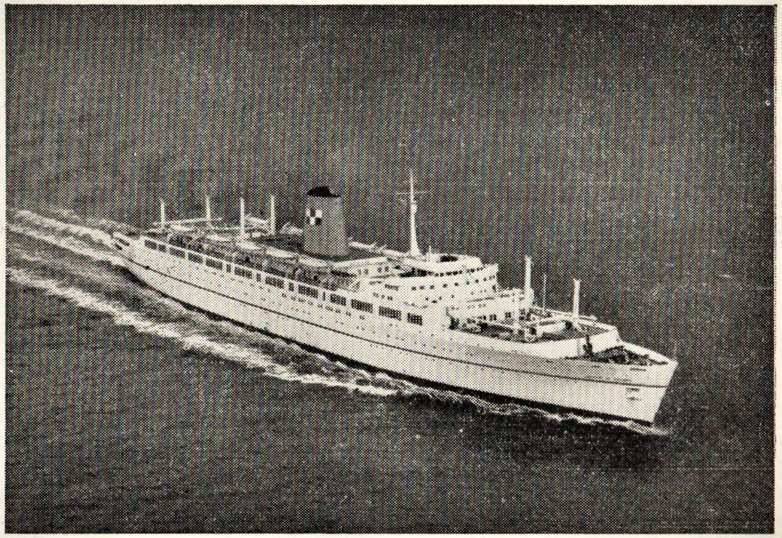
The next point dealt with is the menus, for this determines the extent of machinery required in the Kitchens.

Thereafter consideration is given to public room facilities.

In a one-class vessel the lay-out of public rooms is straight-forward, but in a two class ship it is the usual practice to attempt to completely segregate the classes.

Having established the foregoing, the number of Stewards, Stewardesses, Cooks, Bar-Keepers, etc., can be determined and their accommodation requirements can be assessed. In this connection it is interesting to note that no minimum requirements for passengers have ever been established internationally, but in the case of crew they have to be provided with certain standards of space, ventilation, illumination etc., as laid down by Rule.

So far we have the broad requirements of the vessel from the passenger side and



assumptions can be made concerning the numbers of personnel required in the deck and engine departments.

A basis General Arrangement drawing of the proposed vessel can now be produced which will show the overall length, breadth, loaded draught, disposition of accommodation etc., also tentative areas for propelling machinery.

Most vessels have to navigate rivers, pass through locks etc., and it may now be found that the provisional overall length is such that the vessel could not pass up a river on account of the vessel length, *i.e.* the radius of bends in rivers limits the length of the vessel. Certain sacrifices must now be made in order to reduce the length of the vessel, and perhaps in order to achieve this reduction, the designer considers increasing the breadth of the ship (beam) or the loaded draught. By increasing the beam it may be possible that the ship could not enter the dry docks at the terminal ports and therefore she would have to go off her normal route to dry dock (which is a disadvantage), and by increasing the draught she may not be able to navigate certain rivers, enter dry docks etc.

In the early stages of the design it will have been decided that the terminal ports will be so and so and the economic speed between these points will be a given value.

A wax model of the proposed vessel is now made, and this is towed in a tank at varying speeds and the power requirements are obtained.

It may now be found that due to hull form, etc. propulsive efficiency is down and the required horse-power exceeds the anticipated horse-power, thereby possibly requiring more than the allotted space for propulsion machinery. The designer now has to endeavour to improve the propulsive angle or, alternatively, make provision of the required extra space.

CINEMA ROOM

Now the foregoing briefly describes the general design approach and in a measure this matter of compromise has to be followed in the layout of public rooms.

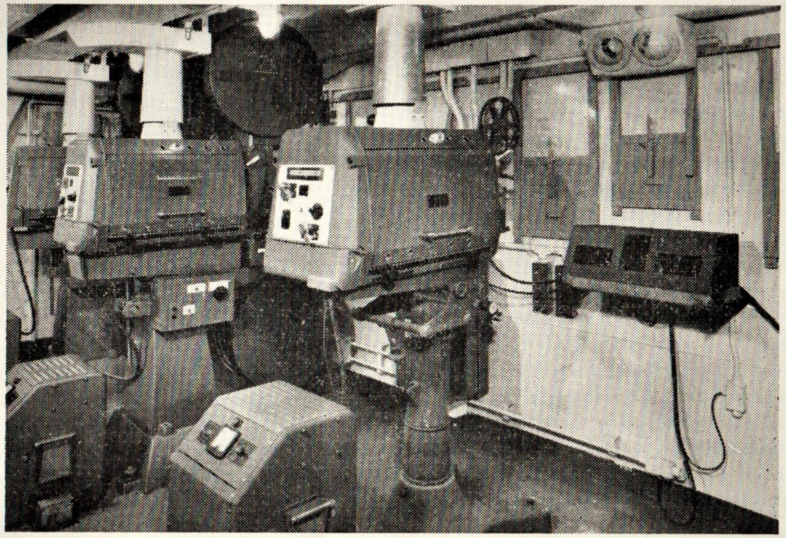
In laying out a cinema room the following considerations must be dealt with :-

1. The total number of passengers must be able to see each picture show.
2. The cinema room should be easily accessible to both classes of passengers without either having to pass through the accommodation of the other class.
3. The cinema room must be as free from motion as possible.
4. Good viewing and sound must be provided from all parts of the hall.

On a large passenger vessel it is uneconomic to provide a cinema room capable of seating all passengers at the same show and it is often necessary to run four shows per day in order to cope with the demand. It must be understood that the space occupied by public rooms is not earning capacity in the strict sense of the word. The real earning capacity is the space allotted to each passenger and normally one could regard the provision of public rooms as loss of potential earnings, insofar that, were these spaces used for cabin accommodation, more passengers could be carried. On the other hand, on many routes, passenger rates are controlled by international agreement, and it is by giving special attention to public room facilities that shipping companies hope to attract business, and today a cinema room is almost a " must."

The passenger numbers being known, and assuming that a given number of performances will be given each day, the seating capacity can be obtained. The designer now prepares a basis drawing of the ideal layout of seating accommodation, projection booth, stage screen etc. and in effect moves this around on the basis general arrangement to see if it can be accommodated between the various hatch trunks, elevator shafts, boiler room and engine room hatches etc. It may be found necessary to alter the shape of the ideal design or maybe resite the obstructions quoted, although this is unlikely.

Thereafter it is necessary to ensure sufficient height between the deck and deckhead to provide adequate slope to the deck. This in turn may introduce certain complications insofar as any change in the deck to deckhead dimension on any one deck may tend to weaken the structure at the change in height. To compensate for



Photographs by permission of Canadian Pacific Steamship Co.

this weakening effect it is necessary to introduce additional strength members, such as deep beams at that position. The introduction of such beams has the effect of partially off-setting the increase in height and so once again the final design must be a matter of compromise.

At this point in the development the location and shape of the cinema room has been established, and all that remains is for the various services such as ventilation, lighting, sound circuits etc., to be planned and in fact these usually fall into place like the last pieces of a jig-saw puzzle.

The foregoing gives an indication of the compromise that must be accepted in the design of one room only on a ship, and this principle of compromise is followed through from the inception of the vessel to its completion.

CINEMATOGRAPH EQUIPMENT

We can now turn to the actual equipment installed for the cinema on the "Empress of Britain" and the "Empress of England."

For the presentation of 35mm films the well-known Gaumont-Kalee '20' projection and sound equipment was selected. These are fitted with 5000 ft. spool boxes and mechanical interlock for stereoscopic films. For this purpose a composite starter and change-over box was installed to allow the projectors to be coupled or used independently for normal projection. The optical soundheads are Gaumont-Kalee type 83, with the enlarged projected image optical system. Amplification is by Gaumont-Kalee '18' dual channel amplifier, the sound output being fed to the theatre type loudspeaker backstage. The illuminant is a "Universal" 12″ mirror arc lamp using High Intensity trim of 30 amperes. These are supplied from individual Gaumont-Kalee type 609 rectifiers for each projector. One G.B-Bell & Howell model 609 arc projector is installed for the presentation of 16mm films. This arc lamp also uses 30 amperes trim and is fed from its own rectifier. As the colour grading in 16 mm release prints is adjusted for Tungsten Lighting (2,750 K), colour correction of the arc lighting is by Wratten type 85 filters. The screen is a specular reflective type of CinemaScope proportions, complete with motorised variable automatic masking for three aspect ratios with a maximum size of 17′ 2″ x 7′ 4″. The motorised curtain control and system of stage and screen decorative colour lighting can be controlled from the projection room. The reproducer equipment is periodically inspected and serviced at Liverpool or Montreal.

ELECTRIC POWER SUPPLY

Regarding electric power supply, there are two main systems available, *i.e.* D.C. or A.C. and here again an economic study should normally be made for every ship installation. In general it can be stated that for tankers and diesel propelled vessels which have little deck machinery A.C. shows an advantage, but for all other types of craft D.C. best meets all requirements.

Whatever type of power is generated this provides the main lighting installation, but in order to comply with M.O.T. Rules on ship construction, it is necessary to install a considerable number of emergency lights throughout the vessel, and these are supplied from the mains, also from a secondary battery, which works on the mains failure principle, *i.e.* should the main power fail, the battery supply is automatically brought in.

The foregoing is a brief outline of few of the many factors which must be borne in mind, and very carefully considered during the design of the vessel. By reason of improvements in design of all equipment the ship owners endeavour to keep abreast of all developments, and the tendency over the last decade has been for ship owners to build up a much bigger technical staff than was the case twenty years ago.

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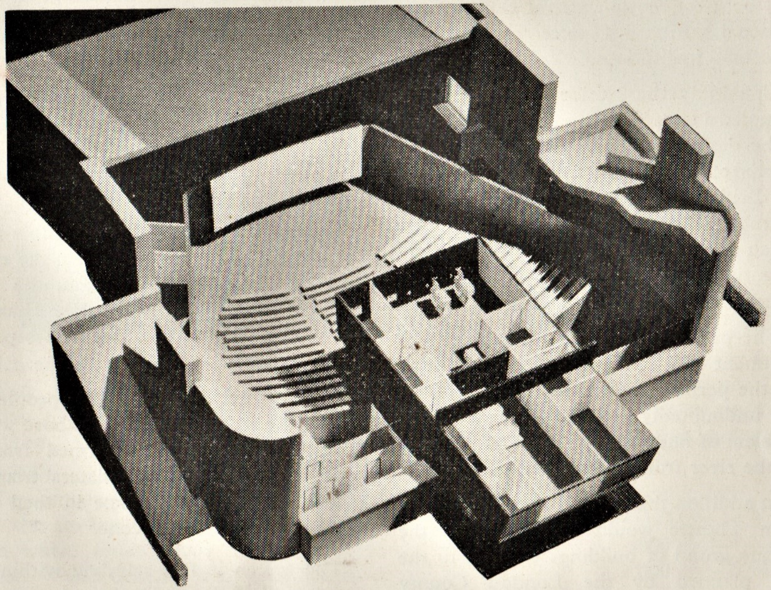
TECHNICAL INFORMATION
for Projectionists

Published by **G.B-KALEE LTD.** **No. 20**



The NATIONAL FILM THEATRE

A Problem in Design

by **Norman Engleback** A.R.I.B.A.
London County Council Architects' Department
R. F. Scott, MANAGER,
Planning & Design Dept., G.B-KALEE LTD.

IT is two years since the first meeting of Frank Hazell of the British Film Institute, Norman Engleback of the London County Council, and R. F. Scott of G.B-Kalee Ltd., when Mr. Hazell outlined the project to build a National Film Theatre.

The mandate was simple : a theatre to embrace the whole of cinema engineering and to provide for the foreseeable future—in short, a challenge and the first real opportunity to design a pure cinema without the encumbrance of ' stilted ' tradition.

The site selected was the vaults of the southern end of Waterloo Bridge—this gave rise to many planning limitations, all of which have been effectively overcome by the architect.

Solution to a Space Problem

by **Norman Engleback** A.R.I.B.A.

This article from the 'Kinematograph Weekly' is reprinted by kind permission of the Editor.

IN spite of pessimists' forecasts in 1951 that no one would cross the Thames from the accepted North Bank to hear a concert or visit a cinema, it is now quite clear, from the past six years' experience, that both the Royal Festival Hall and the National Film Theatre are highly successful institutions.

Unhappily the National Film Theatre occupied a temporary building which is due to be demolished to make way for commercial offices, and the problem confronting the British Film Institute was to find an alternative building on the South Bank which would be ready in time to ensure a continuous patronage from their 30,000 members.

The proposal to use the Southern arch abutment of Waterloo Bridge as a housing for the permanent National Film Theatre was undoubtedly a clever solution to the problem of finding a site at a nominal cost on the river front of the South Bank.

In addition the site of the new National Film Theatre would be related to the unique group of buildings devoted to the arts planned by the London County Council architect's department to occupy the river front between London County Hall and Waterloo Bridge. It will share the advantages of the growing patronage of such a centre with its accessibility from all parts of London.

The planning approach has been conditioned by a number of factors created by the use of an existing vault, the largest factor being the limitation of height caused by the cantilevered bridge members and the access limitation by the surrounding structure.

The position of the screen and the projection box was thus predetermined. The entrance beneath the projection box is from the Thames side of the vault.

This offers two clear advantages. In the first place it will be possible to use the bridge as a shelter from the weather. Secondly, the problem of conditioning the audience to the dark auditorium is helped by the relatively dark area underneath the bridge. This has been exploited again in overcoming the lack of conventional publicity space by the proposal to " back project " publicity on to a screen above the entrance.

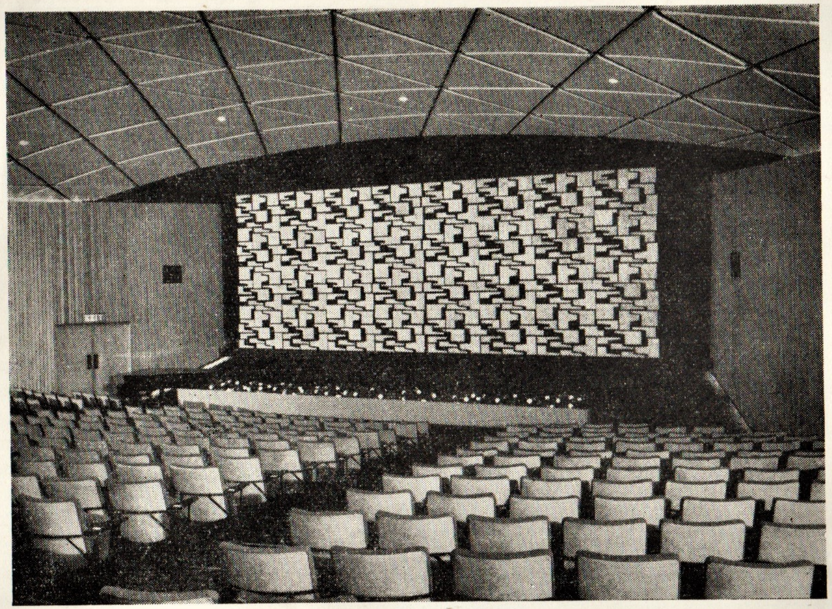
The elements of the design fall naturally into place. The entrance foyer is directly below the projection suite and small theatre. The auditorium is on one floor sloping down from the foyer level, the staff accommodation is directly accessible from the left and the club room from the right. The heating, which is by gas, the ventilation, and the electrical intake chamber are sited behind the screen with separate external access.

The auditorium, for 504 people, is defined by a continuous wall, above which is suspended a canopy formed from a series of fibrous plaster equilateral triangles following the general shape in total of a segment of a truncated cone.

The screen is free-standing within the screen wall of the auditorium, but outside the canopy. The projection box is visible from the auditorium between the flanks of an opening in the canopy. The seating is concentric following the limiting angles of wide-screen projection. The viewing distance has been kept within narrow limits, 24 ft. at the front row to 64 ft. at the rear row.

The universal screen permits a series of film ratios and is protected by a decorative metallic screen which masks unwanted areas when the widest ratio is not in use. This screen consists of a series of gilded abstract shapes assembled on vertical rods and it divides and travels horizontally in opposite directions stopping at predetermined positions.

Decoration of the auditorium is subdued in tone. The wall is of natural obeche timber ; the carpet is of a special non-



directional design developed by the London County Council furniture and display section in collaboration with the project architect. Colours used are greens, black and grey.

The canopy is painted light green-grey, and the seating upholstery is also green. The whole visual focus is towards the screen. When closed it is a highly illuminated gilded pattern of plates, When open for projection the simplicity of finish in the auditorium becomes unobtrusive and restful.

A number of tests were made by the Building Research Station and the architect, within the Bridge vault, to assess the level of transmitted noise through the structure of the bridge. This was found to be negligible ; in fact, conditions in the empty vault were greatly superior to those in the existing " Telekinema."

Thus the acoustic problem is simply confined to the desirable characteristics of the auditorium itself. The volume of the auditorium has been determined by the position of the canopy, which will be lined on its upper surface with absorbent material as an extra safeguard against the possibility of transmitted noise.

The auditorium wall is treated with 3 in. timber strips which have been modified at certain points to permit absorption over 20 per cent. of its area. The carpeted floor and the canopy of reflecting hard plaster give the following figures :—

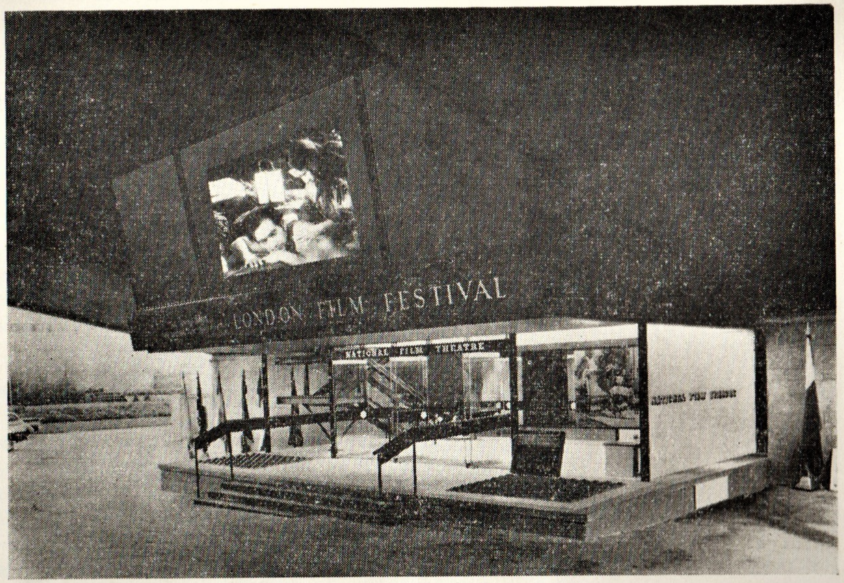
Volume per seat—150 cubic feet.
Reverberation times—125 cps—1.3 sec.
500 cps—1.0 sec.
2,000 cps—0.94 sec.

The foyer has been designed as a connecting circulation area between all the other elements of the design. The staff and the manager are immediately adjoining the foyer on one side, and the club room and bar are similarly sited on the other side.

Within the foyer itself there is an advance booking desk, which will also serve as an information desk. The box office is a dual unit equipped on one side with an Automaticket machine and on the other side with a discreet display of confectionery.

The auditorium is screened by two lobbies, into which retractable seats are fitted for the cinema attendants. A spiral staircase connects the foyer with the small theatre and projection suite.

The foyer lighting and finish have been devised to provide the maximum brilliance at the entrance, where the passer-by will



view the cinema foyer through extensive glass screens.

A white marble floor and an illuminated ceiling contribute to this effect. This element provides the total elevation to be seen from outside. Beyond the inner doors of the foyer the lighting and colour are reduced, in fact there is a progressive reduction of light in order to accustom patrons to the auditorium conditions.

The small theatre and projection suite make use of a two-way projection system to feed both the auditorium and the small theatre and, alternative to the latter, an external screen by back projection within the projection box. Four 35-mm. projectors and two 16-mm. projectors have been installed with subsidiary equipment. Adjacent to the projection box the commentator's booth, sound insulated, contains the non-synchronous sound apparatus.

Television projection by the conventional method will be possible by the limited throw of 50 feet to the auditorium screen.

The small theatre will seat up to 20 persons and is intended for editing and compiling programmes by the Institute without the use of the large auditorium. This theatre will obviously have other uses for lecture courses.

Staff accommodation has been unified in plan for ease of control by the manager, who has the advantage of a direct view from his office into the auditorium. This has been achieved by a tinted glass window and blind. In addition he has been provided with a changing room entered from his office.

The club room occupies the whole of the area to the right of the auditorium. It falls into three sections, two of which share bar facilities.

Nearest the foyer there is an area for associate members of the Institute. Here it will be possible to drink coffee and to view exhibits in a showcase. The bar is divided into two sections to be served by one steward. On the associate members' side coffee and sandwiches will be served. On the members' side it will be possible to enjoy fuller drinking facilities.

Adjacent to the members' bar there is a conference room which can be used in conjunction with the bar or isolated for meetings, or as a reception area for visiting cinema personalities who can from this room reach an apron stage in the auditorium.

Technical Considerations and Planning

by **R. F. Scott.**

The first stage was to determine the relative areas, Main Auditorium, small preview theatre, projection suite, offices, club rooms and general service areas.

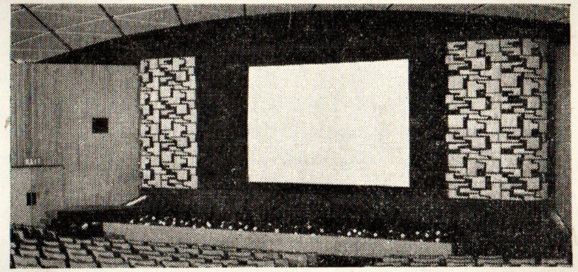
Each requirement was decided by straightforward reasoning and practical common sense rather than safety first copy methods of pseudo Functionalism, which seem to be fashionable today.

IN deciding the shape for the Main Auditorium, simple geometry provided the answers. Due to the height of the screen being dictated by the underside of the bridge and a sharply inclined floor under the screen, the possible height of the picture was 12 ft. 6 in., the width of the widest ratio therefore was CinemaScope at 32 ft. 6 in. From experience gained during recent years the best viewing distance from a screen of these dimensions is between two and five times the height, thus making the front row at 24 ft. and the rear row 64 ft. The extreme sides of the seating area were determined at the maximum angle from the screen surface taken from the widest picture commensurate with good vision. This angle is 115°. The resulting seating capacity is 500 seats. To provide uninterrupted viewing the floor of the auditorium was formed by excavation to give a 1 in 8 slope on curved steppings, covered with a specially designed carpet.

The screen has to provide for all known film systems, including any system still in the process of development, with the result that no less than 10 ratios were required. In addition, to provide for future development and give the greatest flexibility it was decided to place the screen inside the auditorium. This will no doubt be the subject of some controversy but I have long thought that a proscenium is alien to good cinema.

A space frame of tubular construction standing on four 3 in. diameter tubes was designed to suspend the Harkness stereo screen, which has a wide diffusive surface, and which incorporates the now well-known electrically operated magnascopic masking for varying the width of the picture, the height being common for all ratios, thereby giving an inter ratio balance.

In order to present the programme and to provide a feature to the auditorium, the architect designed a panel of abstract shapes which was made into a two leafed shutter as part of the screen space frame. This shutter parts in the centre and transports on special tracks to the rear of the screen during film presentation. In detail the shutter consists of no less than 342 separate panels of 9-mm. ply each surfaced with plastic paint treated to give a broken stucco effect, with a gilt finish. The panels are separately hinged and suspended on steel rods.



Decorative shutter and masking opened for 1.33:1 *normal, silent picture presentation*

The entire framework and picture format is covered with a suit of tailored black masking. This latter will be another talking point, I am sure. Experiments have produced no evidence that there is any better colour for surrounding the picture, and until the industry decides on one aspect ratio it will be impossible to eliminate masking altogether.

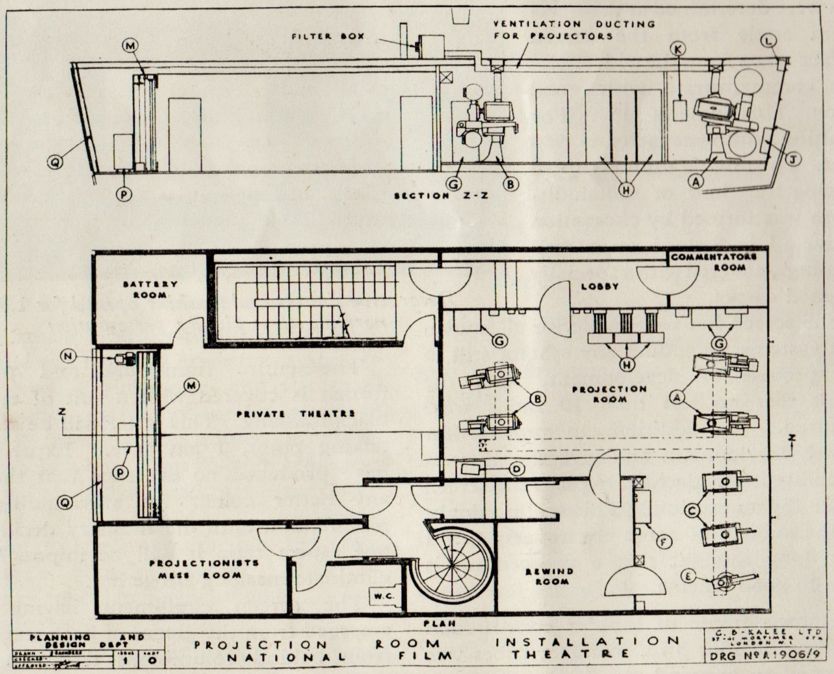
The screen equipment having now emerged from the gloom of back stage and from behind voluminous draperies, and having so to speak "Come of age," we have in keeping with other 'scopes' and 'isions' given it a name. The Gaumont-Kalee "Monovistal."

As the auditorium will be used for lecture purposes a sectional staging has been supplied consisting of 15 sections on lightweight tubular beams which are supported in floor sockets over the sloping floor in front of the screen. A sectional box along the front houses lighting and microphone wiring. This staging can be erected or dismantled in a very short time.

The small preview theatre, seating 25 people, is situated over the entrance and is unique in providing not only all the screening facilities of the large auditorium (10 ratios), but in addition a rear projection screen to the front of the theatre. This could not have been done were it not for the fact that the building is beneath Waterloo Bridge, so that even on the brightest day the plate glass facia is in shadow. This will be of immense value for advertising purposes.

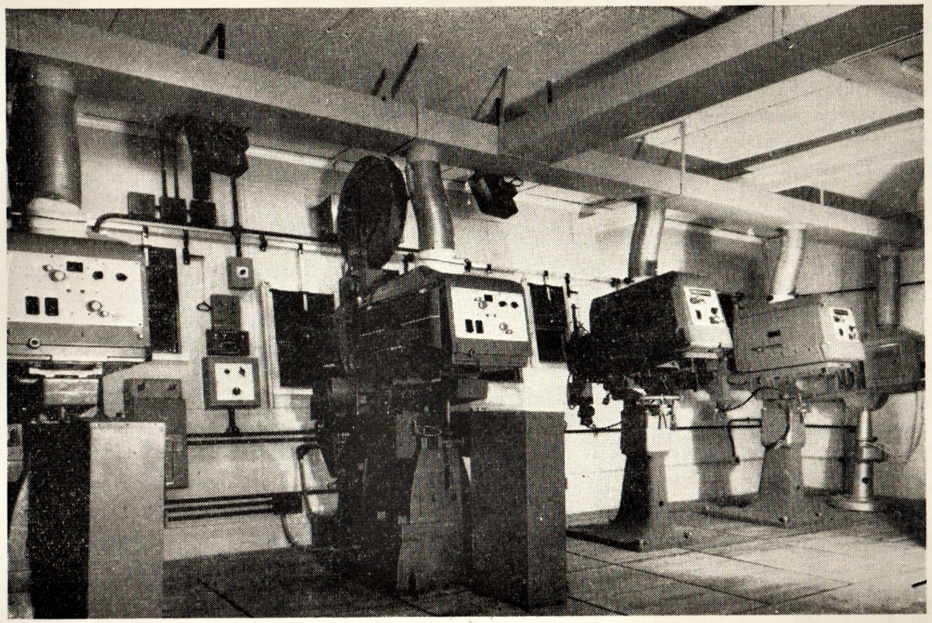
This facility gave rise to many problems —in order to project onto the special Harkness rear projection screen, the normal screen had to be removable. This was overcome by designing a special tubular steel open-type frame with side electrically-operated magnascopic masking. This has a Harkness pull-up roller screen operated by winch gear, with black plastic masking incorporated on the screen at the top and bottom. This framework also carries an orthodox velour curtain and dress legs.

The projection room is situated between the two theatres and serves both but with completely separate installations. Serving the main theatre are two Gaumont-Kalee " 20 " 35mm. projectors, which will run at 16 and 20 frames per second for silent films, and 24 frames per second for sound films. They have series ' S ' lenses and Varamorph variable anamorphic lens for all ratios (see table). The sound system is Gaumont-Kalee " 21 " dual 30W optical

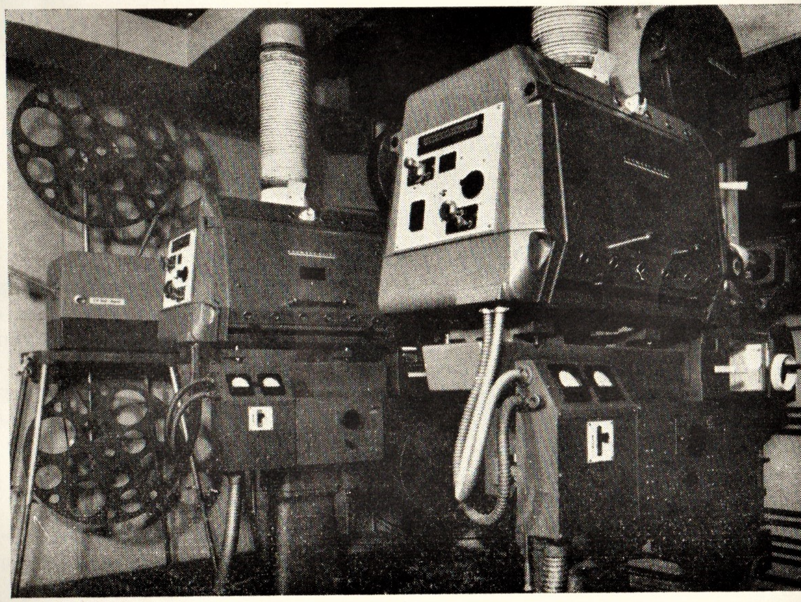


KEY

A Gaumont-Kalee ' 20 ' 35mm. Projectors
B Gaumont-Kalee ' 18 ' 35mm. Projectors
C G.B-Bell & Howell model ' 609 ' 16mm. Projectors
D G.B-Bell & Howell model ' 630 ' 16mm. Projectors
E Slide Lantern
F Gaumont-Kalee Non-sync. record player
G Rectifiers
H Amplifier Racks
J Voltage Amplifier
K Effects Control Unit
L Magnetic Pre-amplifier
M Roll-up Screen and Curtain Frame
N Electric Curtain Controller
P Type 717 Loudspeaker
Q Rear Projection Screen



reproducer equipment with the addition of a four-track magnetic stereophonic system, with 10 auditorium effects speakers and three main speakers behind the screen. Provision has been made for future installations of multi-magnetic/optical track follower heads and interlocks. The arc lamps are Gaumont-Kalee 'Presidents'. The projectors are interlocked for projecting three-dimensional films and unmarried prints, and allowance has been made for future developments in new film presenta-



tions as far as is possible.

At the side of the 35mm. machines are two G.B.-Bell & Howell Model '609' arc 16mm. projectors equipped to run at sound and silent speeds and either optical or magnetic track sound reproduction.

The preview theatre is served by two Gaumont-Kalee "18" 35mm. projectors and Dual 18 watt sound film reproducer with Universal arcs; one machine is equipped for rear projection. To provide 16mm. projection facilities, a single G.B.-Bell & Howell Model 630 equipment specially adapted for long running with both optical and magnetic sound systems and recording facilities on magnetic track is installed.

In determining the position of the projection room, the length of throw and angle to the main screen was the main consideration in order to allow lenses of the most advantageous focal length. It is possible that some form of television projection may be required in the future.

The angle of projection is slightly positive so that there is no distortion of the projected picture.

In a short feature it is impossible to deal in detail with all facets of this unique project. We must wait and see whether the National Film Theatre will create a new tradition in design, it will, I am certain, form a basis for realistic thought and not a little argument. However, from a technical point of view it will certainly fulfil all the many requirements laid down by the British Film Institute.

November, 1957.

Projection Table Data

Main Theatre

35-mm.

1.33:1 Silent 16 frames per second
1.33:1 Silent 20 ,, ,, ,,
1.38:1 Sound 24 ,, ,, ,,
1.66:1 ,, ,, Wide Screen
1.75:1 ,, ,, Metroscope
1.85:1 ,, ,, VistaVision
*1.75:1 ,, ,, VistaVision
*2.00:1 ,, ,, R. K. O. Scope
*2.35:1 ,, ,, CinemaScope
*2.55:1 ,, ,, CinemaScope
* *Anamorphic*

Three-Dimensional Projection
Unmarried Prints

35-mm. Sound System
Optical track
Magoptical.
Four-Track Magnetic Stereophonic
Single double or treble magnetic tracks to CinemaScope Track positions.

Main Theatre—Contd.

16-mm.

1.34:1 Silent 16 frames per second.
1.34:1 Sound 24 ,, ,, ,,
*2.68:1 ,, ,, ,, ,, ,,
* *Anamorphic*

16-mm. Sound System
Optical Track
Half Stripe/Magnetic Optical Tracks
Full Stripe Magnetic Track
Edge Stripe Magnetic Track

Preview Theatre

35-mm. as for main theatre plus rear projection at 1.38:1 on one projector without stereophonic sound.
16-mm. as for main theatre plus recording facilities for all magnetic tracks.

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TECHNICAL INFORMATION
for Projectionists

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Film Damage from Faulty Equipment*

Eastman has Suggestions For Projectionists to Aid In Reducing Bad Prints

by James P. Cunningham, *Equipment Editor*

GOOD PROJECTION is entirely dependent on the skill of the projectionist and the condition of the film and the projector. Satisfactory screen reproduction is not possible with a bad print regardless of how efficient the projectionist might be. Likewise, good results with a perfect print cannot be expected from faulty projection equipment. Through constant use, projector parts become worn and out of adjustment. The replacement of worn or damaged parts when needed represents a wise investment because any expenditure in this direction will improve projection and materially reduce unnecessary film damage.

While the maintenance of the projection equipment is the responsibility of the theatre, the projectionist can do many things, which will aid in eliminating print damage. There are, for example, various projector parts which may sometimes seem unimportant but which demand frequent attention on the part of the projectionist. Film damage may occur at any one of them and may often be avoided if adjustments are made at the proper time and if damaged or worn parts are discovered and replaced promptly.

Suggestions Follow Long Study

The foregoing observations certainly are not new. In this instance they are the previously stated basic conclusions of plant and field engineers of Eastman Kodak and are presently presented for timely consideration by both exhibitor and projectionist in view of the increasing complaints against damaged prints.

Film damage may be caused in a variety of ways and in any one of the various places where film is handled, from laboratory to exchange, to theatre, by failure to provide adequate storage facilities, improper laboratory methods, inadequate inspection in the exchanges, careless handling in the projection room and worn or imperfectly adjusted projectors. In the interest of reducing unwarranted film damage, Eastman Kodak continues to pursue a long-time program of first hand field inspection of film handling and projection practices, in the backrooms of exchanges and in the booths of theatres.

Information, suggestions and recommendations for reducing unwarranted film damage, based on the results of numerous field investigations and observations related to various types of print damage, are made available by Kodak to laboratories, exchanges and theatres. The following resume covers that part of Eastman's report on "Common Causes of Damage to 35 mm. Release Prints" which must be given careful attention by the projectionist if the maximum wearing qualities are to be obtained from film (other sections of the published report deal specifically with the laboratory and the exchange):

Magazine Valve Rollers

It should be remembered that severe abrasion is often the only reason for discarding a print. It is probable that more film is scratched in the magazine valve rollers than at any other part of the projector. This is especially true for those rollers in the upper assembly, the first point of contact with the film after it leaves the feed roll. At this point, dirt,

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oily matter and film chips may accumulate so as to prevent free turning of the rollers or they may become so clogged that one or more of the rollers may not turn at all. The roller tracking may also develop flat spots and wear down to the point where the center of a non-turning roller is in direct contact with the film. Under these conditions, the relatively soft emulsion of a new print is very susceptible to abrasion and the scraping is frequently so deep that the emulsion is completely plowed off. Support-side scratches show up as dark lines on the screen and might be equally disturbing, particularly when they become filled with oil and dirt. With duplitized film (certain types of colour prints), there are two emulsions which are affected. Most projectionists are familiar with the objectionable red and green "rain", or deeper scratching on some of the duplitized films.

Straight scratches and those that weave slightly in a repeating pattern due to uneven reel flanges moving the film from side to side, can be caused by the valve rollers, although the perfectly straight abrasions are more often associated with some guided position.

Padding of Trap Doors

Occasionally release prints are encountered which give a slight flutter in the gate or trap. This gives a slight in-and-out-of-focus effect on the screen. In an effort to control this flutter, some projectionists fasten strips of pressboard, velvet, or layers of tape between the tension pads, both above and below the aperture, thereby discouraging any forward motion of the film. This practice cannot be recommended because it can cause serious support-side abrasion, particularly in the case of films having a higher positive curl than usual. Increased curl is a common condition with newer prints during dry Winter months.

Abrasion Due to Curl

In the case of prints having higher positive curl there is always a possibility of support side abrasion at some other point which is normally not contacted by flat film. Attention has already been drawn to the importance of making sure that the valve rollers turn freely. Another place at which contact may occur is at the intermittent guide holder. On some projectors the centre clearance at the intermittent guide holder is not great enough for films with high positive curl. Some projectionists have filed this centre section to increase the clearance, This is a satisfactory solution to the problem if it is very carefully done and the surface is polished to satin smoothness after filing. If any file marks remain, however, there is the chance that these can cause even more severe damage than that caused by the holder in its original condition.

Another method which has been used successfully by a number of projectionists but which is possible only on certain makes of projectors, is to raise the lower loop slightly by threading *over* the first pad roller and *under* the second roller as usual. When this is done, it may be necessary to readjust the rollers in such a way that there is sufficient clearance at the second roller for two thicknesses of film. This alternate threading procedure permits the film to flow onto the sprocket from the intermittent loop more easily and with less plopping of the loop than is the case when the film is threaded in the conventional manner.

Signalling Devices

Signalling devices contained in the film supply magazine which employ a small ball or roller, which rides on the emulsion side of the film, should be checked frequently for binding or wear. Such devices in poor operating condition could prove harmful, particularly on a new print when the emulsion is most susceptible to damage.

New Print Sticking

While a new print is assumed to be ready for projection, the projectionist might encounter sticking on first runs due to insufficient lubrication of the print. This is commonly referred to as "green print" trouble. In order that the projectionist may be better advised, it might be well to explain why this sticking occurs, how it affects the film and what steps can be taken to relieve the trouble.

One of the usual ingredients of the emulsion of motion picture film is gelatin—a substance which is hygroscopic and readily gives up or absobs moisture to reach equilibrium with the prevailing atmosphere. The gelatin in freshly developed emulsion retains a considerable amount of moisture and is readily affected by heat which makes it soft and tacky. The first point at which new film comes in contact with high temperature is at the aperture of the projector. Here the light is concentrated and produces heat to a degree which softens the gelatin and causes it to collect on the tracks or shoes at either side of the aperture or at a point slightly above or below this level. Here it rapidly dries to a bone-like hardness. As the new film is projected, this hard deposit continues to accumulate and offers further resistance, which may result in deep rub lines, usually along the line of perforations or in the area between the row of perforations and the edge of the film. As this resistance increases, there is the added danger of the teeth of the intermittent sprocket seriously damaging the perforations, sometimes to such an extent that the print is beyond repair.

When print sticking occurs, prompt action is necessary. Some projectionists apply oil in generous amounts to eliminate the trouble. This is effective but it is unnecessary and undesirable. Such application covers the picture area of the film where no oil is needed and seriously impairs the quality of the protected image. A very small amount of oil on the thumb and finger, applied at intervals to the perforation area (alternating from one side to the other), before the film enters the trap or gate is all that is needed to work the film through. At the end of the run, the tracks can be cleaned to remove any remaining hardened deposit. This should be done with a damp cloth or if necessary, a copper coin—never with a hard metal such as a screw driver, knife or razor blade. A scraper fashioned from a toothbrush handle, is a handy implement for this purpose. It must be remembered that deposits will form more readily once the highly polished metal surfaces are scratched.

Guide Rollers

The guide rollers located above the gate or trap serve as a guide for the film as it passes down past the aperture to the intermittent sprocket. If these rollers are out of line with the sprocket, the teeth will engage the film perforations off centre, and the sides of the perforations may often become broken. Also, if the rollers do not turn freely, they will eventually develop ridges which may roughen the edges of the film, particularly if the film is old and brittle. These ridges, if deep enough, may even loosen the corners of poor splices. The guide roller assembly should be inspected frequently and, if necessary, removed for thorough cleaning. The guide roller tension springs should be checked occasionally to see that they have not become so weak that proper tension is not maintained. Weak springs might allow sidewise unsteadiness, particularly with a fluttering oversize loop.

Sprocket Pad Rollers

Sprocket pad rollers or idlers are frequently set too close to the sprocket so that they ride the film and often cause marking and creasing. If they bind on the shaft, rubbing will occur at the side of the picture or possibly into the sound track area, particularly in the case of new prints. Such rub marks in the sound track area can seriously impair the sound reproduction quality. They generally cause frying noises and any picked-off spots which occur at intervals will result in "motorboating', although it is also true that the latter effect might often be caused by a printing defect. If roller spacing is too great, the film may also jump the sprocket, especially at a stiff splice. The generally accepted setting is at the point where the idler can still turn freely with two layers of standard thickness film on the sprocket. To insure free turning, the rollers should be removed occasionally so that the shaft can be cleaned of any gummy deposit, then lubricated slightly. On reassembling and resetting, it is important to make certain that there is no binding between the roller and sprocket teeth. It is also advisable to check the lock nut on the adjusting screw periodically.

Proper Method of Making A Tension Test Is Described In Eastman's Film Guide

Trap or Gate Tension

One of the principal sources of film damage is excessive tension exerted on the film by the springs in the gate or trap. Some projectionists judge the tension by merely pressing on the pads, checking one side, then the other. As far as is known, there seems to be no generally accepted standard setting for any given projector. The results of tests made in the Kodak Research Laboratories on various projectors and over a long period of time, indicate that complete, equalized trap tension in excess of 16 ounces is unnecessary and only increases the wear on the film, while settings as low as six ounces appear, in some instances, to be sufficient to give a steady screen image. It would seem from these tests that the tension should fall somewhere within the range from six to 16 ounces.

The proper pressure will, of course, depend upon the projector used, the length of time it has been in service, and the type of surface treatment the film has received. The projectionist does not usually know what the tension might be for his projector, since he is not ordinarily faced with the necessity of checking it when the equipment is in a smooth-running condition. He should, however, be familiar with the method of measurement.

Tension Testing

To determine the total trap tension, a full width piece of reasonably new film of standard thickness and free from oil is placed in the trap or gate of the projector. The test should be made on a *cold* projector to insure uniformity. Care should be taken to see that the perforations are not engaged by the intermittent sprocket teeth and that the film is held properly in place by the tension shoe before proceeding. Using a small, graduated spring balance, which has been fastened to the film, an upward pull should be exerted slowly until the film just starts to move. If the film appears to stick at the start it should be moved slightly and the operations should be repeated. If the tension is found to be above 16 ounces, the tension should be reduced so that it falls within the range from six to 16 ounces, preferably near the lower end of the range. The projector should then be checked for steadiness of the screen image.

Tension Adjustment

Tension adjustment on the newer type projectors has been greatly simplified. Centralized pressure exerted on the pads by cone-shaped springs has eliminated practically all of the difficulties previously experienced with double-pronged finger-type springs. Vertical unsteadiness may often be traced to an accumulation of dirt at the base of the intermittent sprocket teeth, rather than to low trap tension. Bands on new prints from the exchange usually carry a sticker, noting that it is a new print or that the tension should be reduced, but in the case of many older type projectors still in use, this means that the double-pronged springs would have to be removed and bent by hand. These springs would have to be bent back again for use with older film. Since they were never intended to stand such repeated bending, it is advisable to adjust them to give the minimum tension which will give good steadiness with older prints.

Tension on Upper Shaft

Proper adjustment of the spring tension on the feed spindle is important. If set too loosely, the film may come from the feed roll with a jerky motion. This is especially noticeable when the roll is loosely wound or if a bent reel is used, and is particularly bad for film in a noticeably worn or dried out condition. If the tension is too tight, the pull on the last forty or fifty feet might be sufficient to cause serious perforation breakage, more so if a small-hubbed reel is used. It is not at all uncommon to lose the upper loop or for the film to break under this strain.

Intermittent Film Guide

Considerable sprocket and film damage, may be attributed to improper setting of the intermittent film guide or shoe, the intended purpose of which is to hold the film snugly against the sprocket. The older type of guide holder used can easily become sprung if excessive upward pressure is applied in attempting to remove a snug-fitting trap door from the older type holder. When replacing such a door or plate, care should be taken to see that it is seated properly, otherwise the sprocket may be badly damaged. A loose-fitting holder should also be repaired, since this might allow the sprocket teeth to strike the inside walls of the guide due to the slightest side motion. It has been common practice to deliberately bend the older type guide holder by hand, either to insure better contact of the film with the sprocket, or to eliminate the "clicking" due to cantact with the teeth. Improved design and construction and the two-stud trap door locking arrangement on newer projector models has greatly reduced the possibility of trouble from this source.

Some projectionists prefer to use a light guide spring, since they claim it is easier on the film and allows stiff splices to pass with less effort. Others insist that heavier pressure at this point gives a steadier picture, even though the trap tension might be lower than usual. Instances have been noted where two of the newer conetype springs were nested together and used as a single spring in order to obtain heavier pressure against the film at the sprocket. It is obvious, however, that if the pressure at this point is unnecessarily high, the film wear will be greater and the sprocket may become rimmed in a short time.

Bad Sprockets

Through carelessness and neglect, intermittent sprockets are frequently kept in service until they develop pronounced cuts or are otherwise so badly worn as to cause serious perforation damages. This is particularly true, if the trap tension is excessive or if poor guiding allows the bad teeth to strike the perforations noticeably off centre. Although present day sprockets are hardened in order to give longer service, the teeth are often so badly damaged that small pieces of film are torn from the pull-down edges of the perforations. Even the smaller cuts in worn sprockets result in noisy operation, since they prevent the film from leaving the sprocket freely. Noisy operation and serious film damage are even more liable to occur when an excessively large lower loop is used.

Sprocket teeth which have knife-like edges resulting from contact with the inside walls of the metal guide, cause the small straight cuts parallel to the edge of the film, extending downward from the pull-down edges of the perforations and well in from the corners. These small cuts quickly develop into more serious damage which can soon result in complete breakdown.

Film Loops

Excessively large loops not only result in noisy operation and in some instances sidewise unsteadiness, but may also allow the emulsion side of the film to rub against metal surfaces. The sound synchronization is also affected by an oversize intermittent loop. On the other hand, the loop must be large enough to prevent the possibility of binding.

Pleating

Projectionists will recognize the type of damage, as that resulting from folding of the film in the sound head due to a break at this point. It is often erroneously referred to as "buckle" by the exchange people.

Take-up Tension

The take-up adjustment should be checked from time to time to avoid unnecessary damage to the hold-back edges of the perforations. Excessive pulling at the hold-back sprocket can be detected by a pronounced "singing" sound and might be caused either by oil on the friction disc or by improper spring adjustment, particularly on older type equipment. If the tension is too great, as is often the case when adjustments are made to avoid the possibility of loose winding at the end of a large roll, serious damage to the hold-back edges of the perforations in the first part of the roll may occur.

The hold-back sprocket should be checked occasionally for any signs of premature wear. If such wear is found, the take-up tension should be examined and re-adjusted to minimum setting for correct winding.

Automatic Rewinds

Automatic rewinds should be checked for proper alignment. If the flanged and tracked control roller is cocked slightly either vertically or horizontally, undue strain will result on one edge of the film, particularly if the tension is excessive and if there is binding against a bad reel flange.

Hand winding, however, seldom gives the smoothly wound roll obtained by motor winding unless the film is correctly guided to the reel. Film edges which protrude from the reel after poor winding usually break off in small or large sections when the roll is forced into the case, or during shipment.

Cue Marks

A considerable portion of the film mutilation which admittedly occurs in the projection room is due to the various types and sizes of cue marks at the ends of rolls. In many cases, these are so carelessly done that large portions of the picture area are affected. Two, three or more sets of marks are not uncommon and they consist of punch marks, lacquer bands, large cross lines and scratches of every description.

As stated before, considerable loss of footage is caused by the end of the film whipping around on the rewind or projector take-up before the roll can be stopped. This makes it necessary to place new cue marks on the film, but it is not necessary to have an elaborate assortment of marks. Many projectionists cover at least some of the unwanted marks with narrow strips of adhesive tape, but these strips must be checked for tightness as they have been known to peel off and become lodged in the magazine valve rollers. On the other hand, when unwanted cue marks are removed, shortening of the end section results and this encourages placement of additional markings on the film later on.

Sprocket Tooth "Roping"

Sprocket tooth dents, often identified as "roping" or "run-offs" by exchange inspectors, is also a consistent cause of film mutilation. These marks are commonly seen between the perforations and are also often found through the track and picture areas in a weaving pattern. A "runoff" may start at a bad splice if the film jumps the sprocket, but it can also result from improper threading. Often the film becomes so weakened that subsequent edge bending causes the edge to break. The space between the rollers and the sprockets should be checked, and it is important to see that both rows of perforations are properly engaged with the sprocket teeth before clamping down the rollers.

Edge Bending or Creasing

Projectionists are familiar with film bending through the perforations, or more often between the perforations and one edge. This type of damage, which is usually referred to as "idler cramping", can be especially harmful in the case of film which is somewhat brittle and when the bending is against the emulsion side, since long edge sections may be broken off completely. This particular type of mutilation has been known to occur repeatedly at the first pad roller following the intermittent loop. The trouble usually starts at an edge break or at a loosened corner of a splice. It might also result from careless threading. If no attention is given to this trouble, this bending may continue to the stiffened area of the following splice before the film properly reseats itself.

Projection for Increased Screen Brightness

In recent years much interest has been shown in the problem of obtaining higher screen illumination, particularly for use in drive-in theatres and for indoor theatres using very large screens. Increased illumination has been made possible by developments in high speed optical systems and new types of carbon arcs. With the increase in the screen illumination, there has been a corresponding increase in the temperature of the film at the aperture. The film performance places a limitation on the maximum light available for screen illumination, since as the film is heated to higher temperatures a point is reached beyond which satisfactory projection becomes difficult.

One of the first effects noted in the film as projection intensity is increased is an embossing of the frames and of the image within each frame. When examined by reflected light, at an angle nearly coincident with the plane of the film, each frame can be seen to stand out like a small cushion and frequently the image itself appears as though it were carved into a small plaque. Most film, after having been projected shows some embossing and the extent of this embossing increases with the light source intensity. This embossing, however, even when severe, does not impair the screen image quality, although when embossed film is spliced to unembossed film it may be necessary to refocus slightly at the splice.

As the light source intensity is increased still further, the film may, in many cases, show a discoloration of the image. This discolouration is not noticeable when the picture is projected upon the screen but when the film itself is examined against a piece of white paper, the frame areas show a distinct sepia tint. No real danger to the print exists, however, as a consequence of this effect, since it is still capable of giving a top quality screen image.

However, if the intensity is increased still further, an in-and-out-of-focus effect may be produced on the screen and the film may even become blistered from the intense heat. The in-and-out-of-focus effect usually begins during the second or third projection under conditions where the intensity is excessive. When this effect occurs, the focus shifts, so rapidly from frame to frame that it becomes impossible for the projectionist to keep the picture on the screen sharply focused at all times. At these dangerously high intensities it is possible to blister the print so severely that it is no longer usable. At the early stages of blistering small bubbles occur between the emulsion and the base of the film and these areas have a dirty, grainy appearance. At later stages the bubbles break through the emulsion surface and appear as white spots with burnt edges. Blisters can be detected by examining the film by reflected light, at an angle close to the plane of the film, in which case they appear as tiny bubbles in the emulsion surface. More severe blisters can be seen from the base side of the film and have a whitish appearance. Heavy blistering can be seen from any angle. Blistered prints cannot be repaired or restored in any manner for further use in projection.

Limits of Increased Light

Several methods have recently been proposed for extending the safe limit for increased screen illumination. One method utilizes heat absorbing glass between the arc and the film. This filters out some of the infra-red portion of the arc spectrum, since this only increases the temperature of the film and does not contribute to higher screen illumination. Many theatres employing higher amperages use a blower system for directing a current of air to the surface of the heat absorbing glass in order to keep the glass itself at a lower temperature. Air cooling has also been applied directly to the film in the aperture by means of high velocity air jets. These jets actually cool the film and permit it to perform satisfactorily in a hotter beam than could normally be tolerated. For the projector itself, water cooling has in some instances been applied to the gate in order to reduce the temperature of the metal in contact with the film and to make projector threading more convenient.

When maximum light output is desired from projection equipment, it is necessary to make certain that all optical elements of the projector are clean and adjusted properly and that the lamp is operating at its highest efficiency. The arc current should never be increased arbitrarily without first ascertaining by test whether such procedure is liable to cause film damage.

TECHNICAL INFORMATION
for Projectionists

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Loudspeaker Characteristics and Sound Quality

by **Robert A. Mitchell.**

THE loudspeaker is the voice of the screen—a " voice " that must successfully mimic all other voices, speak with the eloquence of every musical instrument, thunder with the deafening roar of a train, and whisper as gently as a half-heard summer breeze. The theatre loudspeaker must be capable of reproducing in a natural manner the extensive sound spectrum included between 50 or 60 cycles and 8,000 or 10,000 cycles. If the speaker is inadequate to its exacting task, the illusion created by the projected pictures is largely lost.

To use scientific terminology, a loudspeaker may be described as an electro-mechanical " transducer " of sound energy supplied in the form of alternating electric currents. And it is the *mechanical* aspect of a speaker that warrants special attention. The function of a speaker, like that of a motor, is to transform electrical energy into mechanical energy.

SPEAKER QUALITY

The sound-system amplifier (an all-electronic device) supplies a tremendously amplified " signal " which is a practically perfect electrical replica of the weak sound signal generated in the soundhead. When the speakers behind the screen *mechanically transform* the fluctuating sound currents into the varying air pressures of audible sound, however, the complex wave-forms of the signal may undergo alterations and emerge as distorted sound. Because distortion, particularly if minor and persistent, is usually created by the loudspeakers and their associated baffles and horns, the quality of the speakers, used in a theatre very often means the difference between good sound and bad sound.

It isn't hard to understand the terrific stress and strain under which loudspeakers operate. The metal or paper diaphragm is required to move in and out like a piston as rapidly as 10,000 times each second for the highest treble tone and as slowly as 50 times each second for the lowest bass tone. When reproducing several bass and treble tones simultaneously, complex amplitude combinations often demand nearly *instantaneous* changes of diaphragm position.

No actual diaphragm can follow instantaneous changes in the sound signal. A speaker diaphragm, like any other object having an appreciable mass (weight) possesses *inertia*, or resistance to movement. At its worst, the inertia of a diaphragm distorts and weakens the higher sound frequencies and creates false sum-

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and-difference frequencies. The latter effect is called "intermodulation;" and because the spurious frequencies may bear no harmonic relationship to the frequencies which generate them, intermodulation sounds very bad.

When functioning at its most efficient best, a speaker diaphragm often experiences mechanical stresses 10 times more severe than those undergone by an aircraft coming out of a high-speed dive!

COMMON ACOUSTIC DEFICIENCIES

The mass of a speaker diaphragm also introduces *resonance*, another serious mechanical defect. Any material body has a certain natural frequency at which it vibrates most readily; and speaker diaphragms are no exception. Resonance causes some frequencies to be over-amplified and others to be weakened or suppressed. A "peaky" response results in nonlinear, or frequency, distortion, and is produced not only by the diaphragm of a loudspeaker but also by the resonance characteristics of associated horns, baffles, and bass-reflex cabinets.

Resonance in the range of audible frequencies adds to the reproduced sound

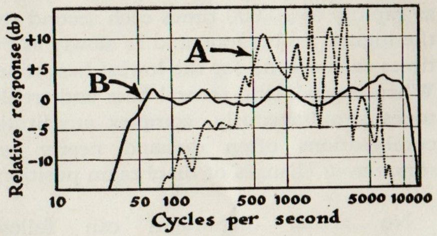

FIG. 1. The frequency-response characteristics of two theatre loudspeaker systems. *A* is the response curve of an early "restricted-range" speaker having an excessively "peaky" response. *B* shows the relatively level response to be expected of a modern high-fidelity speaker installation.

a false quality which may be variously described as "hollow," "boomy," "wooden," "metallic," "harsh," etc. It is at a minimum in speakers having the flattest "response curves" (Fig. 1.)

It is important to bear in mind that the amount of distortion produced by a loudspeaker bears no relationship whatever to its acoustic efficiency, or ability to transform sound current into sound waves. Some of the horn-type speakers used in the early days of sound pictures had an extremely high efficiency, but nevertheless produced sound so distorted that it would be unacceptable today.

And the smaller and less efficient "dynamic" cone-type speakers employed in good radios and home "hi-fi" equipment possess a more uniform frequency response with less acoustic intermodulation and harmonic distortion than many high-efficiency speakers used in expensive theatre sound systems.

It is much more difficult to obtain truly high-fidelity sound reproduction with large theatre sound systems than with small, and relatively inefficient, home units. Accordingly, theatre sound systems of the highest quality are necessarily many times more expensive than small, simple units capable of equally good reproduction in the home.

EVOLUTION OF THE LOUDSPEAKER

The evolution of the modern loudspeaker from the crude metal-diaphragm, fixed-coil telephone receiver is easily traced. The basic principle of Alexander Graham Bell's primitive receiver of 1876 is utilized even in the most modern speakers for high-fidelity reproduction. The fluctuating magnetic field produced by sound currents in a "Voice coil" interacts with a magnetic field of constant strength to cause an iron diaphragm to vibrate in step with the sound-current variations and thus generate sound waves in the air. Every commercial speaker except the condenser and crystal types (neither of which is much used in the theatre) operates on this electromagnetic principle.

The first loudspeaker was the simple telephone, or headphone, receiver fitted with a megaphone-type horn to reinforce the sound waves. Even though this crude loudspeaker did much to popularize commercial radio broadcasts (which previously could be heard only through earphones), its limited frequency range and "peaky," distorted response instigated the development of better speakers for more natural sound reproduction.

The weakly squawking horn of the early 1920's was soon displaced by cone-type speakers, often ridiculously large for their low power, driven *via* mechanical "armatures"; and these were superseded in the middle 20's by metal-diaphragm and paper-cone *dynamic* speakers of the type used today.

DYNAMIC SPEAKERS THE STANDARD

Dynamic speakers are distinguished by their use of *moving* voice coils attached directly to the diaphragm. The voice coil was formerly wound around the legs of the field magnet, and hence remained in a fixed position. This construction wasted a large part of the sound power in a magnetic "short circuit"; and the vibrating iron diaphragm was only weakly impelled by the varying magnetic field. Dynamic speakers are much more efficient.

In the metal-diaphragm dynamic speaker, still used for main-range and high-frequency reproduction, the voice coil is

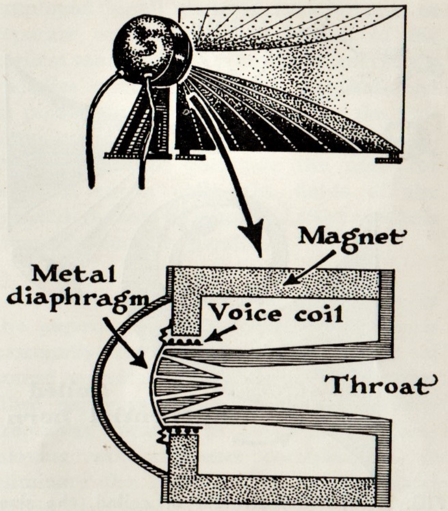

FIG. 2. A modern metal-diaphragm "receiver." When attached to a trumpet-shaped exponential horn, this receiver forms the high-frequency unit of a modern speaker system.

wound near the edge of a cup-shaped metal diaphragm free to move in and out in the manner of a piston (Fig. 2). Before the use of "woofer" (low-frequency) and "tweeter" (high-frequency) combinations, this type of speaker was often used alone (e.g., the old Western Electric 555 receiver attached to a large exponential horn). Sound reproduction by such a speaker is noticeably deficient in the lower frequencies, hence sounds "thin" and "tinny."

All metal-diaphragm dynamic speakers consist of a "receiver unit" and a horn of special design. The horn is necessary to "load" the small vibrating diaphragm so that the acoustic power is effectively transferred to the air, and thence to the ears of the audience. The size of the horn determines the lowest frequency which the unit can reproduce, and the shape and rigidity of the horn have an important bearing on the quality—the naturalness—of the sound.

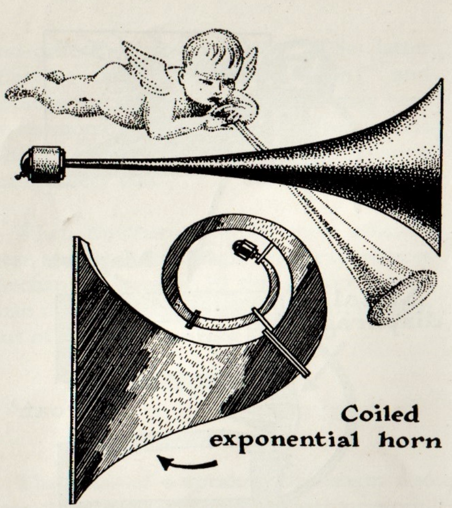

FIG. 3. Whether straight or coiled, the size of an exponential horn at any point along its length is mathematically related to the distance from that point to the small end. The exponential horn makes the metal-diaphragm dynamic speaker the most efficient type of loudspeaker.

Both old-style and modern metal-diaphragm speaker horns flare out gradually from the receiver end to the mouth in conformity to an exponential formula which relates the diameter of the horn at any point to the distance between that point and the small end (Fig. 3.)

The exponential horns used with modern " tweeter " (HF) units are ordinarily constructed in the form of several small horns placed closely together to insure a distribution of high-frequency sound corresponding to the wide diffusion characteristics of the " woofer " (LF) unit.

CONE-TYPE DYNAMIC SPEAKERS

Dynamic speakers having paper-cone-diaphragms are used for reproducing the entire sound spectrum in small sound systems (phonographs and radio and television sets), and for low-frequency reproduction in the larger systems employed for theatre sound (Fig. 4).

The voice coil of this type of speaker consists of a small coil of fine copper wire or aluminium ribbon wound upon a cylindrical tube made of a light, but rigid and warp-proof, material. This tube is mounted in a circular air-gap in the field of a strong magnet, and is centered by a " spider " of corrugated, springy metal or plastic. The voice coil is thus free to vibrate in and out like a piston in step with the fluctuations of the audio current flowing through its windings.

To transform the vibratory movements of the voice-coil assembly into pressure waves of audible sound, a paper cone held at its outer rim by a corrugated or flexible leather border is firmly attached at its center to the voice-coil tube. All movements of the voice coil are thus transferred to the paper cone.

ELECTROMAGNETIC AND PM UNITS

The strong magnetic field against which the varying field of the voice coil operates was formerly supplied by a large electromagnet energized by an external source of steady direct current. With the discovery of alnico and similar magnetic alloys, the old-style field electromagnets have been replaced by more compact permanent magnets (" PM " speakers) which provide a constant magnetic field of considerable strength without the need of DC " field current."

Modern speakers, therefore, have only two terminals—the voice-coil terminals—whereas older speakers have four, two for the voice coil and two for the field. The

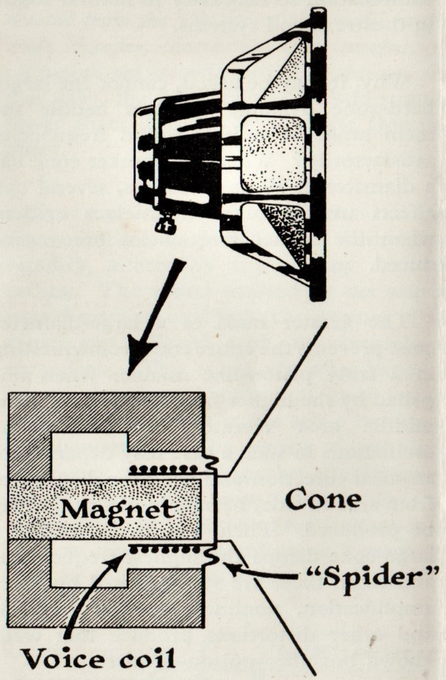

FIG. 4. A cone-type dynamic speaker. This type of speaker, employed only for low-frequency sound reproduction when large in diameter, must be used in conjunction with a baffle-board, bass-reflex cabinet, or folded horn to provide "acoustic loading" for the efficient transfer of sound energy to the air.

polarity of *both* the voice-coil and field connections are equally important when more than one speaker is used in an installation. Complete directions for phasing loudspeakers are given in IP's " Manual of Practical Projection " (Chapter 27).

PM speakers not only do away with the need for a source of smooth DC to energize the field magnets, but they also eliminate the hum created by field DC which has not been adequately " filtered " by large choke coils and capacitors.

Some of the older sound equipments utilized the amplifier " power-pack " rectifier for the field supply, while others employed small motor-generator sets or separate rectifier units. Several of the earliest sound systems employed emergency switches which enabled the projectionist to power the speaker fields from the arc-lamp generator in case of rectifier breakdown! And to eliminate the need for separate choke coils, the fields of the projection-room monitor and stage speakers were connected in parallel !

The quality, weight, and stiffness of the paper cone of a dynamic speaker is extremely important to the fidelity of sound reproduction. Soft, porous, coarse-fibre paper is sometimes used for low-frequency speakers in 2-way systems employing woofer-tweeter combinations to eliminate the need for an efficient, and hence expensive, crossover-network unit. The soft paper absorbs and muffles the higher frequencies, thereby reproducing only the lower tones even though the voice coil receives the entire range of frequencies. Only a high-pass capacitor is needed as a " network " to cut off the lower tones from the HF tweeter unit.

" SOFT " CONES FOR LF UNITS

Soft-cone speakers are not entirely satisfactory, however. They literally get rattled by the higher frequencies they absorb and dissipate, and consequently produce unpleasant intermodulation effects which the public immediately recognizes as distortion. Moreover, soft-cones exhibit a strong tendency to " cry out " harshly at some frequency not related to the applied frequency. This phenomenon, although confined to the 1000—3000 cycle range, nullifies the performance of a high-fidelity amplifier and gives the impression of poor sound.

Any speaker which is overloaded reproduces the signal with a great deal of distortion. The voice coil with its flexible centering spider moves in and out so violently that it strikes against the field-magnet assembly and " blasts " or is restrained by the rigidity of the cone to so great an extent at the limits of its excursions that severe nonlinear distortion results. Resonance and intermodulation add to the distortion. Overloading is common in theatres having powerful amplifiers and inadequate speaker units.

The undesirable phenomenon of cone resonance, mentioned previously, can be minimized in three ways. The cone may be made oval in shape instead of circular. This has the bad effect of raising the natural frequency of resonance, but it reduces the tendency to resonate. The cone may be made very large to lower the resonant frequency below the audible range, but this expedient introduces distortion and high-frequency attenuation in speakers intended to reproduce the entire range of sound frequencies. Third, the corrugations at the periphery of the cone may be made sufficiently irregular to damp resonance.

Cones made of hard paper have the advantage of comparative freedom from " cry," but resonance poses a greater problem. Because hard-paper cones are more efficient reproducers of the higher frequencies than are soft-paper cones, effective crossover networks are necessary to block the treble tones from large hard-cone " woofers."

HARD-CONE " WOOFERS " SUPERIOR

Small hard paper dynamic speakers give fairly uniform response over the 50- to 10,000-cycle range with only slight attenuation of the lowest and highest frequencies. For this reason, 4-, 5-, and 6-inch cone speakers may be used for the entire audible range in home radios and phonographs. In fact, hi-fi apparatus designed for the small living room does not require the tweeter-and-woofer speaker combination so necessary to natural sound in theatre sound systems.

Why, it may be asked, cannot the larger hard-cone dynamic speakers handle the main range of audible sound frequencies satisfactorily? When the speaker cone has a diameter of 10 or 12 inches, several bad effects usually make themselves evident when the higher frequencies are reproduced.

The greater mass of a large-diameter cone prevents the entire cone from vibrating in a truly piston-like manner when impelled by the higher frequencies. Only the middle area vibrates; and since the oscillations in such a case may depart from an axial direction and bend the diaphragm from side to side, harmonic distortion may be produced. Then, too, the inertia of a large cone damps the highest frequencies; and when these are strengthened by over-amplification, nonlinear speaker response and other distortions produce that well-known boxoffice poison—bad sound.

THE DOPPLER EFFECT

The third, and most interesting, fault of a large cone energized by the entire frequency range is the " Doppler effect." An understanding of this effect and its incurable nature requires preliminary explanation.

If you stand near a railroad track as a train rushes by at high speed, and the whistle is being blown, you will notice a peculiar sound phenomenon. The pitch of the whistle drops at the moment the train passes by, and sounds lower as the train recedes into the distance. *The speed of the train is added to the velocity of the sound waves when the train approaches, increasing the number of vibrations per second received at the ear.* To a stationary listener, the pitch of the whistle sounds higher than it really is. Conversely, after the train has passed by, *the speed of the train is subtracted from the velocity of the sound as the train recedes, decreasing the number of vibrations per second received by the ear.* In this case, the pitch of the whistle sounds lower than normal. This is the Doppler effect.

Now consider the case of a sound source that oscillates back and forth with great rapidity, alternately approaching and receding. The sound emitted by the source would seem to warble in the manner of an organ pipe played with the tremulator turned on. This is exactly what happens when a large speaker cone of great excursion range sounds a treble and a bass tone simultaneously. The source of the high-frequency tone—the speaker diaphragm—moves toward and away from the listener with a periodicity equal to the frequency of the low tone. The treble tone " gargles," and the sound seems " raspy."

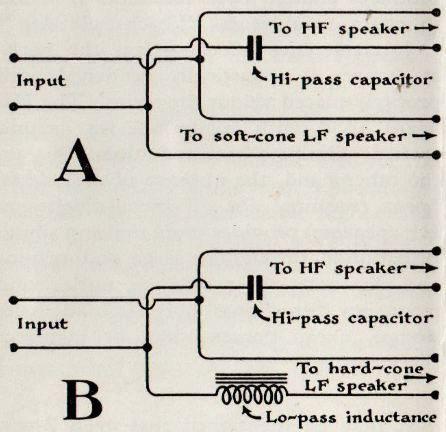

FIG. 5. Elementary "crossover" networks for separating the low- and high-frequency components of sound signals. The simple high-pass circuit shown in *A* requires a low-frequency speaker which fails to respond to the higher sound frequencies. The better sound systems, however, employ the type of circuit shown in *B*. The low-pass reactance coil prevents the high frequencies from reaching the low-frequency speaker.

The Doppler effect is minimized by using a battery of several smaller speakers in place of one large speaker, and it is eliminated by using a 2-way speaker system consisting of a bass-reproducing woofer and a treble-reproducing tweeter. The treble tones are then reproduced independently of the bass tones.

CROSSOVER-NETWORK CIRCUITS

The success of a 2-way speaker system depends heavily upon the efficiency of the crossover-network filter circuits which allow *only* the bass frequencies to activate the LF units and *only* the treble frequencies to energize the HF units.

Elementary filter circuits are shown in Fig. 5. The " crossover " frequency range for the simple capacitor circuit (requiring a soft-cone woofer which loses radiating power above 4000—5000 cycles) is 3000—5000 cycles. Because the HF unit does not receive a signal lower than about 4000 cycles, this unit may be small and relatively inexpensive. Although cheap to manufacture, this type of 2-way system should not be used in any but the smallest theatres.

A crossover network employing an inductance (" sound choke ") in addition to a capacitor performs an actual separation of the high and low frequencies into two electrically distinct channels. For a tone of continuously varying pitch, the sound output would appear to " cross over " from one channel to another at 300—500 cycles for the most carefully engineered sound systems, or in the range covered by 1000—2000 cycles for " economy " systems having smaller and less expensive metal-diaphragm HF units.

A 2-way speaker system employing a crossover network is an *electrically balanced* system, a fact that must be kept in mind whenever speakers or amplifiers are replaced. The most efficient transfer of electrical energy takes place between matched impedances. This means that the impedance (the AC resistance expressed in ohms) of the amplifier output must be very nearly the same as the impedance of the speaker circuit.

Most loudspeakers have impedances of 5 to 25 ohms—the impedances of their voice coils. Since the internal resistance of the amplifier power tubes is very high (several thousand ohms) it is obvious that the speakers cannot be connected directly to the power-tube output with good results. Accordingly, the power-tube plates are connected to a *matching transformer* having a primary (input) winding of several thousand ohms impedance and a secondary (output) winding of only 5—25 ohms impedance to match the speakers.

The impedance of the crossover network, itself, may be as high as 10 or 15 ohms. This must be added to the impedance of the amplifier matching-transformer output. And since impedance varies somewhat with the frequency of the sound current, electrically mismatched components produce distortion as well as weak sound.

Similarly, the power-handling capacity of a speaker, measured in watts, must be at least as great as the maximum output of the amplifiers. To connect a 15-watt speaker to a 40-watt amplifier will produce the overload distortion previously described.

MULTI-SPEAKER UNITS

The use of a large number of small cone-type dynamic speakers—several dozen 5- or 6-inch speakers for a theatre—obviates the need for a 2-way crossover network with woofers and tweeters. In fact, a speaker system of this kind powered by a matched amplifier is the simplest and cheapest way to get good sound for a small theatre. The components can usually be purchased at a discount, and any projectionist or hi-fi enthusiast having a good knowledge of sound electronics can build the baffle, mount the speakers, and wire the system. But are there any other advantages of a 1-way speaker system of this type? And what are the disadvantages?

Theory indicates that a woofer-tweeter combination eliminates the Doppler effect and permits the use of a LF speaker sufficiently large to resonate at a subsonic, and therefore inaudible, frequency. An array of small dynamic speakers, like a single small speaker in a home radio, is prone to resonance in the audible range.

Also, a battery of dynamic speakers produces enough back radiation of sound to cause troublesome " back-wall slap " and interference effects unless the backstage area is acoustically deadened with properly placed velour draperies. The HF horns used with modern 2-way sound systems eliminate back radiation. But, on the other hand, the absence of directional horns (required for all metal-diaphragm HF speakers) provides more uniform sound distribution throughout large auditoriums and eliminates the resonance, rattles, and frequency distortion of horns of inadequate design, cheap construction, or incorrect placement.

It may be mentioned that even 2-way systems designed for the larger theatres have always utilized more than one speaker of each type. Two or more HF units have sometimes been used with a single LF speaker to insure good sound distribution; and in recent years nearly all manufacturers of sound equipment have offered a battery of two or more medium-size woofers in place of one large unit. The reason for this is largely a matter of economics, for low-frequency sound is practically non-directional.

No loudspeaker, whatever its type or size, can work satisfactorily as an isolated unit. This inescapable fact may be demonstrated by removing from its cabinet the speaker of a radio set or phonograph. When the instrument is played with the still-connected speaker outside the cabinet, the sound is weak and very harsh and distorted. The cabinet acts not only as a *director* of sound waves, throwing them forward into the room, but, more important, as an *acoustic load* against which the speaker diaphragm may work.

HORNS AND BAFFLES

To prevent a wild and aimless rattling of the diaphragm of the theatre speaker, therefore, a horn or baffle must be provided. Exponential horns are best for metal-diaphragm speakers. By providing the proper amount of acoustic load for the small diaphragm, an acoustic efficiency is obtained which is appreciable higher than that of a paper-cone speaker working under the most favourable conditions. Moreover, the horn, usually in the form of a multicellular trumpet consisting of several exponential horns, directs all of the sound forward and prevents back radiation.

Low-frequency cone-type speakers require a baffle-board for acoustic loading. A flat baffle having the speaker placed in a centrally located circular hole increases in effectiveness as its area is increased; and since the optimum size of a baffle is related to the wavelength of the lowest frequency of sound to be reproduced, flat baffles for wide-range sound systems should have a large area.

To conserve the space demanded by flat baffles, both " bass-reflex cabinets " and " folded horns " have come into favour. The bass-reflex cabinet is a heavy, ruggedly constructed wooden box having a hole of the correct size in its front panel to accommodate the speaker.

The secret of the bass-reflex cabinet is the action of the back panel and the opening in the front panel below the speaker in reinforcing the sound with the back-radiated waves. It is extremely important, therefore, that the wooden back panel of a bass-reflex cabinet be at least ¾-inch thick, very rigid, lined with sound-absorbing felt, and fastened solidly with glue and a greater number of screws than mere strength requirements would indicate as necessary.

An improperly designed or poorly constructed bass-reflex cabinet produces a severe deterioration of sound quality!

FOLDED-HORN BAFFLES

The folded-horn type of baffle is nowadays very popular for theatre sound systems. This is essentially a baffle " folded " in such a way that it reinforces and projects the sound in the manner of a crude exponential horn. It departs from the perfect exponential shape by having plane, instead of curved, surfaces; but the departure does not affect the quality of the low-frequency tones reproduced by its associated LF speaker.

There is nothing really new about the folded horn: it was used in acoustic phonographs many years before the invention of electric sound amplification.

The folded-horn baffle works extremely well when made of plywood at least ¾ of an

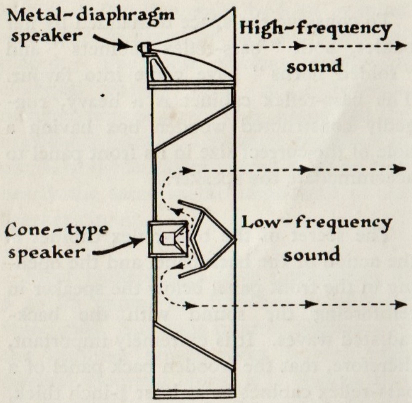

FIG. 6. Cross-section of a "folded horn" for low-frequency cone-type speakers.

inch thick and rigidly constructed. Like the bass-reflex cabinet, the folded horn must be glued under pressure and additionally fastened with a large number of long screws. Vibration of any part of a folded horn will create distortion, and rattles caused by loose or " sprung " joins are very annoying and are difficult to locate and correct.

The HF speaker with its multicellular horn is ordinarily mounted on the top of the folded-horn cabinet. The mounting must be exceptionally solid to prevent rattles. Only the positioning of the HF horns need be changed to insure the best sound distribution and to reduce echoes and the effects of faulty acoustic phasing. The position of the LF units, once established, need not ever be changed.

The non-directional characteristics of the low sound frequencies make possible a decided economy in stereophonic sound installations. Three HF units are needed, but only one woofer unit, which is placed behind the middle of the screen. The three HF speakers for the centre, right, and left stereophonic channels should have identical frequency-response characteristics.

HORN POSITIONING

It is desirable to position the HF horns in such a way that their sound-radiation axes do not cross in the auditorium, but meet at a point in the middle of the rear wall. If the beams of projected sound cross, patrons seated at one side of the auditorium receive excessive sound volume from the speaker behind the opposite side of the screen. This bad effect has been observed even at " showcase " presentations employing wide film and the most expensive equipment.

Single-channel optical tracks give especially pleasing results when played over all three of the stereophonic speaker channels in theatres having good acoustics. Multiple-channel reproduction of single-channel tracks permits a slightly lower volume at each individual speaker with a reduction of nonlinear distortion, and overcomes the " point-source " effect of a single speaker behind the middle of the screen.

Many observers consider this kind of reproduction superior to Cinema-Scope stereophonic sound for unobtrusive naturalness. The use of several channels simultaneously seems to project the apparent source of the sound closer to the audience.

Since only one amplifier of adequate power capacity is required, and only a matched set of three HF speakers need be obtained, even the smallest theatre can avail itself of the most natural sound. And when such a setup is reinforced by " surround " speakers in the auditorium for special-effect scenes and overture and intermission music played from disc records, appreciative audiences will repay the effort by continued patronage.

This is something to think about now that better pictures prove conclusively that things are beginning to " look up " for the exhibition industry.

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