America's Oldest Radio School

RCA INSTITUTES INC.

A Radio Corporation of America Subsidiary

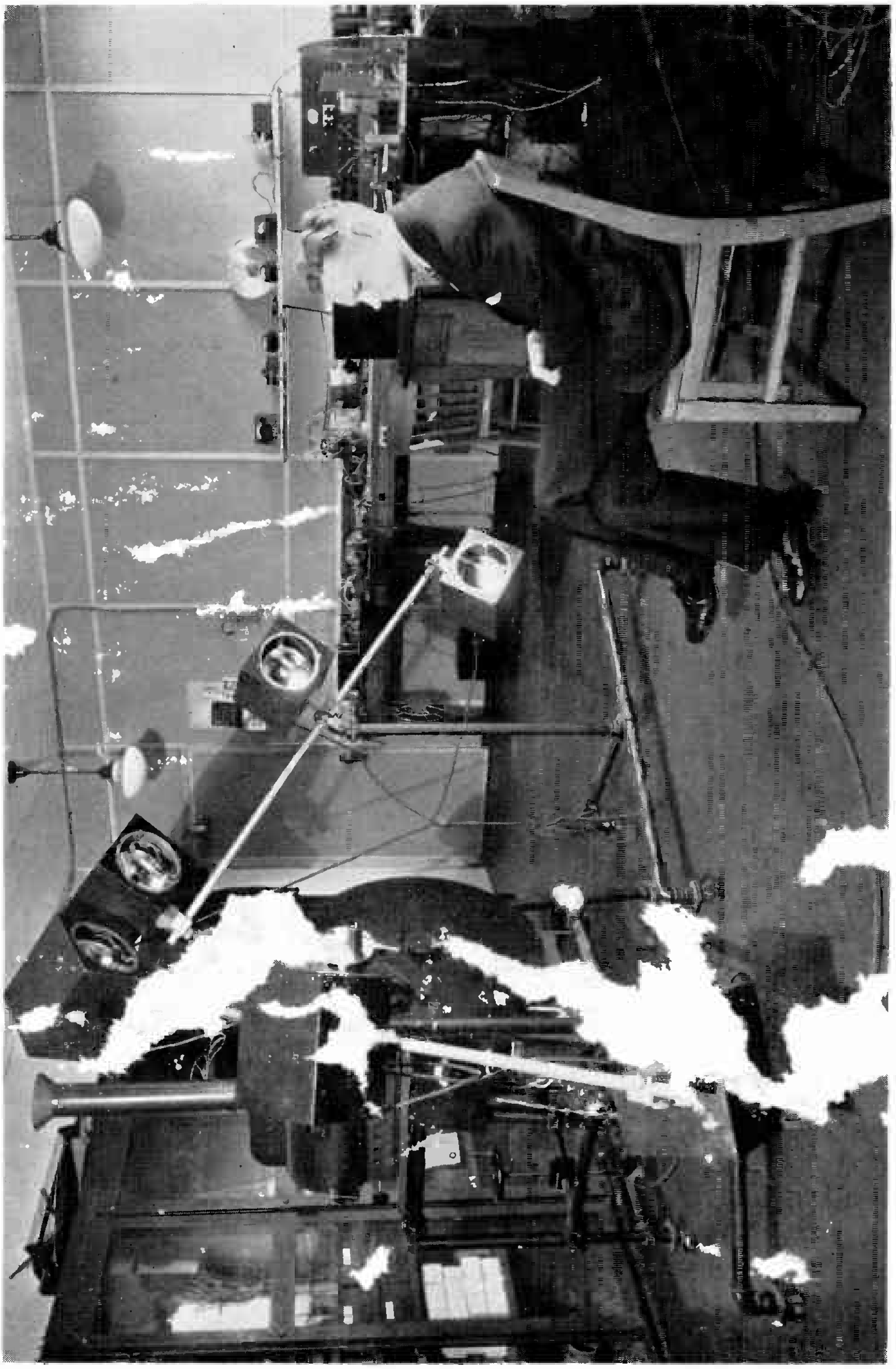
HOME OFFICE
75 Varick Street, New York
NEW YORK, N.Y. CHICAGO, ILL. PHILADELPHIA, PA. BOSTON, MASS.

The reflector on each lighting unit prevents waste of light by directing light rays on the scene being photographed.

Combination Lenses and Reflectors

Vol. 58, No. 8

Dewey Classification R 580



A battery of six reflectors gather light from the television subject and direct it to the photoelectric cells

Printed in U. S. A.

America's Oldest Radio School

A Radio Corporation of America Subsidiary

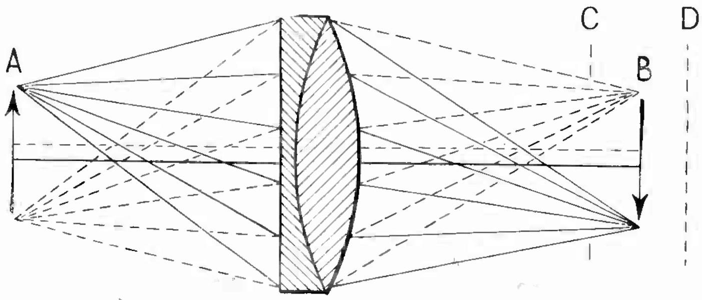
RCA INSTITUTES INC

HOME OFFICE
75 Varick Street, New York
NEW YORK, N.Y. CHICAGO, ILL. PHILADELPHIA, PA. BOSTON, MASS.

Combination Lenses and Reflectors

Distortion in Lenses

The table of comparative densities of various materials in another lesson showed that different transparent materials or mediums through which light travels have different densities. For examples of this peculiarity we have water which is denser than air, and glass which is denser than water. An examination of this chart shows further that even different kinds of glass have different densities. For instance referring to the chart it will be noted that flint glass is more dense than crown glass. At this time we wish to point out the fact that different mediums have densities of varying degree and the greater the density of any particular medium the more will it refract or bend light rays. As an



FIG[illegible]—*How a true image is formed b*[illegible]*ns.*

illustratio[illegible] flint glass ha[illegible] power than crown glas[illegible] kinds of glass just mention[illegible]d ex[illegible]ing combination or [illegible]rected lense[illegible] they a[illegible]apable of correct[illegible] ma[illegible]istortion present in sing[illegible] uncorrected len[illegible] namely, spherical aberration [illegible] ab[illegible]ration.

Spherical Aberration

Spherical aberration is the distortion of an image caused by the failure of a simple or uncorrected lens to focus all the rays of light passing through it at the same distance from the lens. We know that in order to produce a true image of an object a lens must gather rays of light from every point of the obj[illegible] and focus them on a plane surface, l[illegible] a screen, in proper relation to each other, or in other words the rays must have the same relation to each other as they had when leaving the object.

Figure 1 shows how a true image is formed by a corrected lens and it can be seen that the rays of light leaving each point of the object "A" is brought to a focus at the same distance from the center of the lens. These many points of light form an image "B" of the object in reversed form the image being clear and sharp only because the points are in focus at the focal plane of the lens. If some of the points of light came to a focus at "C", some at "B", and others at "D", they would not form a true image of the object.

Figure 2, shows how an uncorrected lens focuses the rays passing through its center at a greater distance from the lens than the rays passing through the edges of the lens, and it can be seen that at no place are all the rays brought to a point. This fault of uncorrected lenses is due to the fact that near the edges of the lens the light rays are refracted out of proportion to those passing through points nearer the center. We know that at the exact center there is no refraction at all, because the rays of light passing through at this point are on a line with the normal of the lens surface at which place no refraction occurs. Figure 2, shows that the rays from various parts of the lens are focused at different distances from the lens or on different planes, as on planes "A" and "B". It should be realized that each part of an uncorrected lens from the center out to the edge has a different focal plane although only two points have been shown in Figure 2 to simplify the diagram.

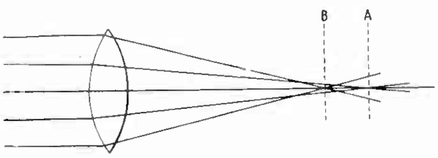


FIGURE 2—*An uncorrected lens does not focus all rays to a single point.*

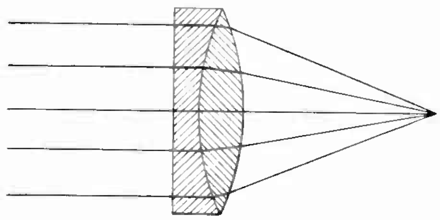


FIGURE 3—*Construction of a corrected lens.*

It is known that if the rays of light passing through the lens between the center and the edge are made to focus at a point further away from the lens, then all the rays can be brought to a focus at a single plane, as for instance to a plane "A" in Figure 2. The method employed in the manufacture of a lens is based on this fact and a corrected lens becomes an improvement over a simple lens by using two kinds of glass each having a different density and form as shown in Figure 3, the two kinds of glass used in most lenses being crown glass and flint glass. The rays that would be focused too close to the lens in an uncorrected lens are now caused to change their courses and come to a focus at a single focal plane by the different refractive powers of these two materials when used together.

Chromatic Aberration

Many different forms of this type of corrected lens are found in actual practice but the purpose of each of them is the same, to correct distortion and produce a clear, sharp image of the source with the least possible loss of light. The other form of distortion, chromatic aberration, mentioned in the first paragraph of this lesson, is caused by the fact that a simple, uncorrected lens separates the various colors which together make white light and focuses each color at a different focal plane. Thus, a beam of white light striking upon such a lens will have that part of it which passes through the lens nearest its edges, separated into the various colors which make up the "spectrum", the light being focused at various distances from the lens, the violet color coming to a focus nearest the lens, and the red color furthest away from the lens.

This chromatic aberration is always present in the type of condenser lens used in the lamphouse of a motion picture projector and inasmuch as the lens produces a ring of color on the outside edges of the spot of light thrown on the aperture of the picture head, we now see more clearly that the spot of light must not be allowed to become too small or some of the colored light will pass through the aperture and appear on the motion picture screen. Occasionally, this color is seen by the audience when the arc sputters for a moment, changing its position and throwing the edge of the spot on the aperture, thus passing the color through to the screen. Figure 4 shows how the various colors of the spectrum are focused at different planes by an uncorrected lens, such as a convex condenser lens. The dotted line "V" is the plane at which the violet rays are focused, "B" the blue, "G" green, "Y" yellow, "O" orange and "R" red. By correcting the lens as shown in Figure 3, the various colored rays are caused to come to a focus at the same plane and the colors joining each other produce white light. A very conclusive demonstration that these various colors, when joined, will produce white, is to make a cardboard wheel and paint or chalk in segments of these colors shaped like pieces of pie. When the wheel is revolved rapidly persistence of vision causes the colors to blend so that the entire wheel or disc appears white.

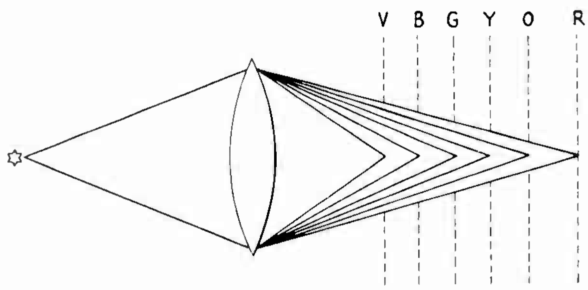


FIGURE 4—*Separation of white light into colors.*

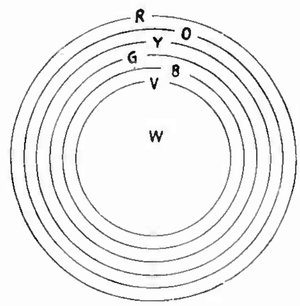


FIGURE 5—*Showing the projection of the light of Figure 4 on a screen.*

In Figure 4 only the rays of light from the source that strike the edges of the lens are shown because it is at the edges of a lens that the distortion or aberration is most marked. The color rings shown in Figure 4 would appear in the positions shown in Figure 5 if they were projected to a screen. The colored rings from the inside out are violet, blue, green, yellow, orange, and red, while the circle in the center "W" is white due to the fact that the white light from the source, passing through the central area of the lens is not separated into colors. Therefore, in motion picture work usually when color shows up on the screen it is because the light of the arc is focused to too small a spot on the aperture and instead of passing only the white center of the beam through the aperture, a part of the colored edges of the spot is also getting through to the screen. It is evident that when this condition occurs the appearance of the picture on the screen is damaged by this rainbow of colors drifting around the edges of the screen. While corrected lenses in the picture head prevent chromatic aberration of the light delivered to them at the aperture, if the light is already colored by condenser lens distortion then the screen will show colored light. The remedy in this case is to enlarge the size of the spot so that only the white center of it passes through the aperture, while the colored edges are cut off by the cooling plate of the picture head.

Combination or Corrected Lenses

Figure 6, shows a modern combination lens, made by Zeiss, used in photography, the focal length of which is 4 inches which means that parallel rays of light converge as shown at the focal plane "F", or principal focus which is located 4 inches from the lens. This plane "F" is where the film is placed in a motion picture camera and the image of the scene being photographed is brought to a sharp focus in order to expose the sensitive emulsion on the film. As can be seen in Figure 6, the path of the rays through the different combinations that make up the complete corrected lens changes as it passes through so that when the rays finally emerge or come out of the lens they are free from spherical and chromatic aberration and come to a sharp, clear focus at the focal plane "F".

The two kinds of glass used in this lens, namely, crown and flint, are shown by diagonal lines running in a certain direction in one case and in an opposite direction in the other. The part of the lens combination on the right is made up of two kinds of glass cemented together so that no air space separates them and since the cement being used is balsam cement, which has a density about equal

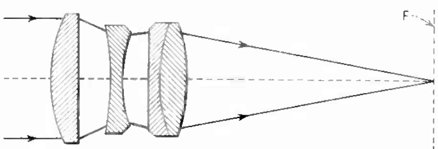


FIGURE 6—*A combination or corrected lens.*

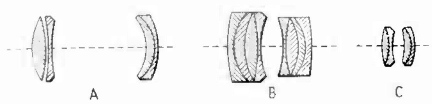


FIGURE 7—*Lenses (a) Tele Tessar (b) Universal (c) Wide Angle.*

to glass there is therefore no refractive effect as the light passes from the glass to the cement or from the cement to the next glass surface. Inasmuch as there is no air space between the two sections of glass the only refraction that occurs is due to the difference in density between the crown glass and the flint glass. This lens is known as an extra-rapid lens because it will allow a large amount of light to pass through in a short time thus permitting very rapid exposures of short duration to be made as in the case of high speed motion picture photography which was discussed in a previous lesson.

Other types of Zeiss lenses are designed for various purposes several combinations of which are shown in Figure 7. "A" is known as the Tele Tessar and is a long focus lens for use in "bringing distant objects closer". As a telescope when held to the eye enlarges distant objects to the vision, so in like manner a Tele Tessar lens makes a distant object appear much closer on the film. "B" is known as a universal lens because it is not necessary to focus on objects at different distances from the lens in order to get a sharp image at the focal plane or film. The lens is fixed at a certain distance from the film and all objects beyond a certain distance from the lens will be in focus. "C" is a wide angle lens used to photograph interiors where a large scene is to be taken but where it is not possible to get the camera back far enough to get the whole scene with an ordinary lens. This lens is also used for outdoor panorama scenes where it is desired to take a picture of a large section of scenery. All of these combinations are made of glass material of various densities cemented together.

Lenses are held in place in the proper position by means of lens mounts, which are metal tubes that can be screwed into the camera front. In the case of motion picture cameras the various lens combinations used for different purposes are mounted on a vertically revolving turret which allows any lens to be rotated to a position before the camera aperture, as we saw in the illustration of a standard motion picture camera in a previous lesson. Figure 8 shows the lens combinations which were described in Figure 7 mounted in lens tubes. "A" is the Tele Tessar, "B" the Universal, and "C" the wide angle combination.

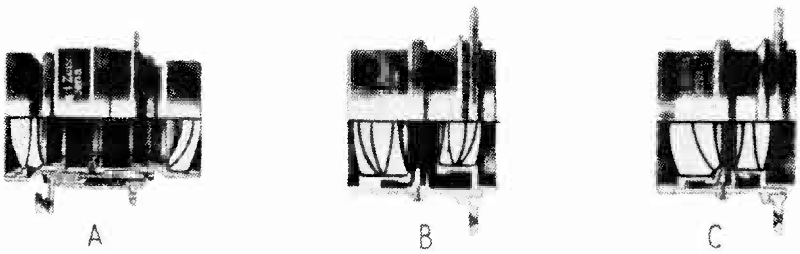


FIGURE 8—*How Zeiss Lenses are mounted.*

Use of Lenses in Motion Pictures

The action of a lens used in a motion picture projector is in certain ways quite the opposite of a lens in a camera. For instance, the lens in a camera focuses the light coming from the object to a small image on the film, in other words the object is usually larger than the image. This is more clearly seen in Figure 9 where "A" is the camera lens, "B" a large arrow which represents the object to be photographed, and "C" the image of this object focused on the film in the camera. If we turn this sketch around and add a source of light, shown passing through the condenser lens "E" in Figure 10, we have an arrangement that shows how the object, in this case the arrow on the positive film in the aperture of the motion picture head, is projected to the screen as an enlarged image. With the aid of Figures 9 and 10 it is possible to show the paths of light rays from the taking of the picture by the camera, to its projection on the theatre screen.

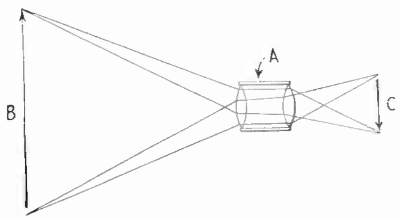


FIGURE 9—*Small image of large object produced by a lens.*

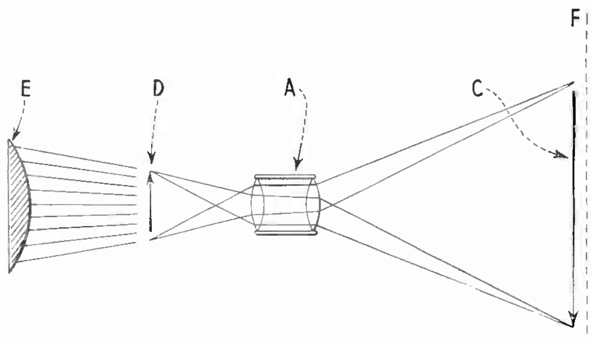


FIGURE 10—*Projection of film image to screen by projector lens.*

Referring to Figure 9 first, the object "B" to be photographed reflects rays of light which enter the camera lens "A" and are focused to an image "C" on the sensitized negative film in the camera. The action of the light rays aided by chemical development later in the process, produce an image of the arrow in metallic silver on the negative film which is used to "print" a "positive" on another strip of film. This positive is threaded into a projector in the operating booth in the theatre and the light from an arc lamp is focused by the condenser lens "E" in Figure 10 on the positive film "D" as it passes through the aperture of the picture head. The light passing through the film enters the projector lens "A" and is focused to an enlarged image "C" on the screen "F". The arrow in these illustrations is used merely to make the sketch clearer and in all cases of actual practice the arrow would be replaced by a scene or a person or whatever the scenario called for in the way of photography. The fact that a lens may be used either for taking or projecting a picture is taken advantage of by some makers of amateur movie equipment, inasmuch as they make cameras which not only take pictures but are also able to project pictures with the aid of an additional light source.

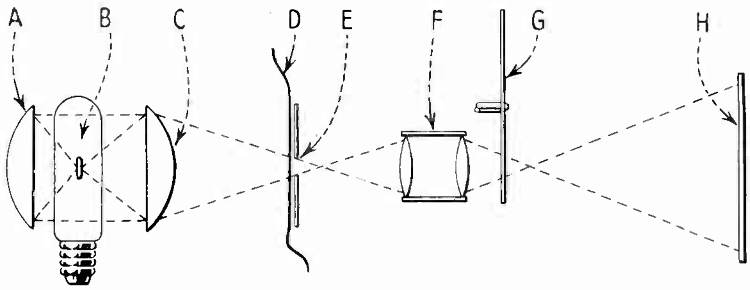


FIGURE 11—*Incandescent lamp and projecting devices.*

The necessary optical elements for motion picture projection are shown in Figure 11. In this illustration, instead of showing an arc light as a source of illumination, an incandescent filament lamp of high candlepower is used. This form of light source is seldom used in theatre projection unless the theatre is extremely small. In general its use is confined to private home installations and to portable projectors such as those made by R.C.A. Photophone and Electrical Research Products, Inc. 1000 watt filament lamps are generally used in these portable projectors and by their use a source of light is secured that is strong enough for the purpose of short range, small screen projection, and yet is more simple in operation and less liable to fire risks than an arc lamp.

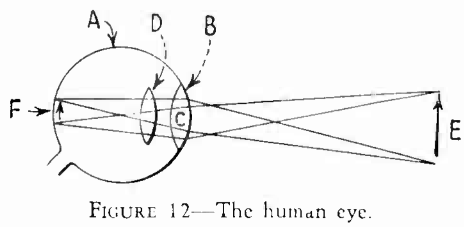


FIGURE 12—The human eye.

Referring to Figure 11, "A", which is a parabolic mirror, reflects the light from the incandescent filament "B" to the cendenser lens "C", which focuses the light to a spot on aperture "E" and the film "D" running before it. The light rays then are received by the projection lens "F" or "projection objective" as it is called, and focused to an enlarged image on the screen "H". The revolving shutter "G" whose action we studied in the lesson on projection, serves to cut the light from the screen at certain intervals to eliminate "travel ghost" and aid persistence of vision.

The Eye

One seldom thinks of the eye as an ingenious arrangement of lenses, yet it is, and moreover in certain respects it functions like a camera as Figure 12 attempts to illustrate. The eye has a lens which takes the rays of light falling upon it from an object, and focuses them to an image on the retina which is an expansion or spreading out of the optic nerve at the back of the eyeball. This retina can be compared to the sensitized film in a camera but, obviously will not keep a permanent record of the

Printed in U. S. A.

image focused upon it as would a camera film. The retina will transmit to the brain objects or scenes only while in view and for a brief moment after removal from view, as explained in our study of persistence of vision.

Observe that in Figure 12 the eyeball "A" has the "cornea" "B", the "aqueous humor" "C", and the "crystalline lens" "D", all of which act as a single lens and focus light from an object "E" on the retina "F". It should be borne in mind that the apparent size of an object seen by the eye depends on the size of the image formed by the lenses of the eye on the retina and for this reason the man in

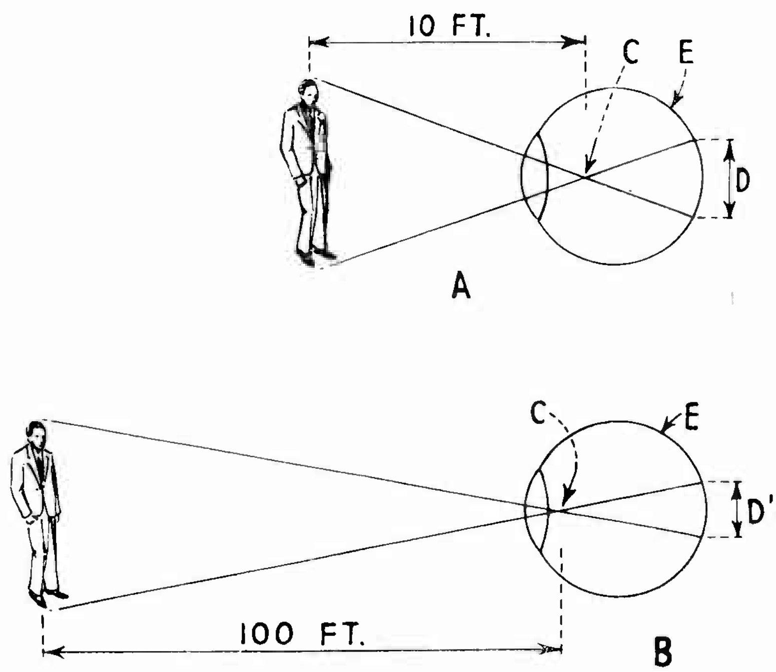


FIGURE 13—*Apparent size of an image depends on the visual angle.*

sketch A, Figure 13, appears in actual life to be ten times as large when he is ten feet away than he appears when he is 100 feet away. This is because the image on the retina of the eye is 10 times as large in "A" as in "B". From experience, however, we have learned that no man is ten times as large as another man and thus we say that one man only "appears" so much smaller than another because he is farther away. In Figure 13 "A" and "B", "E" is the eyeball, "C" the center of the lens system, and "D" the size of image on the retina. The distance "D" in Figure 13A is supposed to be 10 times as long as the distance "D" in 13B. An interesting feature of the lens in an eye is that it focuses objects at different distances, by changing the shape of the lens through muscular movement, thus making a thicker or thinner center of the lens at will. This action is called accommodation and results in a changed focal length of the lens which we know brings the image to a focus at a different place. In order to produce the same effect in cameras the lens is moved back and forth in relation to the film thus bringing the image to a sharp focus no matter what distance the object is from the lens.

Printed in U. S. A.

Telescope and Microscope

The magnifying power of a telescope is due to the fact that the front lens or objective shown at "O" in Figure 14, forms an image in front of the black lens or eyepiece "L". The rays of light "R" from a distant object in Figure 14 are focused by lens "O" to an image just in front of lens "L". Lens "L" changes the wave form of the light rays so that the eye seems to see the object at "I", as a virtual image in enlarged form.

The microscope works on somewhat the same principle as the telescope, as it forms an enlarged image directly before the eyepiece which is then changed in form by the eyepiece so that an enlarged virtual image is seen by the eye. Figure 15 illustrates the action of a microscope where "O" is the object, "J" the objective lens, "I" the image formed by the objective lens, "L" the eyepiece lens. "E" is the enlarged image which the eye sees in inverted form as was illustrated by "E" in Figure 14.

The microscope is used in sound motion picture work to examine the groove cut into the wax disc as sound is being recorded. The grooves are only 1/100 of an inch apart, that is, there are 100 grooves to the inch along the radius of the wax disc so that in order to see whether the recording is being done properly it is necessary to use a microscope which magnifies each groove so that each

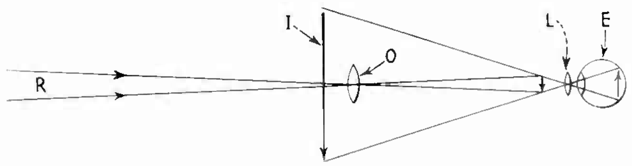


FIGURE 14—*The principle of the telescope.*

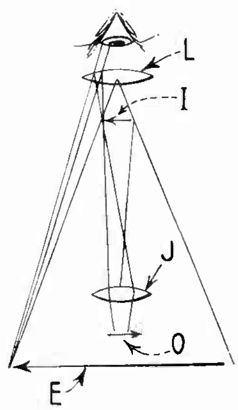


FIGURE 15—*The compound microscope.*

small "wave" cut into it by the recording stylus or needle is clearly visible to the eye. In a following lesson on recording, the microscope will be seen swung into place over the recorder turntable so that the recording engineer can check the operation of the equipment.

Care of Lenses

Lenses, as used in sound motion picture equipment, are expensive and easily damaged, therefore great care must be exercised in handling them. In order to get the best results from lenses it is necessary that they be kept clean, for if oil or fingerprints are allowed to remain on the surface, the sharpness of the image focused by the lens will be seriously affected and what is known as "poor definition" will result. Oil on a lens also causes some of the light to be reflected instead of being transmitted through and this is an undesirable condition because loss of light means a dimmer picture will be found on the screen. Loss of light also means that there is a waste of light and power which may prove expensive. In cleaning a lens only soft, clean, chamois skin or soft cotton material should be used and the surface of the lens should not be rubbed too hard for fear that grit may scratch the glass. A good cleaning fluid for a lens is about half a pint of alcohol diluted with the same amount of water. The lens surface should be washed with this solution and then quickly polished while still wet. Occasionally lens assemblies should be taken apart and the interior surfaces of the various lenses cleaned. In reassembling the lenses in the lens mount special care must be taken to see that they are put back in proper relation to one another.

 Printed in U. S. A.

Projection or Objective Lenses

Projection lenses are usually made up of a combination of four lenses as shown in Figure 16. "A" shows them unmounted and "B" shows them assembled in a lens mount. The two lenses at the left of each illustration are known as the "back factor" of the combination and are nearest the film, while the other two are called the "front factor". It will be seen that the safe rule to follow in assembling a lens is to have the sides with the greatest convexity toward the screen. The back factor has an air spacing between its two lenses while the lenses of the front factor are cemented together with balsam cement.

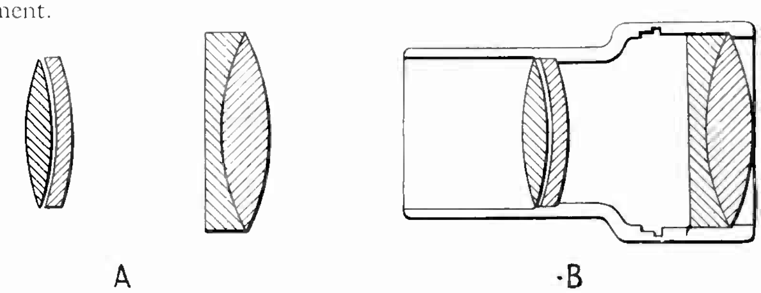


FIGURE 16—*Projection lens (a) Unmounted, (b) mounted.*

The diameter of the lens used in projection is important for if the diameter is too small a large loss of light will result since a small opening will cut off a great deal of light that would reach the screen with a larger lens. However, the smaller the lens opening becomes, the sharper will be the focus of the picture on the screen and the narrower will be the beam of light where it is cut by the revolving shutter; a condition that is desirable. If the projection lens is not of large enough diameter to receive all the light that passes through the aperture from the condenser lens, it will be impossible to evenly distribute illumination over the entire surface of the screen. In this case, the center of the screen will be brighter than the edges and the picture will not be so pleasing to the eye because of the loss of "depth" as this peculiarity is called.

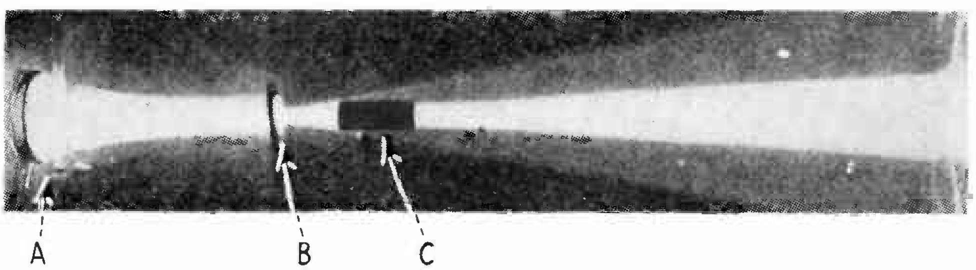


FIGURE 17—*The effect of too small a projection lens.*

This effect of "depth" which gives the impression that the objects in the picture are at different distances from the spectator in the theatre even though the screen as we know is flat, is obtained by proper reproduction on the screen of the light and shadows in the film. The best example of this illusion is seen in stereoscopic pictures of which we shall learn more later. A certain amount of "depth illusion" is possible by the use of (1) proper lighting during the photography of motion pictures and (2) evenly distributed illumination when the picture is projected on the theatre screen.

The effect of too small a projection lens to receive the full beam of light from the aperture is shown in Figure 17 which is an actual photograph of the course of light rays from the condenser lens of a projector, through the aperture and thence through the projection lens. The aperture "B" is the oblong opening that frames each single picture as it is pulled into place by the intermittent movement. The condenser lens "A" focuses a spot of brilliant light from the arc on this aperture, and if the spot is of the right size and properly focused the whole of the picture on the film that is framed by the aperture will be evenly illuminated. If *all* the light from the aperture passes through the projection lens which is shown at "C", then the lens will focus an evenly illuminated image of the film on the screen. Under the conditions shown in Figure 17, however, some of the light coming through the film at the edges of the aperture is not entering the projection lens and therefore is lost as far as the screen is concerned. This means that pictures projected through an optical train like this will have bright centers and dimmer edges which will lessen the depth effect and the enjoyment of the picture by the audience even though they cannot definitely account for the reason. Figure 18 is an illustration of an optical train that will project the picture at the aperture with evenly distributed illumination on the screen, for it can be seen that the entire beam of light from the condenser lens "A", passing through the film at the aperture "B", is received by the projection lens "C" which focuses the light to an image on the screen.

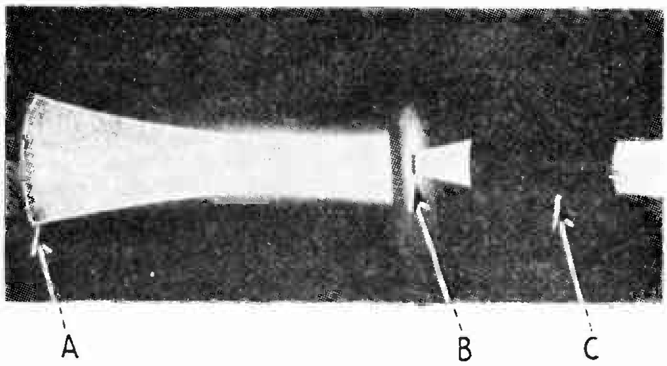


FIGURE 18—*Larger diameter projection lens and its effect on uniform screen illumination.*

Commercial objective, or projection lenses may be obtained in two standard sizes, the "quarter" size or Number 1 lens which has a "free aperture" or opening of about $1\frac{1}{2}$ inch diameter and the "half-size" or Number 2 lens which has a free aperture of about $2\frac{1}{2}$ inch diameter. These lenses, when of good make, usually have the characteristics of: (1) no spherical aberration, which means good definition with no distortion of the image; (2) flatness of field, which means that the image will be equally sharp over the entire surface of the screen; and (3) freedom from chromatic aberration, which means the absence of color fringes in the image. In addition to the above the Number 2 lens gives brilliant screen illumination due to its larger free aperture or opening.

The focal length of the objective lens determines what the size of the picture will be for a certain "throw" or distance between the center of the objective lens and the screen. In the study of single convex lenses we used the term "focal length" to express the distance from the lens that parallel rays of light from a distant source were brought to a single point or focus. The focal length of the lens shown in Figure 19 is five inches because the parallel rays "A" pass through convex lens "B" to a point "C" which is just five inches from the center of the lens. In an objective lens, however, we are dealing with a number of separate lenses that are assembled to form the complete lens combination, so instead of an objective lens having a focal length the assembly has what is called an "equivalent focus" which means that its focus is the same as a single lens of that focal length. To make this clearer look at Figure 20 which shows an objective lens which has an equivalent focus equal to the focal length of the single lens in Figure 19. In Figure 20, however, the equivalent focus is measured from a point somewhere between the front and back factors of the lens, called the "optical center", to the place where the rays of light are brought to a focus, or the "focal plane". "A" shows the parallel rays of light passing through the objective lens "B" which brings them to a focus at "C".

Selection of Objective Lenses

It must be realized of course that while in Figures 19 and 20 the incident rays are parallel, in the actual use of the lens in a projector the "front" of the light rays passing through the film aperture is very curved. From what was learned earlier in the course we know that when the incident wave front is curved the focal plane is removed further from the lens and in the case of motion picture projection the lens is so designed that it brings the image of the picture in the aperture to a focus on the screen many feet away. This brings us to a place where we can discuss how to select the right lens for a certain sized picture screen and a certain "throw". In other words, the problem arises where a picture house is of a certain length and the screen is a certain distance from the projection booth. If an objective lens with the proper equivalent focus, often abbreviated to E.F., is selected the picture can be made to appear on the screen in any desired size within limits. For instance, let us take a theatre with a throw, or distance from lens to screen of 100 feet. If a lens with an equivalent focus of 2″ is used, the size of the picture on the screen will be approximately thirty-four by forty-five (34 x 45) feet. This is a very short focus lens and gives a large screen picture for a given distance while an extremely long focus lens gives a much smaller picture at the same distance, for instance an 8″ E.F. lens throws a picture only 8½ x 11½ feet at the same distance.

Figure 21 is called a lens table of film projection, because with a given size of aperture which is about ¾″ by 1″ in standard motion picture projection, it gives the size of the picture thrown by

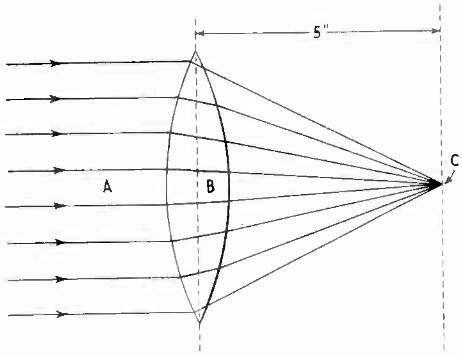


FIGURE 19—*Convex lens with focal point 5 inches from center of lens.*

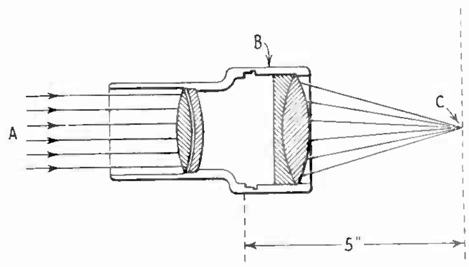


FIGURE 20—*Lens assembly with 5 inch equivalent focus.*

lenses of various E.F. at different distances of throw. Referring to the table, the lefthand column indicates equivalent focal lengths of lenses from 2″ to 8¾″. The top row of figures running from left to right denotes various distances from film to screen, ranging from 15 feet to 116 feet. The rest of the columns indicate the sizes of pictures at various equivalent focal lengths and distances of throw. It will be noticed that in each column opposite an equivalent focus number, there are two figures, the smallest at the top and the largest just below it. The top one of each pair of figures is the measurement in feet from top to bottom of the projected pictures or the height, and the one below it is the width, or left to right measurement of the picture. The proportions of the two measurements are as ¾ is to 1 because the picture on the screen is just an enlarged image of the aperture which is approximately ¾″ by 1″. In using the table to find the proper lens needed to project a picture of a certain size on a screen a known distance from the film, find the distance of throw in the top row of figures and glancing down that column find the size of picture desired. At the extreme left of that row the equivalent focus of the lens needed will be found.

Let us take an example and find the lens needed to project a picture about 15 x 20 feet in size on a screen 90 feet from the projector. Selecting the column with the figure 90 at the top of it we find that running down that column seventeen figures we find the figure 15.24 and directly under it figure 20.31. These are the nearest dimensions to 15 x 20 feet we can find so looking at the number

Lens Table of Film Projection

Distance from Film to Screen

E. F.	15	20	25	30	35	40	45	50	56	60	64	70	76	80	84	90	96	100	104	110	116
2	5.04	6.74	8.44	10.14	11.84	13.54	15.24	16.93	18.97	20.33	21.69	23.73	25.77	27.13	28.49	30.53	32.57	33.93	35.29	37.33	39.36
	6.72	8.99	11.25	13.52	15.78	18.05	20.31	22.58	25.30	27.11	28.92	31.64	34.46	36.17	37.99	40.71	43.42	45.24	47.05	49.77	52.49
2¼	4.48	5.99	7.50	9.01	10.52	12.03	13.54	15.05	16.87	18.07	19.28	21.09	22.91	24.12	25.32	27.14	28.95	30.16	31.37	33.18	34.99
	5.97	7.98	10.00	12.01	14.03	16.04	18.05	20.07	22.48	24.10	25.71	28.12	30.54	32.15	33.76	36.18	38.60	40.21	41.82	44.24	46.55
2½	4.02	5.38	6.74	8.10	9.46	10.82	12.18	13.54	15.17	16.26	17.34	18.98	20.61	21.70	22.78	24.42	26.05	27.14	28.22	29.86	31.49
	5.36	7.17	8.99	10.80	12.61	14.62	16.24	18.05	20.22	21.67	23.12	25.30	27.47	28.92	30.37	32.55	34.72	36.17	37.62	39.80	41.97
2¾	3.65	4.89	6.12	7.36	8.59	9.83	11.06	12.30	13.78	14.77	15.76	17.24	18.73	19.72	20.70	22.19	23.67	24.66	25.65	27.13	28.61
	4.87	6.52	8.17	9.18	11.46	13.11	14.76	16.40	18.38	19.70	21.01	22.99	24.97	26.29	27.61	29.59	31.56	32.88	34.20	36.18	38.15
3	3.34	4.47	5.61	6.74	7.87	9.00	10.14	11.27	12.63	13.54	14.44	15.80	17.16	18.07	18.97	20.33	21.69	22.60	23.50	24.86	26.22
	4.46	5.97	7.48	8.99	10.50	12.01	13.52	15.03	16.85	18.05	19.26	21.07	22.89	24.10	25.30	27.12	28.93	30.14	31.35	33.16	34.97
3¼	3.08	4.13	5.17	6.22	7.26	8.31	9.35	10.40	11.65	12.49	13.33	14.84	15.84	16.67	17.51	18.77	20.02	20.86	21.69	22.95	24.20
	4.11	5.50	6.90	8.19	9.69	11.08	12.48	13.87	15.54	16.66	17.77	19.45	21.12	22.23	23.35	25.02	26.70	27.81	28.93	30.00	32.27
3½	2.86	3.83	4.80	5.77	6.74	7.72	8.69	9.66	10.82	11.60	12.38	13.54	14.71	15.48	16.26	17.43	18.59	19.37	20.14	21.31	22.47
	3.81	5.10	6.40	7.69	8.99	10.28	11.58	12.87	14.43	15.46	16.50	18.05	19.60	20.64	21.68	23.23	24.78	25.82	26.86	28.41	29.96
3¾	2.66	3.57	4.47	5.38	6.28	7.19	8.10	9.00	10.09	10.82	11.54	12.63	13.72	14.44	15.17	16.25	17.34	18.07	18.79	19.88	20.97
	3.55	4.76	5.97	7.17	8.38	9.59	10.80	12.00	13.46	14.42	15.39	16.84	18.29	19.26	20.22	21.67	23.12	24.09	25.06	26.51	27.96
4	2.49	3.34	4.19	5.04	5.98	6.74	7.59	8.44	9.46	10.14	10.82	11.84	12.86	13.54	14.22	15.24	16.25	16.93	17.61	18.63	19.65
	3.32	4.45	5.59	6.72	7.85	8.98	10.12	11.25	12.61	13.52	14.42	15.78	17.14	18.05	18.95	20.31	21.67	22.58	23.48	24.84	26.20
4¼	2.34	3.14	3.94	4.74	5.54	6.34	7.14	7.94	8.90	9.54	10.18	11.14	12.10	12.74	13.38	14.34	15.30	15.94	16.57	16.52	18.48
	3.12	4.19	5.25	6.32	7.38	8.45	9.52	10.58	11.86	12.72	13.57	14.85	16.13	16.98	17.83	19.11	20.39	21.25	22.10	23.38	24.66
4½	2.21	2.97	3.72	4.48	5.23	5.99	6.74	7.50	8.40	9.01	9.61	10.52	11.42	12.03	12.63	13.54	14.44	15.05	15.65	16.56	17.47
	2.95	3.96	4.96	5.97	6.98	7.98	8.99	10.02	11.21	12.01	12.82	14.03	15.23	16.04	16.85	18.05	19.26	20.07	20.87	22.08	23.29
4¾	2.09	2.81	3.52	4.24	4.95	5.67	6.38	7.10	7.96	8.53	9.10	9.96	18.82	11.39	11.96	12.82	13.68	14.25	14.83	15.86	16.54
	2.79	3.74	4.70	5.65	6.61	7.56	8.51	9.47	10.61	11.38	12.14	13.28	14.43	15.19	15.15	16.23	17.32	18.05	18.77	19.86	20.95
5	1.98	2.66	3.34	4.02	4.70	5.38	6.06	6.74	7.55	8.10	8.64	9.46	10.27	10.82	11.39	12.21	13.03	13.57	14.12	15.02	15.75
	2.64	3.55	4.45	5.30	6.27	7.17	8.08	8.98	10.07	10.80	11.52	12.62	13.70	14.42	14.78	15.84	16.90	17.61	18.32	19.38	20.44
5¼	1.89	2.54	3.18	3.83	4.48	5.12	5.77	6.42	7.20	7.72	8.23	9.01	9.79	10.30	10.82	11.60	12.38	12.89	13.41	14.19	14.96
	2.51	3.37	4.24	5.10	5.96	6.83	7.69	8.55	9.59	10.28	10.97	12.00	13.04	13.73	14.42	15.46	16.49	17.18	17.87	18.91	19.94
5½	1.81	2.42	3.04	3.66	4.28	4.89	5.52	6.13	6.87	7.36	7.86	8.60	9.34	9.83	10.33	11.07	11.81	12.31	12.80	13.54	14.28
	2.40	3.22	4.05	4.87	5.70	6.53	7.35	8.17	9.16	9.82	10.47	11.46	12.45	13.11	13.77	14.76	15.73	16.40	17.07	18.06	19.04
5¾	1.72	2.31	2.90	3.49	4.08	4.67	5.27	5.86	6.57	7.04	7.51	8.22	8.93	9.40	9.99	10.59	11.29	11.77	12.24	12.95	13.66
	2.29	3.08	3.87	4.65	5.44	6.23	7.02	7.81	8.75	9.38	10.01	10.96	11.90	12.53	13.16	14.11	15.06	15.69	16.32	17.26	18.21
6	1.64	2.21	2.77	3.34	3.91	4.47	5.04	5.60	6.28	6.74	7.19	7.87	8.55	9.00	9.46	10.14	10.82	11.27	11.72	12.40	13.08
	2.19	2.95	3.70	4.46	5.21	5.97	6.72	7.48	8.38	8.99	9.59	10.50	11.40	12.01	12.61	13.52	14.42	15.03	15.63	16.54	17.45
6¼	1.57	2.11	2.66	3.20	3.75	4.29	4.83	5.38	6.03	6.46	6.90	7.55	8.20	8.64	9.07	9.73	10.38	10.81	11.25	11.90	12.55
	2.10	2.82	3.55	4.27	5.00	5.72	6.45	7.17	8.04	8.62	9.20	10.07	10.94	11.52	12.10	12.97	13.84	14.42	15.00	15.87	16.74
6½	1.51	2.03	2.56	3.08	3.60	4.12	4.65	5.17	5.80	6.22	6.63	7.26	7.89	8.31	8.72	9.35	9.98	10.40	10.82	11.44	12.07
	2.02	2.72	3.41	4.11	4.81	5.51	6.20	6.90	7.74	8.39	8.85	9.69	10.53	11.08	11.64	12.48	13.31	13.87	14.43	15.27	16.10
6¾	1.45	1.95	2.46	2.96	3.46	3.97	4.47	4.98	5.58	5.98	6.38	6.99	7.59	8.00	8.40	9.00	9.60	10.01	10.41	11.02	11.62
	1.94	2.61	3.28	3.95	4.63	5.30	5.97	6.64	7.44	7.98	8.52	9.32	10.13	10.67	11.20	12.01	12.81	13.35	13.89	14.69	15.50
7	1.40	1.89	2.37	2.86	3.34	3.83	4.31	4.80	5.38	5.77	6.16	6.74	7.32	7.71	8.10	8.68	9.27	9.65	10.04	10.62	11.21
	1.87	2.52	3.16	3.81	4.46	5.11	5.75	6.40	7.17	7.70	8.21	8.99	9.77	10.28	10.80	11.58	12.36	12.87	13.39	14.11	14.94
7¼	1.35	1.82	2.29	2.76	3.23	3.69	4.16	4.63	5.19	5.57	5.94	6.51	7.07	8.44	7.82	8.38	8.94	9.32	9.69	10.26	10.82
	1.80	2.42	3.05	3.67	4.30	4.92	5.69	6.17	6.92	7.42	7.92	8.67	9.43	9.93	10.42	11.17	11.93	12.43	12.93	13.68	14.43
7½	1.30	1.75	2.21	2.66	3.11	3.57	4.02	4.47	5.02	5.38	5.74	6.28	6.83	7.19	7.55	8.10	8.64	9.00	9.37	9.91	10.45
	1.74	2.34	2.95	3.55	4.16	4.76	5.37	5.97	6.69	7.18	7.66	8.39	9.11	9.59	10.08	10.80	11.53	12.01	12.50	13.22	13.95
7¾	1.26	1.70	2.14	2.58	3.01	3.45	3.89	4.33	4.86	5.21	5.56	6.08	6.61	6.96	7.31	7.84	8.36	8.71	9.07	9.59	10.12
	1.68	2.26	2.85	3.43	4.02	4.60	5.19	5.77	6.48	6.95	7.42	8.12	8.82	8.29	9.76	10.46	11.16	11.63	12.10	12.80	13.50
8	1.22	1.64	2.07	2.49	2.92	3.34	3.77	4.19	4.70	5.04	5.38	5.89	6.40	6.74	7.08	7.59	8.10	8.44	8.78	9.29	9.80
	1.62	2.19	2.75	3.32	3.89	4.45	5.02	5.09	6.27	6.76	7.18	7.86	8.54	8.50	9.44	10.12	10.80	11.25	11.70	12.38	13.06
8¼	1.18	1.59	2.00	2.42	2.83	3.24	3.65	4.06	4.56	4.89	5.22	5.71	6.21	6.54	6.86	7.36	7.85	8.18	8.51	9.01	9.50
	1.57	2.12	2.67	3.22	3.77	4.32	4.87	5.41	6.07	6.57	6.95	7.61	8.27	8.71	9.15	9.81	10.47	10.91	11.35	12.01	12.66
8½	1.14	1.54	1.94	2.34	2.74	3.14	3.54	3.94	4.42	4.74	5.06	5.54	6.02	6.34	6.66	7.14	7.62	7.94	8.26	8.74	9.22
	1.52	2.05	2.59	3.12	3.65	4.19	4.72	5.25	5.89	6.32	6.74	7.38	8.02	8.44	8.88	9.52	10.16	10.58	11.01	11.65	12.20
8¾	1.11	1.50	1.88	2.27	2.66	3.05	3.43	3.82	4.29	4.60	4.91	5.38	5.84	6.15	6.46	6.93	7.40	7.71	8.02	8.48	8.95
	1.48	2.00	2.51	3.03	3.55	4.06	4.58	5.10	5.72	6.13	6.65	7.17	7.79	8.20	8.62	9.24	9.86	10.27	10.63	11.31	11.93

FIGURE 21—NOTE: This chart applies to standard apparatus

opposite, in the left hand column we find 4 which is the focal length of the lens needed. As another example, let us assume that we have a "throw" of 110 feet and we wish a picture 9 x 12 feet in size. Running down the column headed 110 we find near the bottom the figures 9.01 and 12.01 and at the left in the E.F. column opposite is found 8¼ which is the proper lens for this condition.

It is evident that the lens table can be worked the other way around also and that the size of the picture for a certain throw can be found if the E.F. of the lens is known. It should be realized here that the larger the picture the less brilliant will be its illumination providing the light source remains the same. Therefore, it is only reasonable to expect that if a larger picture is desired more light must be provided at the lamphouse, and this is usually done by using larger carbons and higher current in the arc. That is why houses with large screens use arcs of upwards of 135 amperes current consumption when a smaller house with a smaller screen may use as low as 35 amperes on the arc. There are other factors which also govern the amount of light needed to project a satisfactory picture, such as screen surfaces, shape of the theatre, etc., which will be taken up at a future time in the course.

Reflection of Light

When light rays strike a polished surface, such as a mirror, regular reflection takes place. For example, in Figure 22 consider "A" as a source of light. The light from "A", upon striking the surface of the mirror "M", will be turned away, that is, reflected in a certain definite direction. The

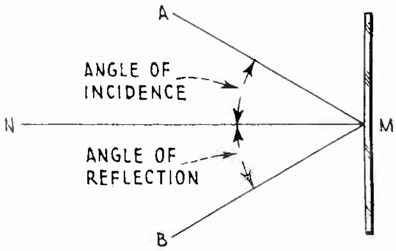


FIGURE 22—*Reflection of light from a plane mirror.*

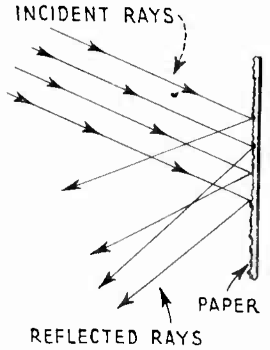


FIGURE 23—*Irregular or diffused reflection.*

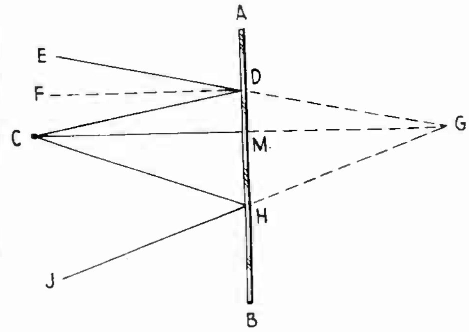


FIGURE 24—*The image of C appears behind the mirror at G.*

law that determines the direction the reflected ray will take is as follows: "*The angle of reflection is equal to the angle of incidence and the two angles thus made will be in the same plane*". Thus we learn that light striking the mirror at "M" will be reflected in the direction "M B". "A M" is called the incident ray, "M B" the reflected ray and "M N" the normal, which is drawn perpendicular to the surface of the mirror. Angle "A M N" is called the angle of incidence, and angle "B M N" the angle of reflection.

Boys often apply this principle in the school room, catching a sun beam on a small pocket mirror and then, by changing the position of the mirror, causing the reflected light to dance across the blackboard and perhaps into the eyes of a student.

Diffused Reflection

Now if we replace the mirror by a non-polished surface, such as a sheet of white paper as suggested in Figure 23, another condition becomes apparent. No longer do we obtain regular reflection because the rough surface of the paper acts as hundreds of small mirrors, the placement of which have no orderly arrangement. The light, therefore, is reflected in all directions. Reflection of this nature is called irregular or diffused reflection and enables us to see other planets and stars as they become illuminated by the sun, the diffused reflection from them traveling to the earth. Daylight, as we call it, is the sunlight repeatedly reduced in strength by an uncountable number of reflections from many surfaces, such as dust particles, the ground, shrubs, trees, houses, buildings, and so on. Now that we are familiar with some of the terms used in the study of reflection and diffusion we can proceed to the study of mirrors which will bring out facts concerning the reflection of light rays.

The Plane Mirror

An ordinary flat mirror, better termed a plane mirror, is a plate of glass having a smooth surface which, after being cleaned, is coated on one side with a solution of silver nitrate, ammonium hydroxide, and some reducing agent such as formaldehyde. This film of silver adheres to the surface of the glass and, after drying, it is varnished to prevent the air from reaching the metallic coating of silver. The coating of silver furnishes a good reflecting surface for light rays.

Assume that "A B", Figure 24 is a plane mirror fastened to the wall. Point "C" is a source of light producing a ray of light "CM" normal to the mirror. "CD" is any other ray striking the mirror at "D". The ray "CM" is reflected back upon itself but the ray "CD" will be reflected along the line "DE" in such a way that the angles "C D F" and "E D F" are equal. Now go back of the mirror and prolong the line "E D" and "CM" by dotted lines until they meet at point "G". We now have two triangles "C M D" and "G M D" which are similar and which make line "M G" equal to "M C". In the same way a third ray "C H" striking the mirror at "H" will be reflected in a line, the prolongation of which, if extended back of the mirror, will cut the line "C M" at "G". From this we are able to understand a peculiar fact concerning a reflecting surface such as a plane

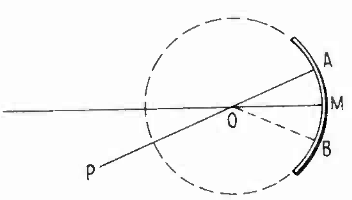


FIGURE 25—*Principle of the concave mirror.*

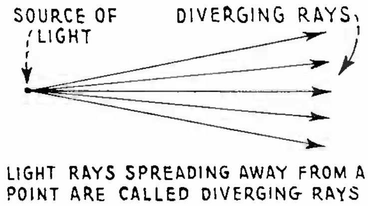


FIGURE 26.

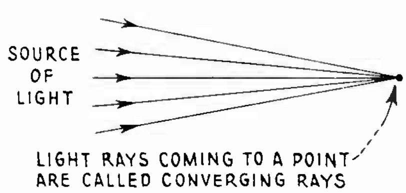


FIGURE 27.

mirror. If you stand anywhere in front of this mirror light rays will strike the eye and appear as though they were originating at "G" instead of at "C" and you will have produced for yourself an optical illusion, for an image of the light source "C" will appear to you as being situated at point "G".

It was previously stated that (1) an object to be seen must first be illuminated, which is true; and also that (2) light travels in straight lines. Furthermore, if an object is to be seen there must be no obstruction between the eye and the illuminated object that will act as a barrier to the light rays. By using a mirror, however, we can see around corners or view events taking place behind us, but this does not alter the law that light travels in straight lines because, between the object "C" and the mirror, there must be no obstruction for the light ray, neither can there be a barrier between the mirror and the eye. When you look into a mirror the objects you see appear to be located at some distance behind the mirror, as though you were looking through an opening in the wall. The eye sees only an image of the objects because the light from the objects are reflected light rays striking the eye from the direction of the mirror, and since the eye sends an impulse to the brain only of the direction from which light enters it, the object appears to be in that direction. If the frame of a mirror could not be seen and the reflecting surfaces were not detected the eye would not be able to distinguish the difference between the real object and its image in the mirror.

Printed in U. S. A.

S. O. 8655

Concave Mirrors

Mirrors of spherical or parabolic shape are employed in motion picture work, a small portion of the spherical surface of the mirror being capable of reflecting light. A mirror of this type shown in Figure 25 is called a concave mirror because it reflects light toward what would be the center of the mirror if it were completely circular as suggested by the light dotted circular lines. To explain the terms necessary to understand the reflecting properties of spherical mirrors let "A B" be a section of a circular mirror made by a plane drawn normal to the surface of a sphere or ball which is not shown. Point "O" of this surface will be the center of the mirror and the point shown at "M" will be the "vertex". A straight line drawn between "O" and "M" is given the name "Principal Axis". Any other line, such as "P A", drawn through "O" is called a secondary axis, and an axis, regardless of whether it is principal or secondary is always normal to the surface of the mirror. (Remember that the surface of the spherical mirror is not shown although the section "AB" represents a portion of it.) The angle formed by the lines "B O A" is called the aperture of the mirror.

Principal Focus

Figures 26 and 27 illustrate what is meant by focus. *A focus is a point from which light rays may diverge or a point toward which they may converge.* In Figure 28 assume that light rays from the sun, for example, are moving toward a concave mirror in a path parallel to the principal axis of the mirror. On striking the reflecting surface of the mirror they will be reflected very nearly to

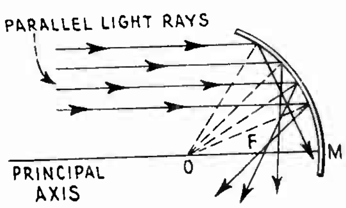


FIGURE 28—*Parallel light rays are concentrated at F by means of the concave mirror M.*

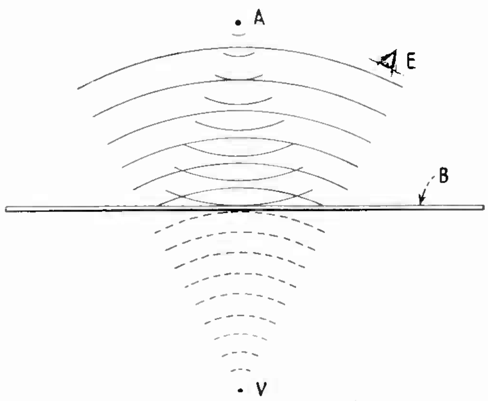


FIGURE 29—*Effect of a plane mirror on a wave front.*

point "F" midway between the vertex "M" and the center of the mirror "O". Those striking the reflector near its edge however will not be reflected to a point very near "F". This is called spherical aberration. The point "F" is called the "principal focus" of the mirror, and the distance from this point to the mirror is called the "focal length" of the mirror. Concentration of light rays from the sun in this manner can be so intense that a sheet of paper placed at the principal focus will promptly have a hole burned through it.

Applying the wave front method to demonstrate the effect of mirrors on light, Figure 29 shows how a wave front from a point source of light "A", striking a plane mirror "B", is reversed in form so that when it strikes the eye at "E" after reflection it is diverging in form and causes the eye to see the virtual image of the source at "V" which seems to be behind the mirror. The reason the source of light seems to be at "V" is that the small section of the light wave that is reflected from the mirror to the eye at "E" is of such curvature that its center is at "V" and the eye "sees" the object as being at this center. The actual path of the wave front is from the source "A" in ever-widening circles to the mirror, where the middle of the wave striking the mirror first is sent back toward "A", being followed by the ends a fraction of a second later. This reverses the direction of curvature of the wave front so that it goes back toward the source "A" in diverging rays and the eye at "E" sees a virtual image of the source "A" just as far in back of the mirror as the source is in front of it.

Focal Point and Center of Curvature

Let us now examine the effect of a concave mirror on a plane wave front as shown in Figure 30. There are two points in relation to concave mirrors, the location of which must be thoroughly understood. One is the "focal point", which is the place where parallel rays striking the mirror, are brought to a focus. The other point is the "center of curvature" of the mirror and is the point at

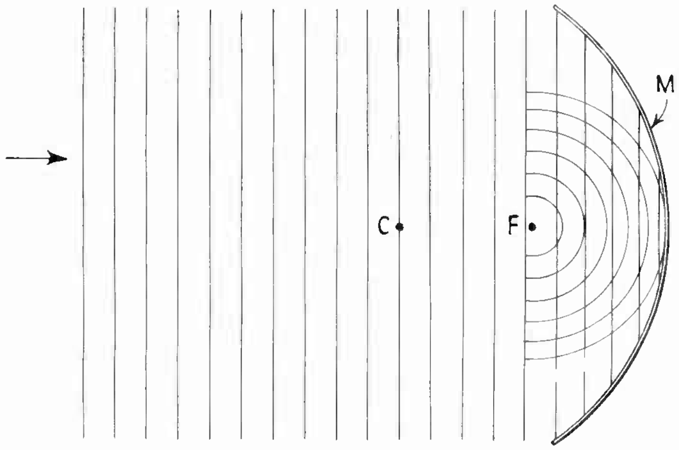


FIGURE 30—*Concave reflector changing curved wave front into plane waves.*

the exact center of the sphere or globe of which the concave mirror is a part. The focal point "F" is always half way between the mirror "M" and the center of curvature "C". Now, if the focal point "F" is the place where parallel rays of light striking the mirror are brought to a focus then if a source of light be placed at "F" the mirror should change the curved wave front into a plane wave front. Figure 30 can be used to illustrate both cases, that is, the first case where a plane wave front

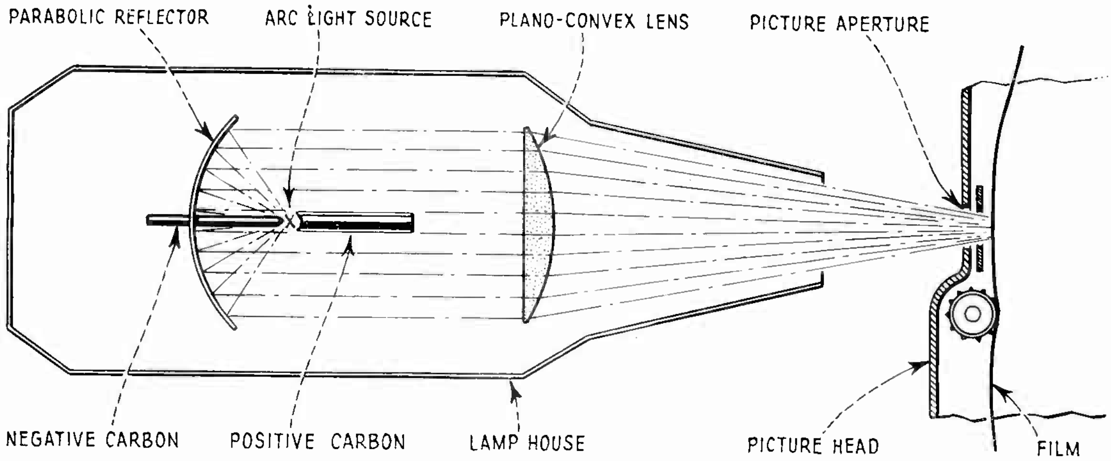


FIGURE 31—*Illustrating general relation of parts in lamp house and picture aperture.*

is travelling from the left of the illustration, in vertical lines and upon striking the mirror "M" is changed to a curved front which comes to a focus at the focal point "F", and the second case where the source of light is assumed to be at the focal point "F" and is changed by the mirror to a plane wave front travelling to the left.

A practical application of the use of a "concave type" mirror is the reflector arc lamp where a parabolic mirror is used to reflect the light from the arc in parallel rays to the cendenser lens which focuses them to a "spot" at the aperture as shown in Figure 31.

The effect of a concave mirror on a curved wave front from a near source of light is illustrated in Figure 32 where an image "I" of the object "O" is brought to a focus between the center of curvature "C" and the principal focus "F". If the source of light or the object were to be placed at "I" then the image would be produced at "O". The changing of the shape of the wave front when the object is at "O" is caused by the ends of the wave hitting the mirror before the center of the wave reaches it, thus giving the wave more curvature as it is reflected, and causing it to focus the image at a new center of curvature "I". In the case where the light source is between points "C" and "F", the middle of the wave strikes the mirror before the ends reach it, resulting in a flatter wave front which converges to a new center at "O". If the source of the light at "O" is moved toward the mirror the image "I" moves away from the mirror until the two points "O" and "I" come together at "C" which is the center of curvature of the mirror. The reason the object and the image coincide at "C" is that the curved wave front from the source of light, located at "C", strikes

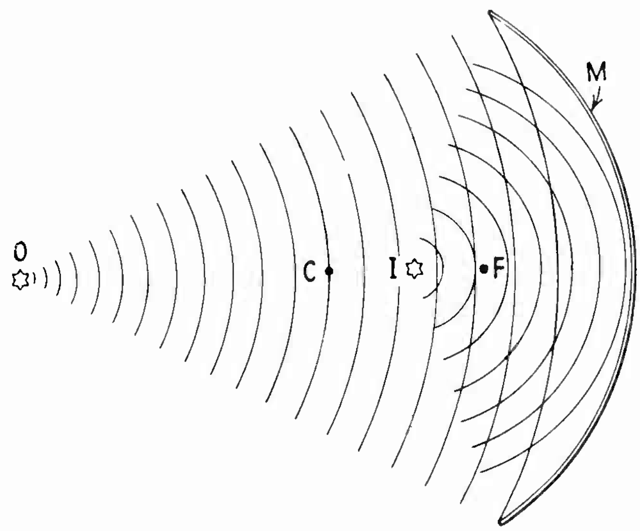


FIGURE 32—*The effect of a concave mirror on a curved wave front from a near source of light.*

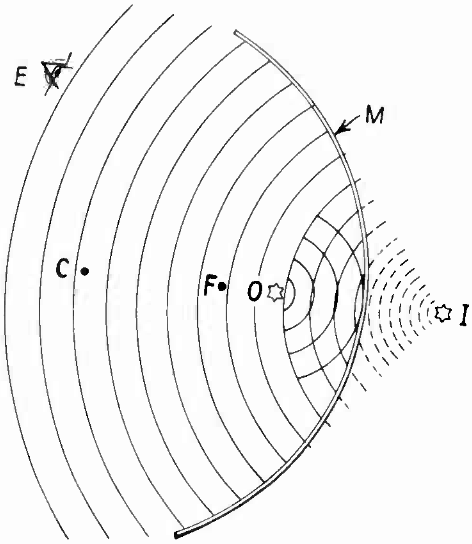


FIGURE 33—*A virtual image in a concave mirror.*

the mirror at all places at the same time and the reflected wave starts back in the same shape it had when it struck the mirror. Thus it comes to a focus at the starting point which is the same as the center of curvature of the mirror.

Another possible condition is that the object or source of light may be placed so close to the mirror that it is between the mirror and the principal focus "F". It has been shown that the wave front reflected from the mirror when the light is beyond "F" is converging, and that the wave front is flat or plane when the light is at the principal focus "F". Similarly it can be shown that the wave front reflected from the mirror when the light is between "F" and the mirror is a diverging one. We learned that a diverging wave front produced a virtual image that could be seen when a small section of this wave front entered the eye. This condition is shown in Figure 33 where "O" is the object, "C" the center of curvature of the mirror, "F" the principal focus and "I" the virtual image, which in this case appears to the eye "E" as if it were behind the mirror. The positions of images are the same with mirrors or with lenses for *real images are always formed by converging rays and are reversed or "upside down"* while *virtual images are produced by a section of a diverging wave entering the eye and always appear erect or "right side* up". Another form of mirror is the convex mirror

Printed in U. S. A.

shown in Figure 34, the images formed by it are virtual images. "O" is the object, "M" the mirror, and "I" the image seen by the eye "E". There are lamphouses that do not make use of a condenser lens, but use a properly located concave reflecting mirror which directs a powerful spot of light of the correct size on the aperture. While there are advantages to this type of lamphouse, such as the absence of the condenser lens with its liability to breakage and the loss of light it causes due to absorption, most of the commercial arc lamps make use of the collector lens (condenser lens).

Motion Picture or Aerial Image

The image projected by a motion picture projector is called an "aerial image" because the image itself is actually in the air at a certain distance from the lens, this distance being the point at which that lens brings the image of the object (film positive in this case) to a focus. In actual practice we place a motion picture screen at this point and the image becomes visible to the eye but whether a screen is there or not the image is at focus in space at that point even though we may not be able to see it. For instance, a picture machine might be projecting an image outdoors in clear air and nothing would be seen of it but if a cloud of dust particles or smoke or steam should suddenly fill the air at the focal point, the image would immediately become visible right in the air, so to speak. This effect

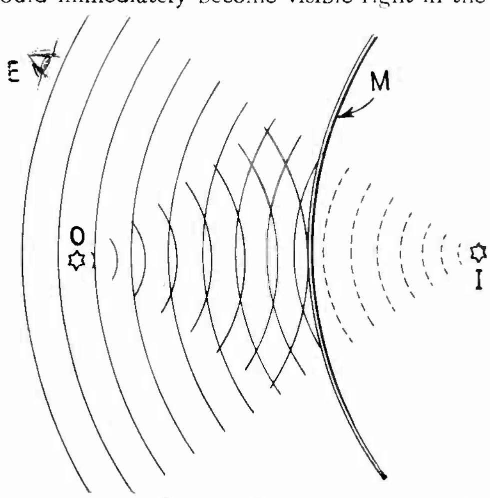


FIGURE 34—*A virtual image formed by a convex mirror.*

is often seen in the case of a searchlight on a clear night when the light it projects becomes visible only as it strikes clouds high overhead. With a powerful enough light source a motion picture could be shown with clouds as the screen.

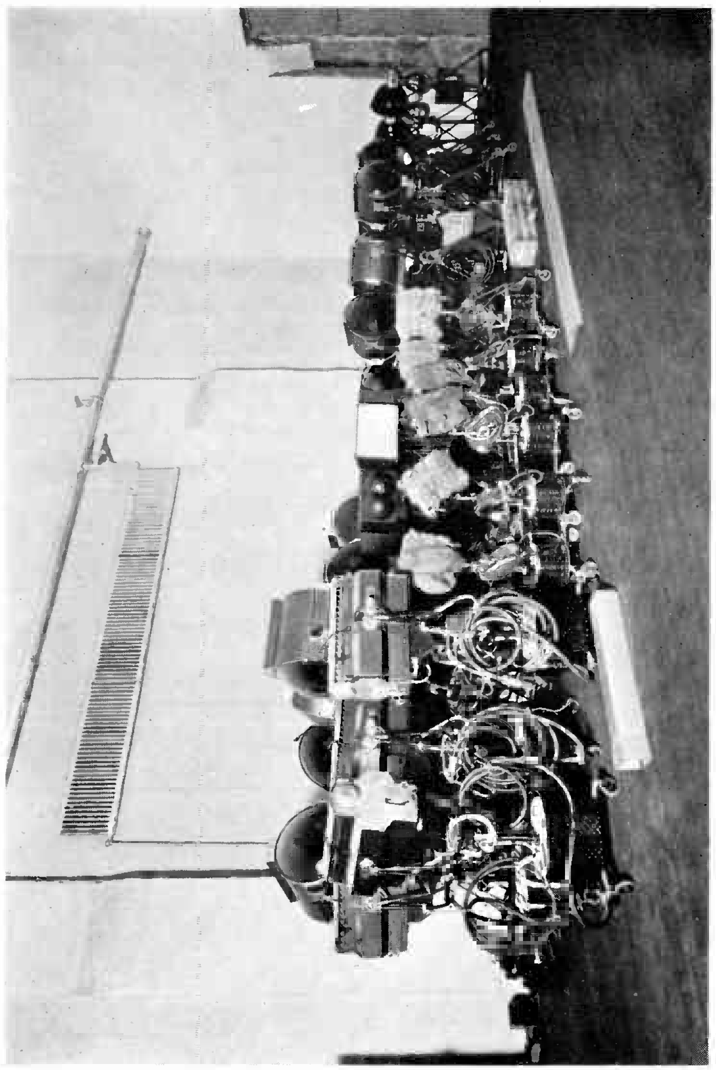
EXAMINATION QUESTIONS

1. What two forms of distortion are produced by an uncorrected lens?
2. Using the "Lens table" find the proper lens to use if a picture 9 x 12 feet is desired with a "throw" of 50 feet.
3. Does a convex mirror produce a "virtual" or a "real" image and where is the image located in regard to the mirror?
4. Is the light from a picture screen seen by "regular" or "diffused" reflection?
5. How are "corrected" lenses made and what two kinds of glass are used?
6. In what part of a motion picture equipment is a concave type mirror used?
7. How is it possible to find, roughly, the equivalent focus of an objective lens?
8. Show by diagram a concave mirror. Put a cross at the center of its curvature and another at its principal focus.
9. What size picture will a lens with an "E.F." of 5″ form with an 80 foot "throw"?
10. Draw a diagram of a modern Zeiss objective lens, indicating front and back factors.

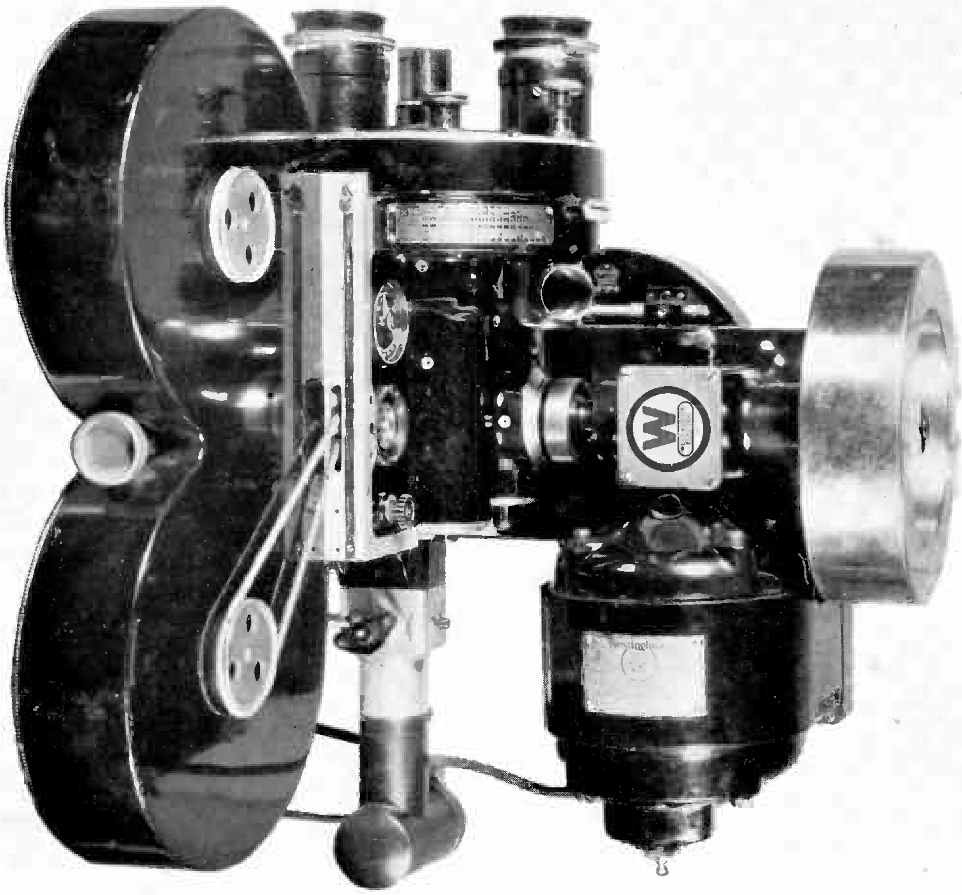
Printed in U. S. A.

NOTES

NOTES



Typical lighting equipment used by a small size sound picture studio.



Looking down on a sound picture camera, showing various lens combinations, any one of which may be quickly rotated into place.

RCA INSTITUTES INC

Printed in U. S. A.

Vol. 58, No. 8

S. O. 8655 1M—12-17-'31