63-2.

LIGHTING DATA

EDISON LAMP WORKS
OF GENERAL ELECTRIC COMPANY

GENERAL SALES OFFICE HARRISON, N. J.

Stage Lighting

Information Compiled by

A. L. POWELL

Lighting Service Department

Synopsis:

For information regarding Mazda lamps and lighting questions, refer to the nearest sales office.

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General

One often wonders how plays were given by the light from flickering candles which had to be snuffed frequently and which did not permit any variation whatever in the intensity or color of illumination, yet, some of the masterpieces of drama originated in those days. For lighting effects, gas was but little better, although by careful adjustment of the stopcocks, variations in intensity could be had.

Fig. 1

View of Stage with Modern Type of Footlights and Borders. Individual reflectors of metal painted white are used with gelatin color screens. 100-watt lamps are placed on 6-in. centers. Four circuits are provided in both foots and borders.

Needless to say that when the incandescent lamp became available, its advantages for stage lighting were at once recognized and almost instantaneously it came into universal use. Its introduction marked the birth of a new art of staging, due to the ease of control, the ability to get much more light from a given space, the remarkable safety and adaptability to color modification.

The various periods of the day, flashing lightning, moving clouds, fire, sand-storms, rain, snow, fog, running water, and dashing waves are among the hundreds of effects now successfully accomplished with the aid of electric lighting.

Light is probably the most valuable single medium available to the stage manager for creating the desired psychological effects and holding the attention of his audience. The stage director of today realizes that color and directional effects are his very best means of securing artistic results, but the use of color on the stage is not entirely modern. Valerius Maximus writing in 78 B.C. says that yellow, red and blue awnings were often stretched over the large theaters and fluttering, dyed the assemblage with the colors of the transmitted light.

Stage lighting in general exemplifies many of the principles of correct illumination, for instance, we never see a brilliant glaring light source on the stage. Footlights, border lights, floods, etc., are invisible to the audience. The stage manager knows that unshielded lamps distract the attention, fatigue and annoy. When he finds it necessary to have a chandelier, portable lamp or bracket fixture as part of the setting, he is clever enough to provide merely enough light in this to render it luminous and does not depend on it for any actual illumination of the scene. A single glaring light will destroy the effect of the most pleasing set. In order that the picture may appear natural, the mechanism of the lighting is entirely concealed from view. One does not even see the reflectors or lamp housings. They are "masked" by some part of the scenery. In spite of this, full advantage of the possibilities of light are not yet universally realized.

Decidedly more subtle effects are coming into use as new equipment is developed and as the fundamentals become better understood. Until quite recently, if an outdoor scene was to be reproduced, there was generally a back drop with a landscape and painted blue sky, a few trees as wings with cut-out foliage and even some painted clouds as borders. Now, in some instances, the stage artist constructs a cupola in the shape of a quarter sphere over the entire stage. He makes this of white material and "paints" it with blue light for the sky, then projects moving clouds and a rainbow if desired on the blue background and a landscape panorama on the lower portion. Similarly, interior sets are reproduced by using plain white drops and throwing the picture of the room on these by an adaptation of the old fashioned "magic lantern."

In order to supply lighting on the stage, it is necessary to know what mechanisms are available or standard for stage lighting, how they operate, what they can do, why they are useful and how they can be applied. With a knowledge of these features one then can adapt standard equipment to the requirements of a particular problem.

At best, stage lighting is a "cut and try" proposition, and its solution cannot be had by following any set rules. Experience in the handling of light and lighting apparatus is an essential as in no other field. One must have the light just where it is wanted, just when it is wanted. For an artistic production, the distribution

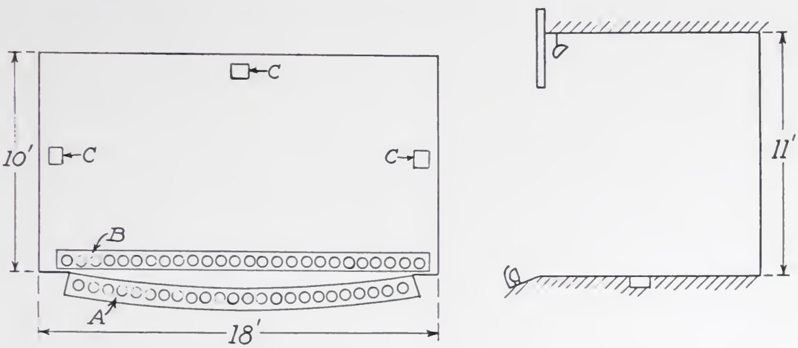

FIG. 2

Plan and Elevation of Typical Small Size School or Club House Stage

A—Footlights, Disappearing Type—Metal trough painted white with receptacles on 6-in. centers, 40 watt MAZDA lamps, alternate outlets on separate circuits

B—Border lights—Metal trough painted white with sockets on 6-in. centers, 60 watt MAZDA lamps, alternate outlets on separate circuits

C—Stage pockets or convenience outlets of 10 amperes capacity each

Switchboard circuits as follows:

1 and 2—Footlights 3 and 4—Border lights 5, 6 and 7—Stage pockets 8—Orchestra lights

must be accurately controlled, and skillful manipulation of dimming devices, following every line of the play or movement, is necessary.

Standard equipment probably will not always fill the bill, and in many instances it is necessary to construct special apparatus. To prevent light reaching certain parts of the stage "louvers" or "spill shields" are essential. Obviously these have to meet particular conditions and must be made "on the job." Where reflecting devices are in use, it may be desirable to cover portions of these with black paint to secure a modification in distribution.

In planning stage lighting, one should keep in mind the general principles of the action of colored light on colored objects, as discussed in a later section. By the application of these principles one set can be used for two or more scenes by manipulation of lights, avoiding the necessity for changing scenery. For many types of productions very little painted scenery is necessary. Colored lights can be used to obtain all the effects desired. It will be found that much more artistic and subtle gradations of tint are possible than when the attempt is made to produce these by the brush. Ingenuity, appreciation of the fundamental principles and experimentation are necessary.

As pointed out later, colored lighting can be obtained by a number of methods. At present, where relatively small lamps are employed, the dipped bulb is the most generally applicable, although there are prospects that glass color caps for this purpose may soon be available. For equipments using the large lamps, the gelatin or glass color screen is necessary.

The desirable equipment for a stage will depend on the type of production likely to be given. In the smaller assembly room, economic considerations prevent the installation of elaborate equipment. Figs. 2 and 3 indicate suggested arrangements for some typical conditions. In this connection, it must be remembered that the effects possible are directly dependent on the amount of equipment available for use. If one hopes to duplicate the production given in the large theaters in the auditorium, he must have at his command a sufficient number of circuits, flexible control and a means of supporting auxiliary apparatus. He will be seriously handicapped if inadequate wiring or crowded conditions prevent the installation of such special devices as may be necessary.

For certain types of productions, one should reproduce as nearly as possible lighting conditions as they exist in nature and at the same time enable the audience to see clearly the actors and setting. On the other hand, many of the stagings of the present day are of what might be termed an imaginary type and it is even possible to improve on natural lighting by skillfully applied artificial illumination. No doubt some of the most pleasing results are secured when bizarre effects are attempted and combinations of colors used which do not exist in nature. In doing this, one is not violating any of the fundamental principles, but merely taking advantage of the available media for expression and producing something interesting, striking and pleasing to the eye.

To accomplish these things, it is necessary to have available light of various colors from many different directions and facilities for changing the direction of light, as well as the quantity or intensity.

Stage lighting devices may be divided in two main groups, those for providing general illumination and those for providing localized lighting. In the first group fall the foot, strip, proscenium and border lights; in the second, the bunch and spot lights and effect machines or sciopticons.

Footlights

The footlights direct a rather strong light from below which intensifies the facial expression and assists to a great degree in holding the attention of the audience. However, such lighting

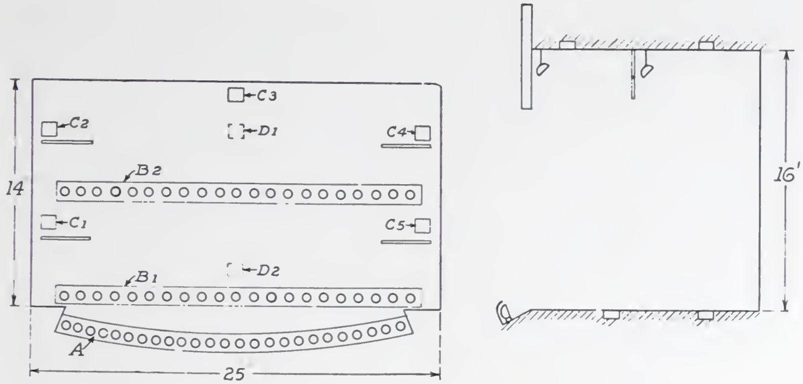

FIG. 3

Plan and Elevation of Medium Size Stage in Hall or Assembly Room

A—Footlights, outlets on 9-in. centers. Mirrored glass or aluminum finish steel reflectors—75 watt MAZDA C lamps—Gelatin color screens—Three circuits (1, 2, 3)
B_1-B_2—Border lights—Outlets on 12 in. centers. Mirrored glass or steel angle reflectors—100 watt MAZDA C lamps, glass color caps—Three circuits in each border (4, 5, 6, 7, 8 and 9)
C_1 to C_5—Floor or side wall stage pockets or convenience outlets of 15 ampere capacity each
D_1-D_2—Convenience outlets in borders or ceiling of 10 ampere capacity
Switchboard circuits as follows:
1-2 and 3—Footlights; 7-8 and 9—Border lights B_2; 15 and 16—Ceiling outlets D_1 D_2
4-5 and 6—Border lights, B_1; 10 to 14—Stage pockets C_1 to C_5; 17—Orchestra lights
Dimmer control as follows:
Circuits 1, 4 and 7 combined. Circuits 2, 5 and 8 combined. Circuits 3, 6 and 9 combined
Auxiliary apparatus desirable:
Olivette type bunch lights for 1000 watt MAZDA C lamps with individual dimmers on stand and gelatin color screens—2
Suspension type spot lamps for 500- or 1000-watt concentrated filament MAZDA C lamps—2
Baby spot lamp for 250- or 400 watt concentrated filament MAZDA C lamps—4
Long throw spot lamp in balcony—1

tends to reverse natural shadows and while still an important factor, is much more subdued than in the early days of the art. Some of the most artistic productions of recent years have been well lighted without the use of footlights. It is doubtful whether this practice should be universally applied and it is always well to provide suitable footlights for use when necessary. The actor must take into consideration whether or not strong footlighting is in use and adjust the make-up to compensate for the reversal of shadow effects.

The footlight in common use a few years ago consisted of a sheet metal trough painted white and fitted with porcelain receptacles close together. In many cases the design of this was given but little consideration and the distribution of light secured was not of the most desirable character, in other instances the lamps were visible to persons sitting in the balcony. Such equipment

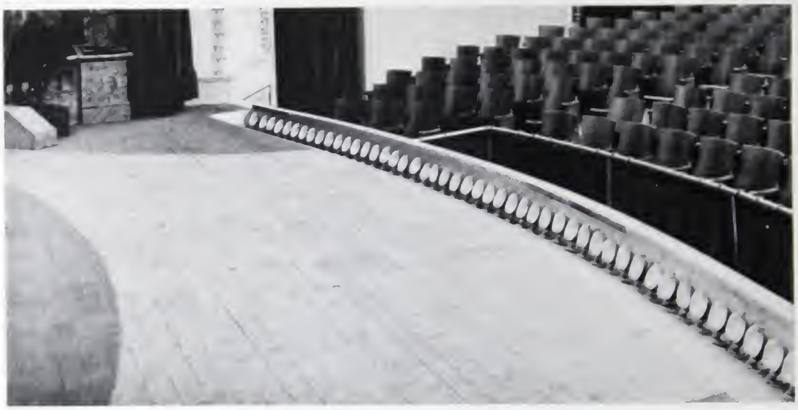

Fig. 4
An Excellent Installation of Mirrored Glass Individual Units for Footlights

is open to severe criticism. An inverted form of footlight with the lamps burning base up and concealed by an overhanging ledge was sometimes used to overcome these difficulties. But with either type, colored lamps were mingled promiscuously and purity of color was out of the question for much of the light was modified in passing through adjacent bulbs, either directly or after being reflected.

At best, the old style footlights were inefficient. Some of the newer types are pictured in Figs. 1, 4 and 5. The modern type of footlight employs Mazda C lamps with individual reflectors and gelatin color screens, and avoids the difficulties experienced with the open type.

The choice of reflecting material for theatrical apparatus will depend on the effect desired. White paint is efficient, but must be renewed frequently to maintain its good qualities. It has the property of giving splendid diffusion and thus reducing sharp shadows. It cannot be used where accurate control of distribution is desired. Aluminum reflectors are also efficient and permit of a certain amount of light control. Mirrored glass or polished metal must be used where a very accurate control is necessary or where concentration is important.

To soften the light from below and overcome the glare which an actor experiences to such a degree that he cannot see the baton of the director, when working downstage, an indirect type of footlight is in use abroad. Lamps are entirely concealed and their light directed on a white curved reflecting surface

At least four and preferably five circuits should be provided for the footlights, so that red, green, blue and unmodified (white light) may be available, with the fifth circuit for amber or "steel blue." The common practice is to provide red, blue, amber and white circuits, but as pointed out later, red, green and blue are the primary colors and a mixture of red and green will give us the yellow or amber light. Some of the most artistic results are secured in those theaters where the electrician or scenic artist understands the fundamental principles and uses green light in its proper place.

The footlights should be divided into at least two sections and preferably three, rather than having one circuit run the entire width of the stage. With this sectional arrangement, one half may be darkened and the other half light—one half may be of one color and the other of some other tint. With the three-section arrangement, it is evident that still greater flexibility can be secured

The disappearing type of footlights is particularly well suited to assembly rooms and auditoriums. Here it is a general practice for dancing to follow a performance, the orchestra being located on the stage. The reduction in lamp breakage will soon pay for the additional cost of the more complicated construction.

Border Lights

The border lights furnish general illumination from a natural direction, that is, overhead. They are therefore a necessary part of the stage equipment. Border lights formerly in use were virtually inverted footlights, suspended from the gridiron structure in such a manner that they could be raised and lowered. The number of sets in use will depend on the depth of stage. Some of the theaters, for example, the Metropolitan and Manhattan Opera houses, employ seven or eight rows.

The size of lamp used for the border will depend entirely on the character of the production. In practice, we find from 25-watt round bulb MAZDA B lamps in miniature mirrored glass reflectors for lighting an interior to 100-watt MAZDA C lamps in the average theater and 1000-watt MAZDA C lamps in such show houses as the New York Hippodrome.

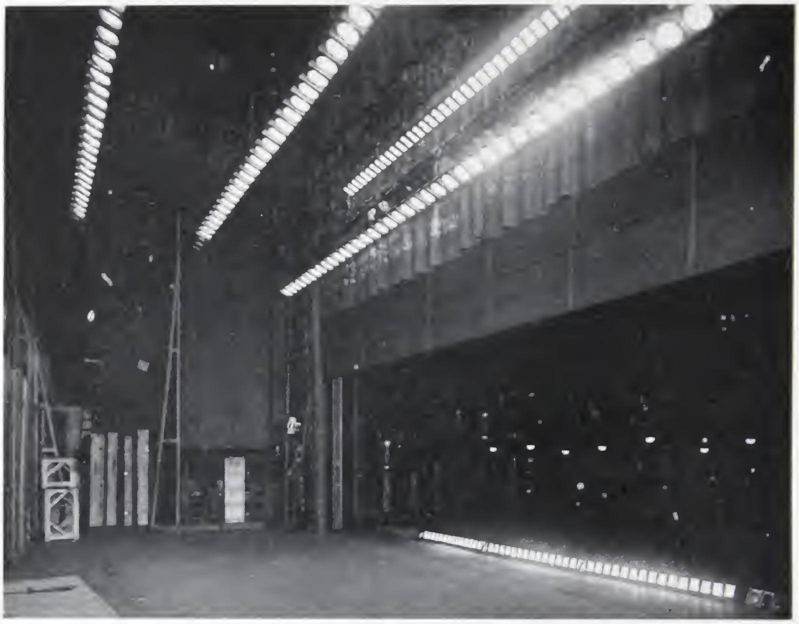

FIG. 5
Individual Aluminum Finish Steel Angle Reflectors with 100-watt MAZDA C Lamps are Used as Border Units on This Stage. The color screens have been removed. Three circuits are provided in the borders and four in the concert border. Footlights are similar in character but more closely spaced

The old style border light is open to the objection stated above in connection with the footlights in improper distribution of light, low efficiency and mixing of color. The newer forms of border lights employ individual reflectors with MAZDA C lamps as pictured in Figs. 1, 5 and 6. They control the light to a certain degree and enable one to employ the higher efficiency MAZDA C lamps. These make it possible to get greater illumination (generally the desire of the producer) for the same wattage. Gelatin screens are ordinarily employed with this equipment to obtain color modification, and special precautions should be taken to have a suitable holding device for this to prevent its being knocked out of place or punctured as a drop is being raised. Unquestionably, the future will see the application of specially designed removable glass color caps to this equipment.

FIG. 6
Two Recent Developments in Border Lights. Individual units of white painted metal for 75- to 200-watt MAZDA C lamps, and removable color screen holder. A border light employing 250-watt concentrated filament MAZDA C lamps and parabolic mirrors to give a concentrated distribution of light

For certain productions it is desired to control the light from the borders to a still greater degree such as is obtained through the use of lens equipment. Borders are in use which are virtually rows of small spot lamps with concentrated filament lamps and remotely controlled color filters.

The remarks given under footlights as to the desirable number of circuits and division into sections apply with equal force to the border lights.

Proscenium and strip lights are virtually border lights hung in vertical positions, and assist in reducing the sharp contrasts which might prevail in the vertical plane. Individual reflectors and lens lamps are now being successfully applied to this service.

Bunch or Flood Lamps

A most useful device for lighting a given area to a greater intensity than the rest of the stage is the bunch light, often known as the "open box" or "olivette," shown in Fig. 7. Hand-fed arc lamps were formerly used for this service, but with the introduction of the high wattage MAZDA C lamps, arc equipment has been replaced by the 1000-watt unit. Its advantages are remote

FIG. 7
At the Left, Typical Bunch or Flood Lamps Using 1000-watt MAZDA C Lamps. One utilizes a spun aluminum reflector of parabolic shape and the other a metal box painted white. The small dimmer for local control is a most convenient feature. At the right, typical lens spot lamps for 1000- to 2000-watt concentrated filament MAZDA C lamps. The color wheel and dimmers should be noted

control (direct from the switchboard), ability to be dimmed and simplicity of operation, which facts materially reduce the number of operators for a given production. Spun aluminum or white painted reflectors are commonly used in the bunch lights although some reflectors are built up of sections of mirrored glass to obtain more accurate light control. Color modification is obtained by the use of gelatin screens. The units are portable and adjustable as to height and direction, and can be plugged in at will from any stage pocket. Open box lights also prove very useful suspended from the gridiron to illuminate cycloramas.

Fig 8
A Suspension Type Lens Spot Lamp for 500- or 1000-watt Concentrated Filament Mazda C Lamps

Spot Lamps

When it is desired to draw the attention of the audience to an individual performer, a group, or a special part of the scene, it is common practice to illuminate this area to a very high intensity of light relative to the surroundings. This is accomplished by means of the spot lamp which directs a strong, concentrated beam of light. The spot lamp is fitted with a single condenser lens which enables the operator to adjust the size of the spot at will. For the very highest intensity the direct-current hand-fed open arc is still used. For most purposes, concentrated filament (floodlighting and stereopticon) Mazda C lamps are suitable. Standard forms of spot lamps are pictured in Fig 7. These use Mazda C lamps with a spherical mirror behind the filament to obtain a higher utilization of light. The direction of the beam can be changed at will and a performer moving about the stage "followed with the spot." The handle at the base of the housing permits one to move the lamp toward or away from the lens enlarging or decreasing the size of the spot. Color modification is obtained by the so-called color wheel or by individual gelatin screens fitting in grooves directly in front of the lens.

Fig 9
So-called Baby Lens Spots
Footlight type for 250-watt concentrated filament Mazda lamp
Adjustable border type for 250- or 400-watt concentrated filament Mazda lamp
Lens lamp for 250-watt concentrated filament Mazda lamp mounted on stand, with dimming device

One of the most useful recent developments in stage lighting equipment is the suspension type spot lamp pictured in Fig. 8. This particular device carries a 500- or 1000-watt concentrated filament Mazda C lamp and, as its name implies, is hung from the gridiron or other support. A color screen holder will be noted at the base of the unit.

One can readily picture the effects which are produced with the general lighting of a moderate intensity in color and spots of different colors of higher intensity superimposed on the general lighting. Ornamental vases, urns and decorative features of this character can be made very effective by the application of suspension type spot lamps. It is often desirable to bring out an individual performer with a spot from overhead, instead of by one in the balcony or "front of the house." Shadows are more natural and the harsh, defined spot does not show up on the drop.

Other useful devices are the so-called "baby spots" (illustrated in Fig. 9) which can be plugged in at the footlights or suspended from the borders. These employ 250- or 400-watt concentrated filament MAZDA C lamps. Spherical mirrors should be used to redirect as much of the light as possible in the beam.

"Effect" Apparatus

There are times when a very sharply defined spot or picture effect is desired and an apparatus known as a sciopticon, similar to a regular stereopticon, is used to produce this (Fig. 10). This has objective lenses in addition to double condensers. By using an opaque slide with an opening of the shape desired, a spot of some particular contour can be obtained.

As an example of a simple effective use of such a device, suppose a solo dancer is representing the "Spirit of St. Valentine's Day." Instead of painting the drop or cyclorama in color, this might well be of a white or some light, neutral tint, the entire stage flooded with pink light and a clear spot in the shape of a heart used to follow the dancer. The clear light should be of a sufficiently higher intensity to overcome, as one might say, the colored light and the dancer would constantly appear in a white spot. As soon as the spot moved, that position would again appear pink. This is obviously more attractive than if the drop were painted pink and a spot lamp merely gave a greater brilliancy in the area of the spot. By working with uncolored drapes, applying the color in light rather than in pigment, effects far in advance of past practices can be readily obtained.

Effect apparatus can be fitted with a special head containing a revolving disk which is painted in a certain manner and driven by an adjustable speed motor or clock-work mechanism. This is used to produce the effect of running water, falling rain or snow, moving clouds, flames, fireworks, sand storms and innumerable special illusions.

A number of effect machines placed in various positions and operated at different speeds are used for some of the realistic cloud effects often seen with the spectacular productions. Abroad, a rather intricate and somewhat cumbersome piece of apparatus is used for cloud effects. Two groups of lens systems projecting pictures of clouds are centered around a powerful light source.

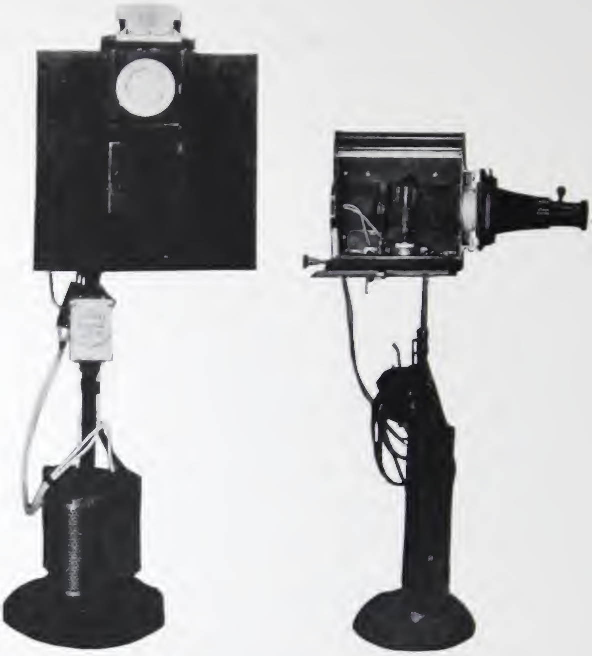

Fig. 10
Typical Effect Apparatus

An arc type effect machine with painted revolving disk, clockwork mechanism and objective lens

Lens lamp for 1000–2000-watt concentrated filament Mazda lamps with double condenser, lantern slide carrier and objective lens

The entire mechanism is rotated and by means of motor-driven mirrors, one group of images is made to pass over other groups at various speeds, giving depth and realism to the picture.

A section of a motion picture film showing breaking waves has been used in a powerful motion picture projector for simulating the dashing surf in spectacles.

The uses of electricity for stage effects are varied indeed and space is not available for discussing all of these. In the early days lightning was produced by blowing a stream of powdered magnesium through a flame. Now, flashing electric arcs give an infinitely more realistic effect. By the aid of electricity, the glowing coal in the fire place is imitated. Until comparatively recently, red light thrown on rising steam was used to produce a conflagration. Now, a number of ingenious substitutes are used for flame effects. *A patented device* utilizes strips of thin silk put in motion by an air current from a blower or fan. With projecting apparatus and properly colored slides the low portion appears yellow, the central red, and the top smoke color, thus simulating actual flame much more effectively. This principle has been utilized in connection with urns and torches, a miniature motor fed from a dry cell being employed in the portable torch to produce an air stream or rotary motion.

Some interesting effects can be obtained by the use of phosphorescent paint on scenery, properties and gowns. Objects painted with Balmain's paint (calcium sulphide) glow for awhile with a bluish light after being exposed to the bare carbon arc or quartz mercury arc. Paints with certain salts of zinc, strontium, cadmium and barium as part of their composition, give other phosphorescent tints, such as yellow, red and green. Combinations of these colors can be used to good effect when the stage is darkened.

Switchboard and Wiring

The switchboard for controlling all the stage lights, as well as the house circuits, should be located in such a position that the electrician can view the entire scene as in Fig. 11. It should be of the dead front type, with all live parts out of reach. Each circuit should be clearly indicated by a suitable legend on the face of the board and colored handles on the dimmers are of assistance in rapid manipulation. Dimmers should be provided to control each of the house circuits and each of the color circuits on the stage. The interlocking and selective types of dimmers offer special advantages in convenience and smoothness of control.

In designing a dimmer, due consideration should be given to the resistance, voltage and candle-power characteristics of the MAZDA lamp, in order that a fine gradation in intensity can be

Bulb Shape

The regular Mazda C lamps for general lighting are so well standardized that it is not necessary to describe these. The following list enumerates the various concentrated filament Mazda C lamps which are usually employed in theatrical work. In most cases these are not the standard projection lamps which are made in the tubular (T) bulb. This bulb, while allowing the lamp to be closer to the lens as is desirable in regular stereopticon service, limits the burning position to within fifteen degrees of tip up—a disadvantage in theatrical work. The round (G) bulb construction is, therefore, generally more suitable.

110, 115, 120 VOLTS

Wattage	Bulb	Diameter	Overall Length	Base
100	G-25	$3\frac{1}{8}$	$5\frac{1}{8}$	Medium
250	G-30	$3\frac{3}{4}$	$5\frac{5}{8}$	Medium
400	G-30	$3\frac{3}{4}$	$5\frac{5}{8}$	Medium
500	G-40	5	$7\frac{5}{8}$	Mogul
1000	G-40	5	$8\frac{5}{16}$	Mogul
2000	G-48	6	$9\frac{1}{16}$	Mogul

These lamps are designed to have an approximate average life of 100 hours. Complete information on the Mazda lamps for motion picture projection will be found in Bulletin Index 2.

Burning Position

Mazda B lamps can be operated in any position. Mazda C lamps from 50 to 200 watts have a so-called "ring" filament and can be burned in any position. Regular Mazda C lamps from 300 to 1000 watts have "loop" filaments with one set of anchors and are designed for operation in the tip down position. If such a lamp is burned tip up or horizontally, it is obvious that when hot, the filament will soften, sag, interlock, short circuit and the lamp will have a short life.

When these lamps are to be used in a tip up position, they should be ordered for *tip up burning*, and will be supplied with the anchors at the lower ends of the loops instead of at the upper, at no additional cost. Wherever such lamps are likely to be burned in any position, they shoud be ordered for *universal burning*, and two sets of anchors are then used.

The concentrated filament MAZDA C lamps for projection purposes (floodlighting and stereopticon) *cannot be burned with the base up* for the hot filament is so close to the supporting button that this is soon softened by the heated gas and the lamp fails. They can be burned in any position except within forty-five degrees of vertically tip down.

One cause for unsatisfactory performance of concentrated filament lamps may be explained as follows: A given lamp is operated for a considerable time in a horizontal position and the filament acquires a permanent sag or loop. This lamp is then burned tip up and another shape of sag may occur causing interlocking of the loops and short circuiting.

Focusing

The advantage of a concentrated filament is that the light source can be placed at the focus of the optical system. If care is not exercised in adjusting the lamp, then this advantage is lost. The filament should be at the correct height and neither to the right nor left of the center of the lens system. Where spherical mirrors are used, they should be placed in such a manner as to reflect the image back on the filament itself. By this means, efficient utilization of light and an even field will be secured. More detailed instructions on focusing will be found in Bulletin Index 21, Fundamentals of Projection.

Handling

While the MAZDA lamp will stand reasonable handling, it is obvious that the rather fine filament may be broken with severe shocks, particularly after having been burned for a while and become crystallized. Men handling lighting apparatus should be cautioned to use care.

The Production of Colored Light

The light emitted by the MAZDA lamp has a continuous spectrum, in other words, all the colors of the rainbow are present. Hence, since all colors are available in the "raw or unmodified" light we have a fortunate condition for obtaining any effect.

Suppose red light is wanted, it is necessary to "subtract" or screen out the orange, yellow, green, blue and violet rays or in other words, the complementary color (blue-green). If blue-green light is wanted, the red, orange and yellow rays are absorbed. If the effect of orange is to be obtained, the green, blue and violet

Fig. 12

This Gives a Very Rough Idea of the Special Equipment Often Installed for a Particular Production. In this instance, none of the regular stage equipment is employed. In addition to twenty-eight units for lighting the cyclorama, a total of sixty lens spot lamps with concentrated filament MAZDA C lamps are employed. These are individually controlled and specially positioned. They are located at each side of the proscenium arch, on the front bridge, at the entrances, in the balcony and beneath glass plates in the floor. Four arc effect machines will be noted on the front bridge.

portion is screened out. To remove any of these rays is a comparatively simple matter. It is only necessary to pass the light through some medium which will absorb the particular part or parts we desire to lose.

A piece of red glass or gelatin, for example, absorbs orange, yellow, green, blue and violet light, transmitting red light. A green screen may absorb red, orange, blue and violet rays, giving a yellowish-green light. It is *impossible to add anything* to the light emitted by the lamp filament and all that can be done is to *get rid of* some portion that is not desired. Hence, all color changes of this character involve a loss of light, the exact amount depending on the color obtained. This means that to obtain the same illumination with colored light, two, three or fifty times the wattage must be used in comparison with that used for unmodified, often called white, light. The following table gives some approximate figures on the absorption or loss of light necessary to obtain various colors of light from the MAZDA lamp. These values are subject to considerable variation, depending on the purity of color secured and other factors.

Ordinary Designation	Absorption Per Cent	Transmission Per Cent	Wattage to Produce Same Illumination as with Unmodified (White) Light Per Cent
Red	85–75	15–25	400 to 600
Orange	70–50	30–50	200 to 300
Yellow	40–20	60–80	125 to 150
Green	80–90	10–20	500 to 1000
Blue	95–90	5–10	1000 to 2000
Purple	98–95	2– 5	2000 to 5000

Fortunately, as will be pointed out later, we rarely require a high level of colored lighting.

The next point concerns the mechanical means of obtaining colored light. There are several methods which possess certain advantages and disadvantages which will be analyzed.

A—Superficially colored lamps are inexpensive and effective. If the bulb becomes broken, the lamp is useless, but the general color effect is not marred. Dipped lamps have what is called a transparent coating, and purity of color can be secured in this manner. It is a rather unpleasant task to apply the dip, and breakage of lamps during the process is likely to be rather high. Very few of the lamp dips are permanent, fading from the heat of the lamp and requiring new coatings at frequent intervals. Where lamps are located in inaccessible places, this is an expensive proposition. Small relatively inefficient lamps must be used, for none of the transparent colors or standard dyes will stand up under the higher temperature of the gas-filled or MAZDA C lamp.

MAZDA C lamps are available with sprayed coatings of a permanent nature. So-called opaque colors are the foundation of the coating. As a result, the emitted light acquires a tint through successive selective reflections from one particle to another of

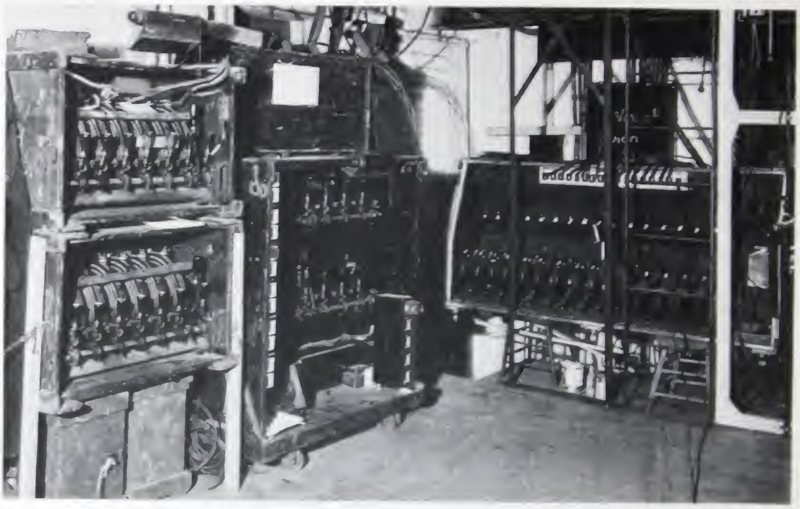

FIG. 13
The Portable or Traveling Switchboard Used with the Equipment Illustrated in Fig. 12. In addition to the individual switches, twenty dimmer plates are necessary to obtain the correct artistic blending of color and direction

the opaque coating. It is obvious that such a process is relatively inefficient, compared with the selective transmission absorption of the transparent dye and further, that purity of color cannot be secured. Sprayed lamps, however, have a definite field of application and find considerable use where "tinted" illumination is required.

B—Natural colored glass lamps possess the advantages outlined above under dipped bulbs and in addition, are permanent. They are available in many colors in any size, but of relatively high first cost.

C—Glass caps possess the advantages of colored bulbs and cost much less over a period of time but where lamps are exposed to view, are somewhat unsightly. To date, caps have been developed for use up to and including the 150-watt MAZDA C lamp. These must have a well designed holding device to prevent any possibility of the cap dropping and also so constructed as to permit no "white" light to escape.

D—Glass plates are somewhat difficult to apply, needing a special holding device and are rather expensive. They are obviously of use across the mouths of only relatively small reflectors.

E—Gelatin color screens are available in a wide variety of tints and shades. They are therefore especially of service to produce delicate gradations of color. The gelatin material is rather difficult to manipulate, being affected by moisture, extreme heat or cold. The screens break easily and the life of the screen in service is rather short. The gelatin screens are inexpensive, but cumbersome to handle. Where used across the mouths of reflectors or in border and strip lights, special precautions must be taken to have a reliable holding device. By this is meant some means of preventing the gelatin from curling, opening a gap and allowing unmodified light to escape, spoiling the effect. A network of fine wire overcomes this difficulty. The means of holding the color-frame in place is also important. A drop will frequently sway as it is being raised to the flies, striking a border light and possibly breaking or knocking a screen out of place. This necessitates lowering the entire border and replacing the screen. If colored lamps are used and this happens, one or two lamps may be broken, but the effect will not be marred. If color caps are used with a good holding device, unless the shock is severe enough to break the cap, the color effect would not be spoiled. It is likely that if the cap is broken, the lamp would be broken also.

F—Fabrics or colored paper screens are at best only temporary. They should be fire-proof in character. They tend to have a very high absorption for a given color modification. They are rarely of service for general color effects, save in times of necessity, but for decorative purposes in introducing a touch of color, ornamental silk shades function well.

The Effect of Color on Appearance of Objects

In order to use colored lighting intelligently, one must have a knowledge of certain comparatively simple fundamentals. It must be remembered that a thing is seen by the light it reflects to the eye. If light does not strike anything, one is not aware that there is light present. In the moving picture theater nothing is seen from the projection booth to the screen, unless there is smoking in the house, then the tiny particles of smoke, as they pass through the beam of light reflect and show the sharply defined edges of the beam.

If a room were finished in a dead black and there were no objects in it to reflect light and lamps were present but not directly visible, one could scarcely tell whether these were turned on unless he could see the light sources themselves. There would be no impression of light or color. Hence, to obtain the maximum effect of light and the special color effects for a given expenditure of power, light colored surroundings which reflect well are necessary.

Colored objects appear so because they pick out certain rays from the light and reflect these back to the eye, absorbing other rays. White light is made up of all the colors of the rainbow. A red object in daylight or under ordinary artificial illumination appears red because it reflects the red rays. A yellow object reflects yellow light and also red, orange and green rays, the other colors and tints act similarly.

Now what is the effect of colored light falling on colored objects? A *pure* red light falling on a red object will be reflected in full value; falling on a green object will be absorbed, and the object, reflecting no light, will appear black. If it falls on a yellow object, the object will appear red, because as mentioned above, the yellow reflects red among other colors.

There are three so-called primary colors of light which, mixed together, will give white. These are red, green and blue. Mixtures of two, or even the three primary colors in varying proportions will give all of the intermediate colors. Red and green will produce yellow; blue and green, blue-green; blue and red, purple; red and green, with more red than green, orange, and so on.

It must be remembered that light, rather than pigments, is being discussed. With pigments which act by the so-called subtractive method, the three primary colors are red, yellow and blue. With pigments, green is produced by mixing blue and yellow. References in the bibliography will give more detailed information on this question.

Certain effects produced by colored light falling on colored objects were mentioned above, and it must be borne in mind that the term "pure" was used. It is rare in practice that one encounters pure colors either in light or pigments. The general effects are, however, of the order indicated.

If one desires to go into the matter from a scientific standpoint, it is necessary to examine the light emitted by the colored lamp, or transmitted through the color screen with a spectroscope. A spectroscope is merely a prism set in some sort of tube and has the property of breaking up the light into its component parts.

A B C

FIG. 14

This Illustrates, in a Crude Manner, the Effect of Colored Light on Colored Objects
The foliage on the trees is green, the trunks and branches are red

A—The appearance when illuminated with white light
B—The appearance when illuminated with green light
C—The appearance when illuminated with red light

White light examined through a spectroscope shows us the complete spectrum or rainbow. Pure red light shows only the red part of the rainbow, the rest of the band or image appearing black. This instrument may also be used for examining the reflected light from colored objects. A very simple form of spectroscope which can be obtained at a very low cost is adequate for rough work.

The commercial reds (glasses, dips and gelatin screens) are usually quite pure; the greens frequently contain blue, yellow, and even a trace of red. The blues are likely to contain all the colors, blue, of course, predominating. In practice, therefore, before making the actual installation, it is desirable to experiment with both the colored light and the pigment intended for use on the scenery or decoration. By manipulation and correct choice of material, a desirable effect can be arrived at.

The action of colored light on colored material is of importance in decorative lighting and on the stage. By the proper combination of colored light and painted scenery, it is possible to entirely change a scene without manipulating any scenery. This effect is based on the following principle:

If we have a red object on a white background and illuminate it with red light, the background and the object will both reflect red light in its full value. There will be no contrast or difference in brightness, and the object will be invisible. Similarly, green light falling on a green object on a white background will cause the object to fade out.

Fig. 14 shows, in a crude manner, the effect just discussed. In this the foliage on the trees is green, the trunks and branches are red. Illuminated with white light, the foliage will appear green and the limbs red. If this is illuminated with green light (or viewed through green spectacles), the foliage fades into the background and the bare branches appear black or a dark brown. If it is illuminated with red light, the foliage appears brownish and the limbs are practically invisible. This crude example is purposely simple but with experimentation, the principle can be extended to produce truly marvelous and startling effects.

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