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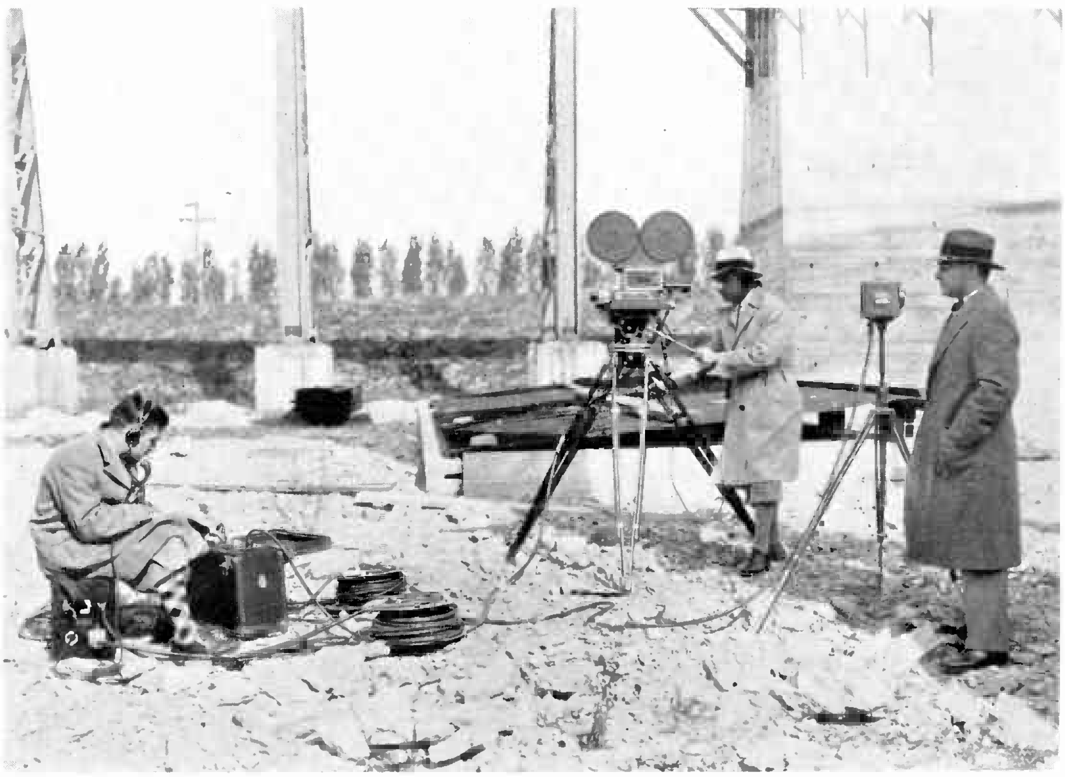

Motion picture camera "on location."

Principles of Photography

Vol. 58, No. 4 Dewey Classification R 580

Camera, microphone, and inter-communicating head-set of portable equipment.

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Principles of Photography

The Pinhole Camera

A very simple experiment can be performed, as shown in Figure 1, to illustrate a principle of photography. This sketch shows how the rays of light from an object pass through a very small hole in a piece of cardboard to form an image of the object on a piece of white material used as a screen.

Although it is not shown in the drawing in Figure 1 the candle flame is throwing off small pencils or beams of light from every part of its surface, for instance, from the point or apex of the flame, from each side of the flame, from the bottom of the flame and so on, and moreover, there are beams of reflected light being thrown off from the wax of the candle itself. The points just named are the "outside" points of the flame and it follows that the area of the flame in between these points is also composed of thousands of small points each of which throws out rays of light.

Since the rays of light from the object pass through the "pinhole" in a straight line each ray strikes the screen at a point different from any other ray. Thus, the rays from the top of the actual flame pass through the pinhole and appear on the lower part of the screen below the level of the hole in the cardboard. Also, the rays from the bottom of the flame pass through the hole and strike the screen at its upper part which is above the level of the hole. Hence, all points of light between the top and bottom of the flame throw out rays of light that pass through the hole and strike the screen in the same relation to each other that they had as points of light in the flame. This causes a com-

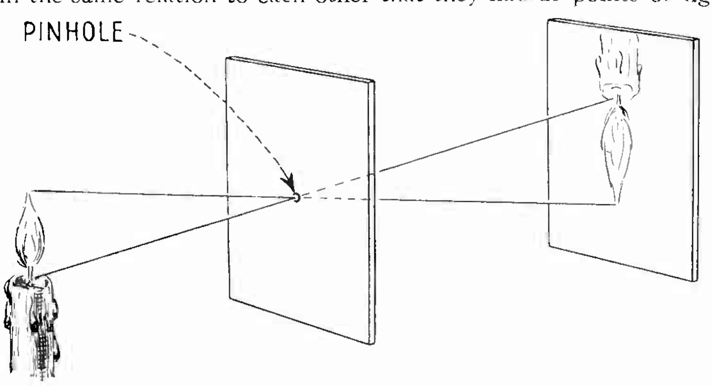

FIGURE 1—*A sharply defined image focused by a pinhole.*

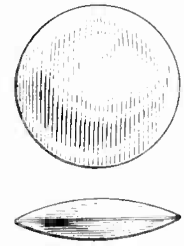

FIGURE 2—*Front and side views of double convex lens.*

pletely reversed image of the object to be formed on the screen, where the top of the flame shows its image at the bottom of the screen and the bottom of the flame shows its image at the top of the screen. Likewise, the left side of the flame shows its image on the right side of the screen and vice versa. If you have ever looked at the ground glass screen of a photographer's camera when focusing for a picture you have seen this "reverse" and "upside down" effect.

The image that is produced by a pinhole camera is always very dim, however, because the small hole allows only a very limited amount of light to pass through. Knowing this fact you might well ask the question, "Why not enlarge the hole and allow more light to pass through to the screen?" But this cannot be done so easily, for you will find that if you try to increase the brightness of the image by enlarging the hole, the image on the screen becomes blurred. This is due to the fact that the beam of light which is thrown off by each tiny point of the flame becomes larger as it travels further away from its source. An effect of this kind is similar to one obtained from a spotlight used in a theatre but on a much smaller scale. In the case of a spotlight the beam of light is about 6 inches in diameter when it starts out from the projection booth high up in the balcony but it gradually spreads and grows larger in size until it appears on the stage as a spot of light about 7 feet in diameter.

Referring again to the image of the candle flame, in Figure 1, let us explain further that the image is made up of many small circles or dots that start out from the candle flame as minute points of light which increase in size until they reach the screen. Now, if these small dots of light are not too large when they hit the screen they will not overlap each other to any considerable degree and, therefore, the image of each dot will show up sharply. All the dots together appear to the eye as a "blend" which gives the effect of "seeing" the candle flame on the screen. You see a demonstration of this power of the eye to "blend" a number of such dots into a single image each time you look at a photographic reproduction or half-tone in either a book, newspaper or magazine. Pictures or half-tones of this kind are made up of numerous dots of ink so closely spaced that the eye does not see them as separate dots but only as the black and white shading or "blend" that forms the picture.

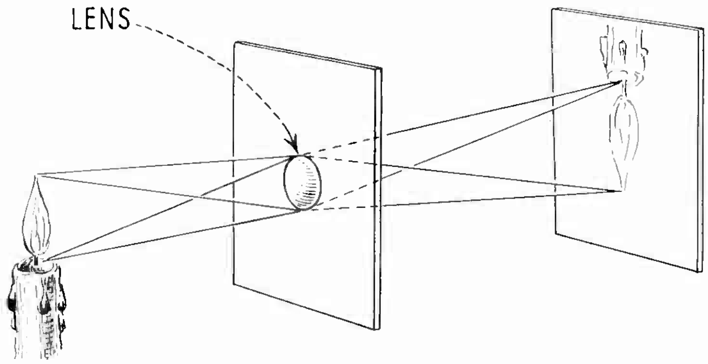

FIGURE 3—*The lens allows more light to be focused on the screen without loss of clarity.*

The Lens

If a larger "pinhole" is used in the pinhole camera experiment the dots on the screen will become so large that they will overlap and lose their sharpness thereby destroying the clearness of the picture. Such a blurred picture is said to be "out of focus". As you will learn later it is necessary to have a certain amount of light pass through the opening in order to produce a picture or photograph. Since it is necessary to have a fairly large opening in order to pass more light and a large opening causes diffusion or a blurr as we just stated then it is obvious that some method must be used which will keep the image clear, that is, prevent it from being blurred on the screen. This is accomplished by the use of a lens like the one pictured in Figure 2. The effect of a lens on the rays of light is shown in Figure 3. Observe from this drawing that each ray of light leaving the candle flame, instead of being allowed to continue its spreading effect until it reaches the screen, is changed upon passing through the lens until all the light thrown off by each point of the flame is "brought to a focus" or reproduced on the screen without overlapping. This results in a good sharp image on the screen. Hence, by employing a lens and inserting it in the opening we find it is possible to in-

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crease the size of the "pinhole" and obtain an increase in the amount of light falling upon the screen without losing the sharpness of the image.

At this point you will notice that we have succeeded in producing a copy of an original object on the screen with the aid of the light rays emitted by the object itself, which in this case is the candle flame. It is well known that when rays of light strike upon any object that reflects the rays then the object itself becomes in effect a source of light rays. Let it be understood, however, that objects can be seen even though they are not sources of light rays in themselves because they reflect or throw back the light from another source.

If the rays of light from the candle fall on an object, such as a person's face for instance, the rays are reflected back from the face and will act on the eye or on a screen in the same manner as though the rays had originated on the face. This property that most objects possess of reflecting light enables us to see things by daylight. The sun is an original source of light but the moon gives us light only by reflecting back to earth the light of the sun that strikes upon it. It is plain, therefore, that it is possible to produce, as on the screen in Figure 3, the image of an object that is not an original source of light by means of reflected light rays. Most images in photography are produced in this way.

Daguerreotypes

There is nothing very permanent about an image made of light rays for if the source of light rays is removed the image disappears. With the image for a guide, one could draw with pencil or ink the necessary lines on the screen to represent the subject but a picture drawn in this way, while more

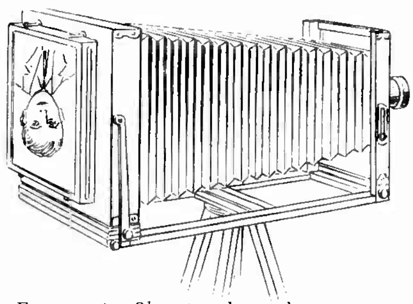

FIGURE 4—*Showing how the image is inverted on the plate of a camera.*

permanent, would be imperfect and not exactly like the original image. Merely making a pencil or ink sketch in this way is not to be compared to the perfected method of preserving images by means of photography as we will now explain.

A man by the name of Daguerre made up a solution that he found would change its chemical composition under the influence of light rays. To make practical use of this discovery he coated thin plates of tin with this solution and constructed what we now call a camera, which was nothing more than a light-proof box with a lens sealed in the front of it. By substituting a coated tin plate, also known as a sensitized plate, for the screen at the rear of the lens in his camera the sharp image of the light rays would fall on the solution. The camera used by Daguerre years ago was practically the same as the one illustrated in Figure 4 which is also typical of those used by professional photographers of the present day for making studio portraits. The lens is shown projecting from the front and a bellows, or light-tight cloth that folds conveniently, joins the lens rack to the plate holder located at the rear. In this sketch a translucent (semi-transparent) screen is shown upon which the image is first brought to a sharp focus by moving the lens nearer to or further away from the screen, this being done before inserting the sensitized plate in the holder.

Daguerre's method of procedure was to place the object to be photographed in the correct position in front of the camera and then by moving the lens to the proper position he would bring the image of the object to a sharp focus on the translucent screen, usually of ground glass. After this he would cover the lens carefully, remove the glass screen from its position and put a holder containing the coated tin plate in its place. When all was in readiness he would again remove the lens cover and the light rays focused from the object would strike the coated tin plate and begin to act on the chemical coating. After being exposed to the light rays for a certain length of time the chemical coating on the plate changed sufficiently so that after proper treatment in a chemical bath there appeared on the surface of the plate all the light and dark shades or areas which bore a similarity to the original subject and, therefore, the picture on the plate was easily recognized.

Owing to the fact that the chemical coating on the tin plate was not very sensitive, that is, it took a great deal of light to complete the proper chemical change, a very long exposure to the light rays was necessary. With this slow process, the subject oftentimes had to hold a certain position for a matter of 10 minutes in bright sunlight.

The necessity for keeping the subject being photographed in exactly the same position during the complete exposure of a tin plate is apparent when you stop to consider that if an object moves so does its image, and were this to occur the light rays would leave off working where they were focused in the first place and start their action on the chemical coating in a new position. Under such conditions the "developed" plate would show an under-exposed image of the moving object for each position it occupied while the picture was being taken.

Daguerreotypes, or tintypes, as these photographic images were called, could not be reproduced. Only one image or tintype picture could be taken at a sitting and, therefore, additional sittings were necessary if more than one picture was needed. The two-pronged head rest, which we often see in old tintype portraits was required because it is obvious that without a support of some kind no one could be expected to hold his head in a steady position long enough to produce a successful Daguerreotype.

Modern Developing and Printing

Years of scientific research taught those in this work how to produce a more sensitive coating for the tin plate so that it was no longer necessary to expose it to the light rays for such a long time. Shortly after this period in the development of photographic plates a method known as the "wet collodion process" was discovered. This method has survived to the present day and is used chiefly by photo-engravers for producing the negatives from which they make the engraved metal plates used in printing pictures. When using the wet collodion process it was necessary for the photographer to make his own plates just before he took the picture. To do this he would clean off a plate of glass, coat it with collodion, which contained iodides and bromides, and then put the plate in a bath of nitrate of silver which formed silver iodide in the collodion film thus making it sensitive to light. The glass plate had to be exposed in the camera while it was still wet, and immediately after exposure it was developed by pouring over it a liquid chemical known as the developer. Next it was treated in another solution, called a fixing bath, and then allowed to dry. All this inconvenience of taking pictures with a wet solution on the glass plate disappeared with the coming of the *gelatin emulsion*, or dry plate process which is the method now in universal use. Moreover, in photographic work the film has largely supplanted the use of glass plates upon which the sensitized coating is placed.

In the dry plate method only one side of a thin, transparent plate of glass is coated with a solution of silver salts contained in a very thin gelatin, called *emulsion*, that solidifies after coating. The silver salts contained in this emulsion change to metallic silver if exposed to the action of light rays and treated in a solution of chemicals called a *developer*. The parts struck by the light that was focused to an image on the emulsion are the only parts in which a change from silver salts to metallic silver takes place and the extent to which this action takes place is governed by the amount of light striking each part.

To cite an example, suppose a photograph is taken of an object composed of three shades which

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are, let us say, white, gray, and black. It follows that the rays of light coming off the white portion of the object will be the most intense and the silver salts on the portion of the emulsion upon which they strike will be turned to a heavy layer of metallic silver. After development this portion will appear black. In the second case where the rays of light are coming off the gray area of the object being photographed they will be about half as intense as those from the white area and will turn the silver salts on the plate to a thinner layer of metallic silver than would the rays from the white portion. After development this portion will appear gray, or lighter than the first portion. In the third case where the rays are coming off the black portion of the object they will be of such low intensity that the silver salts will not be affected at all and during the process of "fixing" will wash off. Thus, after development this portion leaves the emulsion transparent. It can be seen then the shades of light reproduced on the plate will appear to the eye in shades just the opposite of those actually present on the object, that is, the lighter portions of the object will turn out to be the darker portions of the image as shown on the developed plate and so on. Hence a black locomotive will look on the plate as if it were white. A plate of this kind is called a "negative" because everything is reversed in shade as shown in the illustration in Figure 5.

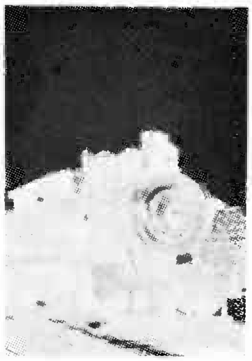

FIGURE 5—*Negative image.*

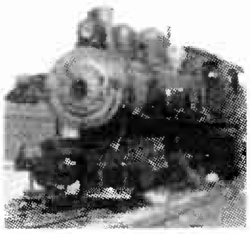

FIGURE 6—*Positive or Print.*

The next step to be considered is how a photograph is produced in which the shadings have again been reversed so that a true image with proper shadings is obtained. Such a photograph is called a "positive" print because the relation between the light and dark shades that form the picture appear like the original subject.

From the foregoing description of the action of light on a silver salts emulsion you can easily understand how a "positive" print can be produced by laying the negative plate over a sheet of photographic paper which was, of course, previously coated with the emulsion. A large amount of light will pass through the negative where the transparent parts of the image lie and this action of the light will turn the silver salts of the emulsion to a deep black. Now suppose only about half the amount of light will be able to pass through the thin layer of metallic silver that represents the gray part of the object. Then this amount of light will be just sufficient to turn the silver salts gray at this place. Or, in other words, where the parts of the negative have a heavy coat of metallic silver practically no light will be able to pass through and consequently this will leave the silver salts on the paper unchanged and after washing this area will appear white.

It is this chemical action that gives us a "positive" image, or a true picture of the original object or subject on the photographic paper. Figure 6 shows a positive print or photograph which was made or "printed" in this manner from the negative plate in Figure 5.

Since a negative must be wound on reels for use in motion picture cameras it is evident that the glass type plate cannot be used for this purpose so a transparent film having an emulsion coating of silver salts is employed instead. Insofar as the action of the chemical coating is concerned and the process of exposure and development they are similar for either a film or glass plate type of negative.

To stop the process of development of either a negative or a positive, when the action of turning the silver salts to metallic silver has gone to the proper stage, another chemical solution called a "fixer" is used. When the negative or positive is immersed in this bath the emulsion is no longer sensitive to light, the process of development ends, and the image is "fixed" in the emulsion. This method works out to a decided advantage because any number of positives can be produced from a negative.

Exposing the Plate or Film

The greatest trouble experienced in photography is in getting the correct "exposure", that is, allowing the light image to fall on the sensitized plate or film so that the best relation of light and dark portions is achieved. The function of "exposure" is to allow just enough light to act on the

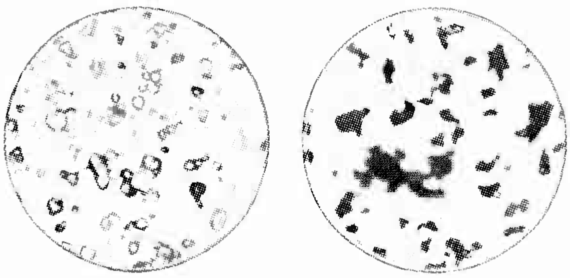

FIGURE 7—*Silver bromide crystals (left) change to metallic silver (right) after development. (Courtesy of Eastman Kodak Co.)*

silver salts emulsion to properly prepare it for the action of the developer. The function of "development" is that of causing the silver salts which have been exposed to light to change to metallic silver.

It is explained that the amount of metallic silver that will be caused to appear by the action of the developer depends on the degree to which the silver bromide was acted upon by the light rays. For instance, the light rays reflected from a white object, which are focused to an image on the photographic emulsion for a certain length of time will affect the silver bromide more than light reflected from a gray object focused on the plate for the same length of time. This follows from the fact that more light is present in the image of the white object than in the image of the gray object.

To obtain a correct exposure consists in allowing enough light to act upon the silver bromide so that in the extreme case of light rays coming from a pure white object, the silver bromide will be affected to such a degree that it will practically all change to metallic silver under the action of the developer. This will produce such a thick layer of silver on the negative that it will appear black and will not allow light to pass through it. In the case of the other extreme, or that of photographing a black object, there is practically no light reflected and, therefore, the image of such an object has no light rays which might act on the emulsion of the negative.

Therefore during development of the negative no metallic silver is produced, the silver salts are washed away during the fixing process and that, part of the plate or film showing the black object is transparent. Objects with colors or shades that reflect varying amounts of light in the range between white and black affect the emulsion differently according to the amount of light each reflects and when the developer has completed its action an image of each object appears in a degree of shading, or "blackness", that corresponds to the amount of metallic silver produced.

Let us see just what crystals of silver bromide look like before and after development. Figure 7 shows the crystals after they have been exposed to light. The left photograph shows the crystals *before* development and the right photograph shows the same crystals *after* development. Before development the crystals are transparent except where they are seen sideways or where their edges appear darker. The photograph on the right shows how crystals which have been exposed to light are changed to black masses of metallic silver by the action of the developer. Bear in mind the fact that the developer changes to metallic silver only those crystals that were struck by the light rays and that when a crystal is so changed it is opaque. These photographs, of course, were taken through a very powerful microscope.

From our explanation it should be clear that after development we have an image in metallic silver corresponding to the light image which was focused on the emulsion by the camera and that the darkness of this metallic silver image is determined by the amount of light that was reflected from the object to the emulsion during exposure.

Figure 8 shows how the number of crystals changed to metallic silver varied for four different

EXPOSED 1 UNIT OF TIME A | EXPOSED 4 UNITS OF TIME B | EXPOSED 16 UNITS OF TIME C | EXPOSED 64 UNITS OF TIME D

FIGURE 8—*The longer the silver bromide crystals are exposed to the light the greater will be the number change to metallic silver. (Courtesy of Eastman Kodak Co.)*

exposures, each exposure being four times as long as the preceding one. In view "A" only a comparatively few crystals were changed to metallic silver. As each succeeding view indicates the number increases rapidly with each increase in exposure time, until a rather heavy deposit of metallic silver occurs as in view "D". The latter film was exposed 64 times longer than the one in view "A". These views of crystals in different stages of chemical change give a good idea of why there is more opacity produced in the emulsion for long exposure to light and why a negative shows black where the most light fell on it during exposure. Figure 9 is a view illustrating the appearance of an emulsion, after exposure and development, when magnified 900 times. The black areas are where the most light from the image was focused on the emulsion.

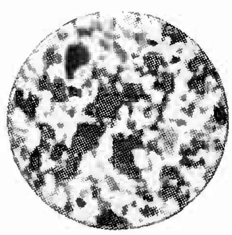

FIGURE 9—*Emulsion as it appears after development—magnified 900 diameters. (Courtesy of Eastman Kodak Co.)*

The term "density" is used to indicate the degree of "blackness" which results from varying amounts of metallic silver deposited on the film. In Figure 10, use is made of this term in computing a "characteristic curve" of an emulsion. The heavier the deposit of metallic silver, the greater is the "density" of the negative and consequently, the amount of light which may be passed through it is inversely proportional to this density, that is, $D = 1/T$, where D is the density and T is the "Transmission", or amount of light passed.

Light and Time

Inasmuch as it is the amount of light falling on the emulsion that determines whether or not the "exposure" is correct it is easy to reason that a correct exposure may be obtained either by letting a small amount of light act on the emulsion for a long time or by letting a larger amount of light act on it for a shorter time. However, the fact remains that for any particular emulsion there is a certain exposure that produces the best possible effect in its action on the silver bromide, and, therefore, emulsions are made in various sensitivities for various purposes. Whether this optimum or ideal exposure is in the form of a large amount of light for a short period of time or a small amount of light for a correspondingly longer period of time makes no difference, generally speaking. Each emulsion has what is known as its "characteristic curve", which is only another way of saying that its silver bromide is affected a certain amount by each variation in the amount of light falling upon it. You will meet the term "characteristic curve" a number of times throughout this course and although it has a highly technical sound you will find it is exceedingly simple in meaning and one of your best friends if you really make an effort to know it well.

Let us go through an explanation of the "characteristic curve" of a certain emulsion as depicted in the graph in Figure 10. Across the bottom of the graph there are numbers showing exposure to light marked off in seconds beginning at 1 sec. at the left and ending at 524,288 secs. at the right.

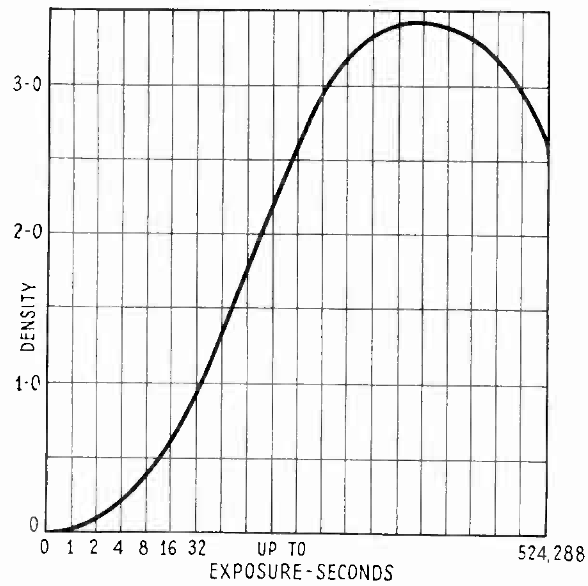

FIGURE 10—*Showing the relationship between exposure time and density.*

Running up on the left side or vertical axis can be seen a scale marked from 0 to $3\frac{1}{2}$. These numbers on the left side represent arbitrary units, that is, they indicate only the density or proportion of silver deposited after development for the different time exposures in seconds as indicated by the bottom set of numbers or, 0, 1, 2, 4, 8, 16, and so on up to 524,288. In other words, the number 2.0 on the left side scale does not indicate any definite amount of silver deposited but only that there is twice as much deposited for any point on the horizontal line drawn to the right of 2.0 when compared with any point on the horizontal line drawn to the right of number 1.0. For instance, for an exposure of 192 seconds the curve is seen to cross the horizontal line marked number 2.0 while for an exposure of about 40 seconds the curve crosses the horizontal line marked number 1. Therefore, we gather from this chart that an exposure of 192 seconds will cause twice as much silver to be deposited as an exposure of 40 seconds. Inasmuch as a deposit of twice the amount of silver means the plate or film will be twice as opaque with the greater amount of exposure as with the lesser amount, a correspondingly smaller amount of light will be allowed to pass through to the "positive" when it is printed.

Let us again repeat that a photograph is nothing more than a series of light and dark areas of varying density arranged on the positive according to their relative positions on the subject originally

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photographed. In this lesson we have considered both negatives and positives but it can be mentioned now that the ultimate end of practically all photography is in the production of the positives. The negative is only a means to that end and its greatest use lies in the fact that positives can be made from it in almost unlimited quantities.

Referring again to Figure 10, note the rather strange behavior of the curve at the extreme right of the chart which shows that after we increase the length of exposure up to a certain point instead of a further increase in opacity there is a decrease. This condition, of course, represents tremendous overexposure and could not possibly produce a good picture.

If a picture is to be true to life it must faithfully reproduce the various degrees of shading that are present in the original subject, hence, in order to accomplish this only periods of exposure represented by the steepest and straightest part of the characteristic curve can be used. This is so because the increase in density is directly proportional to the increase in exposure only along that part of the curve. In order to achieve the same differences in shading in the photograph as are present in the original, it is necessary that for each vertical line to the right the exposure time moves up an even distance as you will notice upon examining the course travelled by the curve depicting this relation. In other words, this means that for each doubling of exposure time the opacity of the silver deposit must increase in even "steps" of the same amount. Therefore, it is apparent that in order to produce a photograph that has the proper values of shading, a very close watch must be kept to see that the exposure is correct or on the straight portion of the characteristic curve. When the exposure is either on the lower or upper portions of the curve the increase in opacity is not proportional to the increase in exposure (light intensity) and "distortion" results.

A vacuum tube also has a characteristic curve and when operated on the lower or upper bend instead of on its straight portion distortion results. Distortion, however, in the case of photography, is a lack of true reproduction of value in shades, whereas, distortion in a vacuum tube results if the characteristics of the electrical output of the tube are not a faithful copy of the electrical characteristics in the input circuit.

Putting Knowledge into Practice

You may have had some experience with photography in your own home, for many of us in these days of widespread use of the camera have developed and printed pictures which we have taken. If you have not had the interesting experience of performing all the operations necessary to produce a finished photograph or "positive" it will be well worth your while to obtain the paraphernalia of an amateur photographer and acquire the knowledge that comes from doing the actual work. You should first of all learn how a negative is correctly exposed and second, how to obtain the proper development and fixing of the positive. There is no doubt but that the knowledge you gain in this way will give you a clearer insight into one of the problems of workers in the sound picture field.

A vast amount of research work is going on every day in the never-ending search for better sound motion pictures and good photography plays a very important part in this field of research. Improvements are constantly being sought after not only in the "taking" of the picture but in new and better methods for "photographing" the sound vibrations on the film itself.

There are at the present time a number of film companies recording the sound on discs or "records" which are geared to run in time or synchronism with the machine which projects the picture on the screen, but this type of recording is gradually losing favor due to the number of factors that are frequent sources of trouble.

By far the greater part of all films now produced are "sound-on-film" recordings and it is generally predicted that the time is not far distant when all sound recording for motion pictures will be done in this manner, that is, the sound parts of a sound motion picture reel will be placed on the edge of the film by photographic means.

According to this commercial trend we may conclude that certain important processes in sound picture work are becoming increasingly photographic in nature and, therefore, a good fundamental knowledge of photographic principles is essential to a good understanding of this subject. Bear in mind that whether these photographic processes are being applied to the taking of the scene or to the photographing of a "sound track" on the edge of the film, the principles involved are the same. If you are interested in actually developing and printing pictures it is suggested that you obtain the book "How to Make Good Pictures" published by the Eastman Kodak Company at Rochester, N. Y.

Knowing how to take, develop, and print "still" pictures, provides a good foundation for the future work in sound motion picture photography, whether it applies to sound recording or to picture recording as we have previously stated. Since motion picture photography is in reality the "taking" of many "still" pictures per second one should carefully study the principles just covered in this lesson on how "still" pictures are taken, developed, and printed. Later we will take up motion picture photography and you will find it very interesting because it represents ingenuity of the highest order in taking advantage of a natural faculty of the human eye known as "persistence of vision". This faculty comes into play only during the later projection of the photographed scene on to the screen in the theatre but the photographing of the scene and the making of the films used later in the theatre must be done in full accord with this principle of persistence of vision.

In the lessons which follow on the photography of objects in motion you will study subjects such as motion pictures in color, wide film, and stereoscopic or three dimension pictures. Also, the various forms of the art as it has been developed up to the present with forecasts of the possibilities and needs for the future are included in the discussions.

EXAMINATION QUESTIONS

1. Is it necessary to have a lens in a camera in order to take a good picture?
2. What is the chief function of a camera lens?
3. (a) What are the three main parts of a camera? (b) Explain the function of each part.
4. What name was given to the first photographs?
5. Name one great difference between the early process of photography and modern photographs?
6. What is the principal chemical ingredient used in emulsions?
7. Discuss the action of light and developer upon a film emulsion.
8. What stops the process of "development?"
9. How may a positive be distinguished from a negative?
10. How many positives can be "printed" from one negative? Give reasons for your answer.

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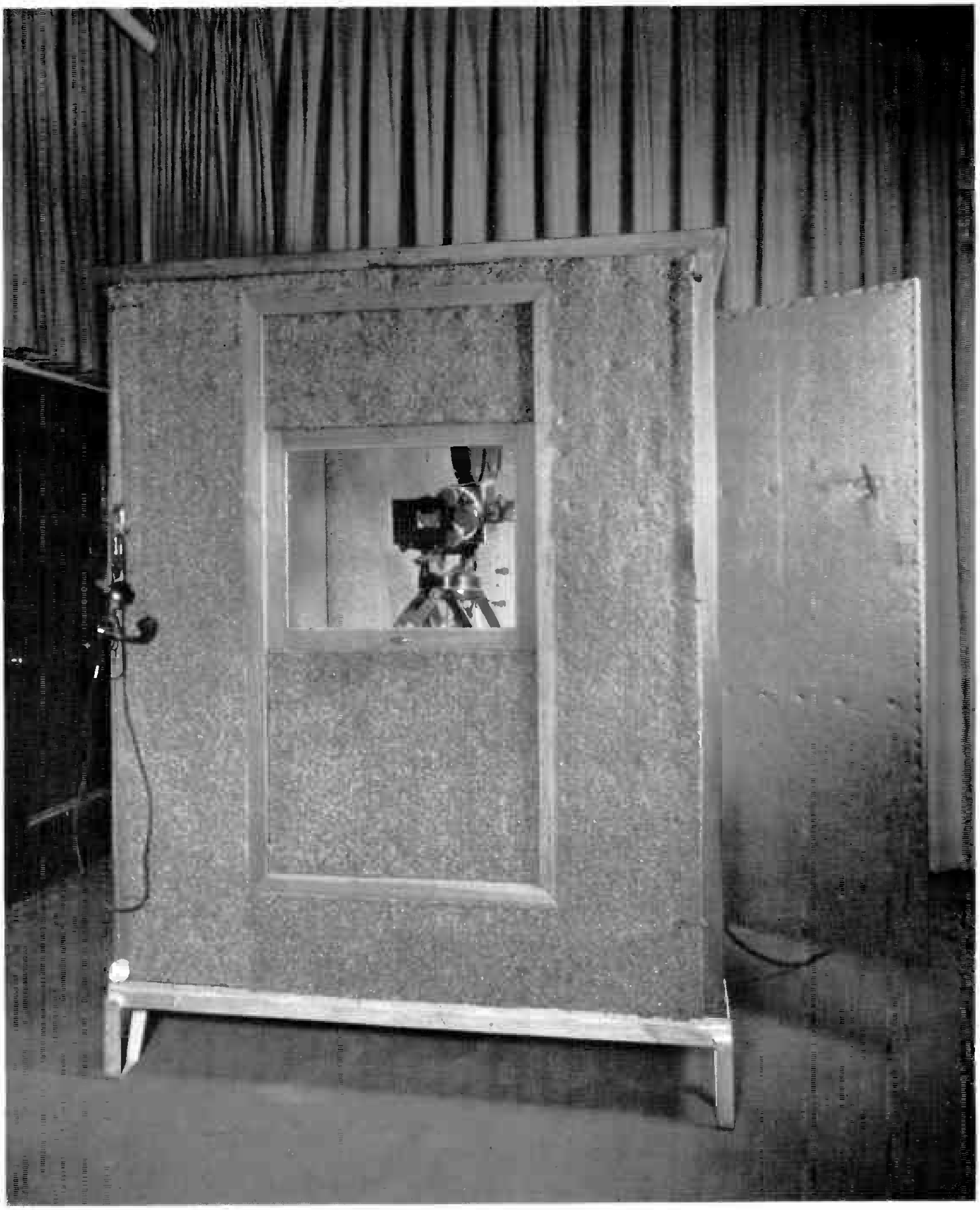
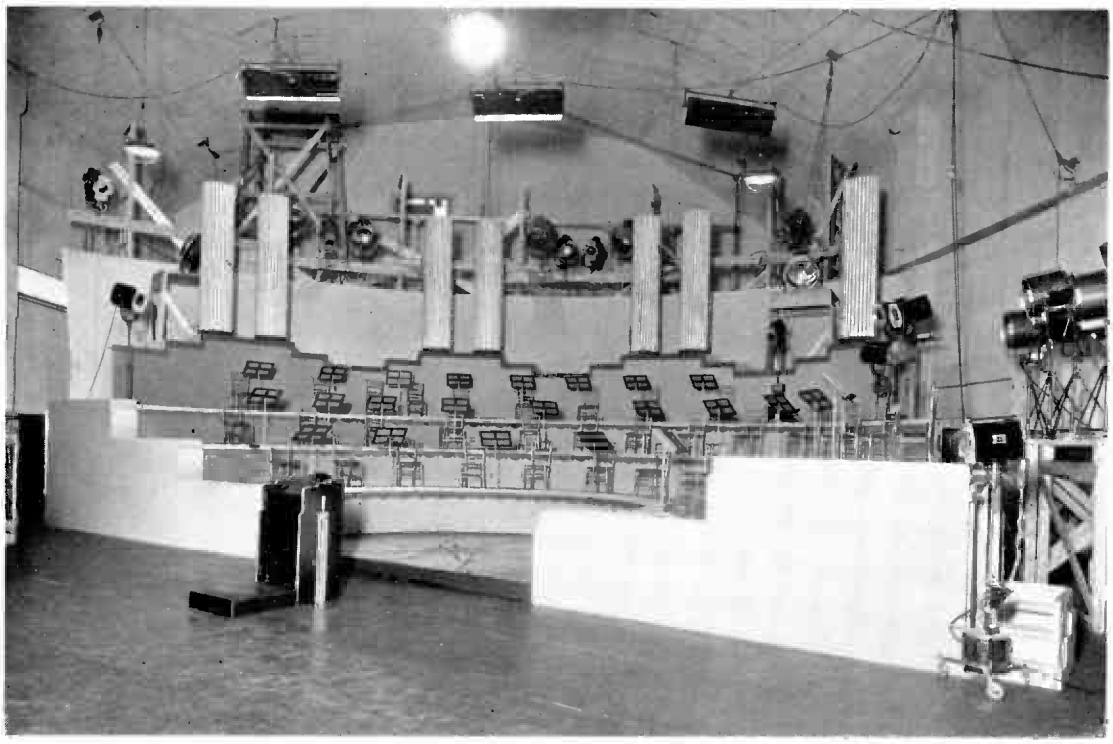


Motion picture camera in sound-proof booth.



Interior set for photographing and recording an orchestra.

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