# The Fundamentals of Photography

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Eastman Kodak Company
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# PREFACE

WHILE a knowledge of the theory of photography is by no means essential for success in the making of pictures, most photographers must have felt a curiosity as to the scientific foundations of the art and have wished to know more of the materials which they use, and of the reactions which those materials undergo when exposed to light and when treated with the chemical baths by which the finished result is obtained. This book has been written with the object of providing an elementary account of the theoretical foundations of photography, in language which can be followed by readers without any specialized scientific training. It is hoped that it will interest photographers in the scientific side of their work and aid them in getting, through attention to the technical manipulation of their materials, the best results which can be obtained.

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# THE FUNDAMENTALS OF PHOTOGRAPHY

## CHAPTER I.

### THE BEGINNINGS OF PHOTOGRAPHY.

THE first person to notice that chloride of silver was darkened by light may have been J. H. Schulze, who made the discovery in 1732. It is probable, however, that this had been observed by others. In 1737 Hellot in Paris, was trying to make sympathetic inks, that is, inks that would be invisible when put on paper but which could be made visible afterwards. He found that if he wrote on paper with a solution of silver nitrate, the writing would not be visible until the paper was exposed to light, at which time it would turn dark and could be read. However, no use was made of these discoveries for the purpose of making pictures until 1802, when Wedgwood published a paper entitled "An Account of a Method of Copying Paintings on Glass and on Making Profiles by the Agency of Light upon Nitrate of Silver."

This reference to making profiles is a reference to one of the forms of portraiture which preceded photography. Before portrait photography was discovered, there were people who made what were called "silhouettes", which were profile pictures cut out of black paper and stuck on to white paper. Some of these silhouettists were very clever indeed. Others who had not great ability arranged their sitter so that they got sharp shadows thrown by a lamp onto a white screen and this gave them the profile to copy. Wedgwood thought that instead of cutting out the silhouette he might print this profile on the screen by using paper treated with silver nitrate, which would darken in the light. Wedgwood not only used his new process to record these silhouettes, but he tried to take photographs in what was then called the "camera obscura", which was the forerunner of the Kodak of to-day.

The camera obscura consisted of a box with a lens at one end and a ground glass at the other, just like a modern camera. It was used by artists to make a picture of anything they wanted to draw, as by observing the picture on

Fig. 1
Silhouette Picture from Old Print.

the ground glass they could draw it more easily. Wedgwood tried to make pictures in his camera obscura by putting his prepared paper in the place of the ground glass. His paper however, was too insensitive to obtain any result; but Sir Humphrey Davy, who continued Wedgwood's experiments, using chloride of silver instead of nitrate, succeeded in making photographs through a microscope by using sunlight. These are apparently the first pictures made by means of a lens on a photographic material.

But all these attempts of Wedgwood and Davy failed because no method could be found for making the pictures permanent. The paper treated with silver chloride or silver nitrate was still sensitive to light after part of it had darkened, and if it were kept it soon went dark all over and the picture was lost. Davy concluded his account of the experiments by saying: "Nothing but a method of preventing the unshaded parts from being coloured by exposure to the day is wanting to render this process as useful as it is elegant."

This much needed method, however, remained wanting from 1802 until 1839, when Sir John Herschel found that

Fig. 2.
Crystals of Thiosulphate of Soda or "Hypo".

"hypo", which he had himself discovered in 1819, could dissolve away the unaltered chloride of silver and enable him to "fix" the picture, as the process has been called ever since Herschel made the discovery, and from that time to this hypo has been the mainstay of the photographer, enabling him to fix his pictures after he has obtained them.

In the meantime, Niepce in France had been working on an entirely different process, depending on the fact that such substances as resin or asphalt became insoluble when exposed to light, and he had succeeded in producing results by taking advantage of this property. In France also, Daguerre was working on various methods by which he hoped to make photographs, and entered into partnership with Niepce, but in 1839 Daguerre published the method of photography which was named for him—*Daguerreotype*. This was the first portrait process and became very popular. It depends upon the sensitiveness of plates of metallic silver which have been fumed with iodine so that the surface is converted into a thin layer of silver iodide. The plates so treated are exposed to light, and after a very long exposure, as we should consider it now, the plate in the dark is exposed to the vapor of metallic mercury, which deposits itself upon the image and produces a positive image of mercury upon silver.

The results were very beautiful, but these early processes of photography required very great exposures so that at first the unfortunate subject had to sit for as long as ten minutes in the full sun without moving in order to impress the plate sufficiently. Although many experiments were made in an attempt to find substances more sensitive to light so that the exposure could be reduced, the only real solution was to find some method by which light had to do only a little of the work and the production of the image itself could be effected by chemical action instead of by the action of the light.

A great step in this direction was taken by Fox Talbot in 1841. He found that if he prepared a sheet of paper with silver iodide and exposed it in the camera he got only a very faint image, but if after exposure he washed over the paper with a solution containing silver nitrate and gallic acid, a solution from which metallic silver is very easily deposited, then this solution deposited the silver where the light had acted and built up the faint image into a strong picture. This building up of a faint image or, indeed, of an image which is altogether invisible, into a picture is what is now called "development". If we expose a film in the Kodak and then, after the shutter has allowed the light to act for a fraction of a second on the film, look at the film in red light, which will not affect it, we shall not be able to see any change in the film. But if we put the film into a developing solution, the invisible image which was produced by light, and which in photographic books is called "the latent image" will be developed into a black negative representing the scene that was photographed.

Fig. 3.
Negative Image.

Fox Talbot was not only the first to develop a faint or invisible image; he was also the first man to make a negative and use it for printing. What is meant by a negative is this: If we look at our film after we have exposed and developed it, we shall find that the sky, which was bright in the picture, is shown in our film as very black, while any shadows in the picture, which, of course, were dark, will be transparent in the film, so that the light let through the film is in the reverse order of the scene photographed, all the bright parts in the scene being dark in the film and the dark parts bright. For this reason the film is called a "negative," and when it is printed on paper the same reversal happens again and the clear parts in the negative become dark in the print while the dark parts of the negative protect the paper from the action of the light, so that the print which we may call a "positive," represents the scene as it appeared.

Fox Talbot, then, made two of the great steps in the advancement of photography when he found how to expose his paper for a time insufficient to darken it completely, and then to develop a negative which he could print on paper covered by silver chloride. Of course, the paper was not transparent as our film is, but he made it more transparent by treating it with oil or wax. In this he was followed many years afterwards in the Eastman roll holder, which was the forerunner of all the Kodaks.* In this roll holder at first a paper film was used to make the negative and then the paper was made transparent for printing.

Fig. 4.
Positive or Print.

Fox Talbot's paper negatives were succeeded by the method known as the wet collodion process, which has survived to the present day. This is the process chiefly used by photo-engravers for making the negatives from which they make the engraved metal plates for printing pictures.

Collodion is made by dissolving nitrated cotton, such as is now used for the film base, in a mixture of ether and alcohol. The worker of the wet collodion process had to make his own plates at the time when he wanted to take a picture. He would clean a piece of glass and coat it with the collodion in which the chemicals were dissolved and then put the plate in a bath of nitrate of silver, which formed silver iodide in the collodion film and made it sensitive to light. Then the glass had to be exposed in the camera while wet, and immediately after exposure it was developed by pouring the developer over it. It was then fixed and dried.

Fig. 5.
Early Photographer with His Equipment.

In order to carry out these operations a photographer who wanted to take landscapes had to carry with him a folding tent which he could set up in the open air. The tent was dark except for a yellow or red window by which to see to make the plates and develop them.

All this difficulty in working disappeared with the coming of the gelatine emulsion process, which is the one now used. The sensitive coating on films and papers now consists of a bromide or chloride of silver held in a thin sheet of gelatine, the gelatine being dissolved in hot water, the silver salt formed in the solution, and the warm solution of gelatine containing silver then coated on the film or paper.

The gelatine solution with the silver in it is called an "emulsion" because of the way in which the silver remains suspended in the gelatine. The first gelatine emulsions were made in 1871 by Dr. Maddox. An emulsion made in much the way that we use now was first sold in 1873 by Burgess.

At first the early experimenters made and sold the emulsion itself, drying it for sale so that photographers had to take this dried emulsion, melt it up in hot water, and coat it on their plates. After a time, however, people realized that this was a great deal of trouble and that there was no reason why the manufacturer of the emulsion should not coat the glass plates with it, and sell the ready prepared plates.

In those days all negatives were made on glass plates. These plates were coated with the emulsion by hand and then when the emulsion was spread over them were put on to cold level slabs for the jelly to set before drying. Glass plates are cumbersome and heavy, and for this reason George Eastman continually experimented to substitute a light, flexible support for the brittle and heavy glass. As already mentioned, he first used paper as a support for the negative, waxing it to make it transparent for printing. This was followed by a paper from which the film carrying the image was stripped, the film being transferred to a glass plate coated with gelatine so that this gelatine made a support for the film.

While experimenting to find a more satisfactory material for coating the film than gelatine it was found that a solution of nitrated cotton would make a clear, transparent and flexible support, and after a period of further experimenting this material was adopted and a roll film was made, the emulsion being carried on the clear, transparent sheet of film support. The only remaining difficulty with this was its tendency to curl owing to the gelatine coating on one side, and this was overcome by coating the other side with plain gelatine, thus producing the non-curling (NC) film.

## CHAPTER II.

### LIGHT AND VISION.

Light is the name which we give to the external agency which enables us to see. In order to see things we must have something which enters the eye and a brain to explain it to us. That which enters the eye is what we call light.

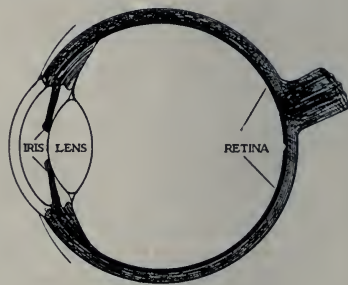


Fig. 6.
Diagram of Human Eye.

The eye consists of two principal parts and can best be understood by analogy with the camera. In front it has a lens which forms an image on the sensitive surface, which is called the retina, the retina playing the same part in the eye that the film does in the camera. The retina, however, differs from the film in that when light falls upon the film it produces a permanent change, which can be developed into a picture, and if the light falls upon the film for too long a time the film is spoiled, while the retina merely acts as a medium to transmit to the brain the sensation of the light that falls upon it, and when the light stops, the sensation stops and the retina is ready to make a new record. The retina behaves, in fact, like a film in which the sensitive material is continually renewed.

It is probable that this sensitive material in the eye is really of a chemical nature because it is apparently produced all the time, and when the eye is kept in the dark the sensitive material accumulates for some time so that the eye becomes more sensitive, while when a strong light falls upon the eye, the sensitive substance is destroyed more rapidly than it is produced and the eye becomes less sensitive.

In this way, the eye has a very great range of sensitiveness. In bright sunlight it is as much as a million times less sensitive than it is after it has been kept for an hour in the dark, and it changes very rapidly, only a few minutes being necessary for an eye that has been in almost complete darkness to adapt itself to the glare of out-door lighting. In order to lessen the shock of changing light intensity, the lens of the eye is provided with an iris diaphragm just like that of a camera, but with the additional advantage that it operates automatically, opening and closing according to the intensity of the light. Measurements of the movements of the iris of the eye have been made by taking motion pictures of the eye when suddenly illuminated by a bright light, and these show what a wonderful instrument the eye is in its adaptation to changing conditions in the world around it.

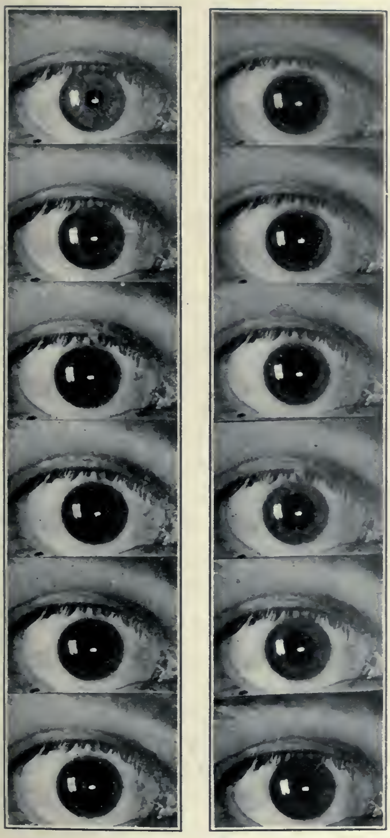


Fig. 7.
Iris Opening and Closing.

The retina is connected with the brain by a great many nerve fibers, each fiber coming from a different part of the retina, so that when light falls upon any part of the retina, the intensity of the light is communicated by the tiny nerve coming from that part of the retina to the brain and the brain forms an idea of the image on the retina by means of the multitude of impressions from different parts of the retina.

The image on the retina is inverted like all lens images, so that we really see things standing on their heads, but the brain interprets an inverted image on the retina as corresponding to an upright external world, and although the eye sees things upside down, the brain has no idea of it.

What we observe is the light which falls on the retina, but this light comes originally from some external source which, in the case of daylight, of course, is the sun. The light from the sun is reflected by the objects in the world around us according to their nature, and entering the eye it enables us to see the objects. When we look at a landscape we see that the sky is bright and the roads and fields are less bright, and the shadows under the trees are dark, because much of the light of the sun is reflected from the sky, less from the fields and roads and still less from the shadows under the trees. All these rays from the sun reflected from the natural objects in the landscape enter the eye and make a picture on the retina which is perceived by the brain by means of the tiny nerve fibers coming from the retina to the brain.

But the eye not only perceives differences in the brightness of the light—it also observes differences in colour—and in order to understand how this can be we must search further into the nature of light itself.

The nature of light has long been a source of speculation, and at one time it was generally held that the light which entered the eye consisted of small particles shot off from the source of light, just as at one time it was held that sound consisted of small particles shot off from the source of a sound which struck the drum of the ear. This theory of light has the advantage that it immediately explains reflection; just as an india rubber ball bounces from a smooth wall, while it will be shot in almost any direction from a heap of stones, so the small particles of light would rebound from a polished surface at a regular angle, while a rough surface would merely scatter them.

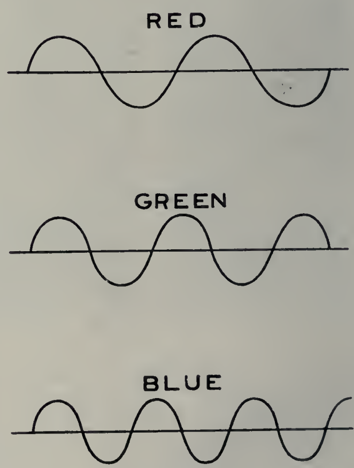


Fig. 8.
Relative Wave Lengths of Red, Green and Blue.

This theory of the nature of light was satisfactory until it was found that it was possible by dividing a beam of light and slightly lengthening the path of one of the halves, and then reuniting the two halves together again, to produce alternate periods of darkness and light similar to the nodes of rest produced in an organ pipe, where the interference of the waves of sound is taking place. It could not be imagined that a reinforcement of one stream of particles by another stream of particles in the same direction could produce an absence of particles, while the analogy of sound suggested that just as sound was known to consist of waves in the air, so light also consisted of waves.

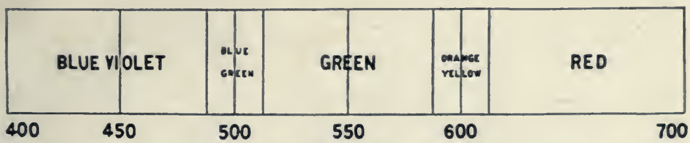



Fig. 9.
Simple Arrangement of Spectrum.

Light cannot consist of waves in the air, partly because we know that it travels through interstellar space, where we imagine that there is no air but through which we can still see the light of the stars, and also because the velocity of light—nearly 200,000 miles per second—is so great that it is impossible that it could consist of a wave in any material substance with which we are acquainted. It is, therefore, assumed that there exists, spread through all space and all matter, something in which the waves of light are formed, and this something is termed ether, so that it is generally held that light consists of waves in the ether.

Just as in sound we have wave notes of high frequency, that is, with many waves per second falling upon the ear, which form the high pitched notes, and also notes of low frequency where only a few waves a second fall upon the ear forming the bass notes, so with light we may have different frequencies of vibration. Since the velocity of light is the same for waves of different frequencies, it is clear that the waves of high frequency will be of different wave length from those of low frequency, the wave length being the distance from the crest of one wave to the crest of the next, and if we obtain waves of different lengths separated out, we shall find that the color depends upon the wave length. Fig. 8 shows the average length of wave corresponding to light of various colors, the diagram being drawn to scale.

White light consists of mixtures of waves of various lengths, but if instead of letting the mixture of waves, which forms white light, fall directly on the eye we pass white light through an instrument known as a spectroscope, which changes the direction of the different waves by amounts which differ according to their lengths, we get the white light spread out into a band of colors which we call the spectrum, and we can scale this spectrum by means of numbers representing the lengths of the waves.

Fig. 9 gives a simple arrangement of the spectrum, the numbers representing the wave lengths in units which are millionths of millimeters. It will be seen that the visible spectrum extends from 700 to 400 units, wave lengths of 700 units corresponding to the extreme red and 400 to the darkest violet that can be seen, while the brightest region of the spectrum stretches from 500 to 600 units and includes the green and yellow colors. The spectrum is equally divided into three regions which may be broadly termed—red 700–600, green 600–500, and blue-violet 500–400.

If we get a piece of colored glass which lets through only the portion of the spectrum between 600 and 700, then we should have a piece of red glass; a glass which let through from 500 to 600 would be a green glass, and one which let through from 400 to 500 would be blue-violet in color, so that from the spectrum we already derive the idea that light can be conveniently divided into three colors, which we may call the primary colors—red, green and blue-violet. It is probable that this is connected with the structure of the retina, and one theory holds that there are three sets of

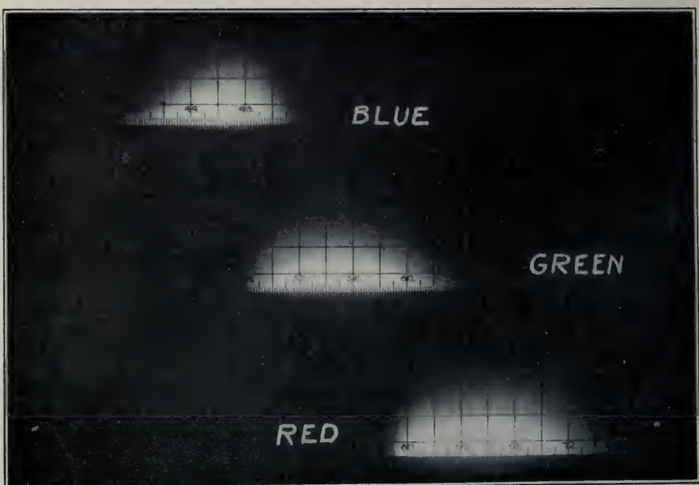



Fig. 10.
Portions of Spectrum Transmitted by Primaries.

receiving nerves in all parts of the retina, corresponding to the three primary colors—red, green and blue-violet.

If we let white light fall upon anything, such as a piece of white paper, which reflects all the wave lengths to the same extent, then the reflected light remains white and we should say that the object on which it falls is uncolored, but if the object absorbs some of the wave lengths of the spectrum more than others, then it will appear colored. Thus, a piece of red paper appears red because from the white light falling upon it it absorbs some of the green and blue-violet light, but reflects all the red light and, therefore, appears red. In the same way a green object absorbs both red and blue-violet more than it absorbs the green light and so looks green, and a yellow object absorbs the blue, reflecting the red and green of the spectrum and so appears yellow.

Light waves differ not only in their length but in their amplitude, that is, in the height of the wave, and the amplitude controls the intensity of the light just as the wave length controls the color. The eye, therefore, can detect differences in brightness which depend upon amplitude, and also differences of color which depend upon wave length.

## CHAPTER III.

### ABOUT LENSES.

IN order to take a photograph we use a lens which forms an image of the object we want to photograph upon the film. The simplest lens which we could use would be a small hole. Suppose that we take a sheet of cardboard and make a hole in it with a pin, and then, in a darkened room, hold the cardboard between a sheet of white paper and an electric lamp; we shall see on the paper an image of the lamp filament.

The diagram shows how this image is produced. A ray of light from each portion of the filament passes through the pinhole and forms a spot of light on the paper, and all these spots joining together form the image of the filament.

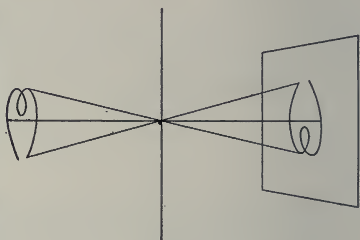


Fig. 11.
How an Image is Produced.

If we take the lens out of a camera and replace it by a thin piece of metal pierced with a hole made by a needle (a No. 10 sewing needle is about right, and the edges of the hole must be beveled off so that they are sharp), then we can take excellent photographs by giving sufficient exposure.

If the pinhole is about six inches from the film then an exposure of about one minute for an outdoor picture on film will be required. It is necessary, of course, to make a well fitting cap for the lens aperture so that no light will get in except through the pinhole, and also to make a cover for the pinhole to act as a shutter for exposing.

But if a pinhole were the only means of forming an image it is very improbable that photography would ever have been developed, since the exposures are so long in consequence of the small amount of light which can pass through the pinhole.

In order to get more light we could try making the pinhole larger, but the effect of this is to make the image very indistinct, and even the smallest efficient pinhole can not give as sharp an image as a good lens.

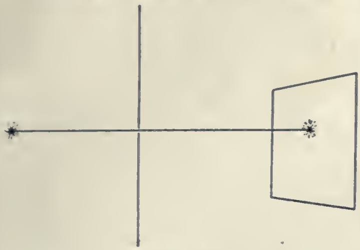


Fig. 12.
Pinhole Image of a Star.

Suppose we have a small pinhole forming an image of a star, as shown in Fig. 12.

If we make the hole larger, we shall get a round, spreading beam of light and no longer get a sharp image. (Fig. 13.)

What we need, if we are to use the large hole is, some means of bending the light so that all the light reaching the hole from the star is joined again in a sharp image of the star on the screen, as shown in Fig. 14.

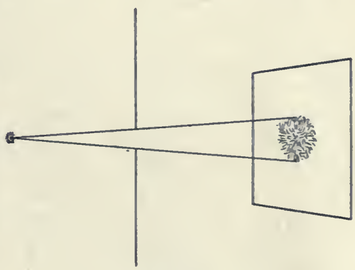


Fig. 13.
Effect of Large Pinhole.

If a ray of light falls on a piece of glass so that it is not perpendicular to it, it will be bent. There is an interesting experiment which shows this very well. Take a thick block of glass and place it so that it touches a pin (which is marked B in Fig. 15) and stick another pin (A) in the board. Now look through the glass and stick a pin (D) between your eye and the glass, and in the same line of sight as A and B, and lastly another pin (C) touching the glass and in the same line of sight as the other three.

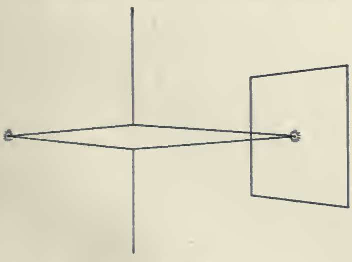


Fig. 14.
Need of Means to Bend Light.

Take away the glass and join up the pinholes with pencil lines. You will find that the line DC is parallel to the line AB but is not in the same line; that is, *the ray of light marked by the line AB was bent when it entered the glass* and then bent back again when it left it, so we can bend light by means of glass.

If we take a triangular piece of glass (called a prism) we can bend a ray when it enters the glass and also more still when it leaves the glass. (Fig. 17.)

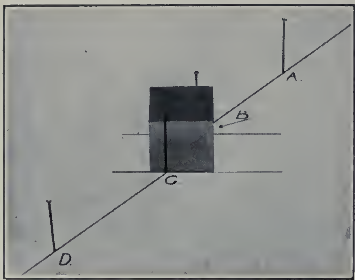



Fig. 15.
Deflecting a Ray of Light.

And a lens is really two prisms stuck together base to base (Fig. 18). So that if we put a lens in the hole with which we want to form an image, we can do what we wish to and make all the rays from the star come together again in the image of the star. And this is the purpose of our camera lenses, to form an image sharper than that given by the smallest pinhole and yet much brighter than any pinhole would give.

Should we place a pinhole, instead of a lens, in the front-board of our camera, we could use the same size of pinhole for making all sizes of pictures, because the image formed by a pinhole is always of the same sharpness, whether the pinhole is far from the film or close to it. If we want a large picture we must, of course, use a large camera with a long bellows, so the pinhole will be a long way from the film, while if we want a small picture we shall only need a small camera with a short bellows, so the pinhole will be near the film. But if, instead of a pinhole, we use a lens, we shall find that the lens must be placed at a certain distance from the film (depending upon its focal length and its distance from the object photographed) in order to obtain a sharp picture. If it is placed at any other distance from the film the picture will be all blurred. The reason for this is that

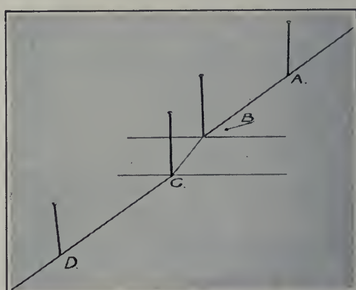



Fig. 16.
Path of Deflected Ray.

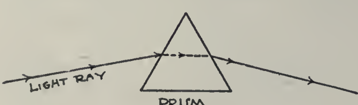



Fig. 17.
Prism Bending a Ray.

a photographic lens bends the rays of light that pass through it so that all the light rays from a star, for instance, will meet again to form an image of the star. By placing a sheet of cardboard at the position where the rays of light meet, the image of the star will be sharp, but if we put the card either nearer to or farther from the lens, the image will be blurred into a circle of light. The distance at which the lens must be placed from the film to give a sharp image represents the "focal length" of the lens.

Fig. 18.
Rays Bent by Double Prism.

The longer the focal length of a lens the larger the image, and the shorter the focal length the smaller the image. Suppose we photograph a tree and place the camera at such a distance from the tree that with a lens of three inches focal length we obtain a picture in which the image of the tree is one inch long.

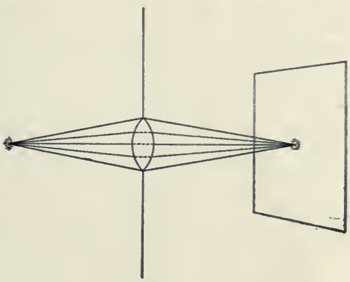


Fig. 19.
Lens Forming a Sharp Image.

Now, if with the camera at the same distance from the tree, we had used a six-inch lens instead of the three-inch lens, which means that instead of the lens being three inches from the film it would be six inches from it, then the image of the tree would be two inches long instead of one inch long in the picture. If we were using the same size film with both lenses, of course we should not be able to include as much of the subject we were photographing in the field of view of the picture made with the six-inch lens as we should obtain with the three-inch lens, because with the three-inch lens the tree would be, say, a quarter of the length of the picture, while with the six-inch lens it

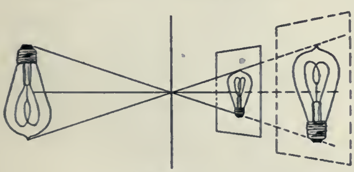


Fig. 20.
Images formed by a pinhole at various distances.

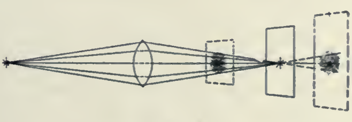


Fig. 21.
A lens forms an image at only one point.

would be half the length of the picture. In other words, the three-inch lens would give us a smaller image, while the six-inch lens would give us a large image of the tree.

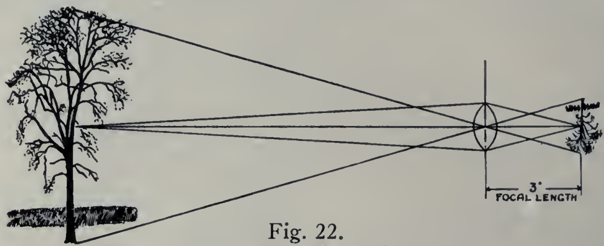



Fig. 22.
Short Focal Length Means Small Image.

The longer the focal length of a lens, the less subject we include in our picture, and the larger the images of objects are, while the shorter the focal length, the more subject we include in the picture and the smaller the images are.

In actual practice we must compromise between a lens which will include as large an area as possible in the field of view, and a lens which will give images as large as possible; consequently, for general all-around purposes it is best to use a lens whose focal length is somewhat longer than the longest side of the film. For a $2\frac{1}{2} \times 4\frac{1}{4}$ film, for instance, we should use a lens of about 5 inches focal length.

It is most important not to use a lens of too short a focal length for the size of the film employed. There is a great temptation to do this. While a lens of $4\frac{1}{2}$ inch focus as compared with a lens of three inch focus means a big lens in place

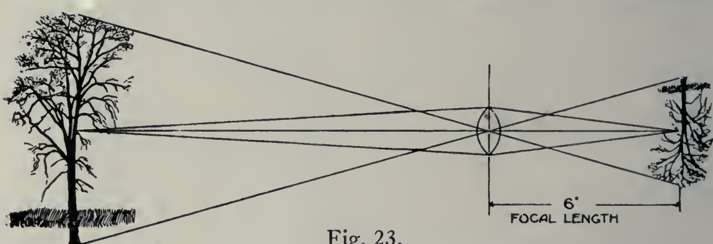



Fig. 23.
Long Focal Length, Larger Image.

of a little lens, and a larger shutter and a somewhat larger camera in place of a smaller shutter and an extremely compact camera, it also means (and this is vastly more important than mere camera compactness) the making of pictures having good perspective instead of pictures with bad perspective; in other words, it means pictures the drawing in which looks right instead of pictures whose drawing looks wrong. The reason for this is that the perspective of a picture is determined by the point of view from which the lens makes the picture. If this perspective is not pleasing to the eye it will not be pleasing in the picture.

Fig. 24.
Made With a Very Short Focus Lens.

Fig. 24 shows a picture made with a very short focus lens used close to the subject. This is a faithful rendering of the perspective that the eye saw from the viewpoint of the lens, but it is far from pleasing.

Fig. 25. Made With a Long Focus Lens.

In Fig. 25 the same subject is shown photographed with a long focus lens, and in this picture the perspective is satisfactory. It likewise represents the perspective that the eye saw from the viewpoint of the lens.

It is a good rule to secure a lens which has a focal length at least equal to the diagonal of the film. A little more focal length is still better.

Lenses differ in another respect than their focal length. They differ in the amount of light they admit, and this is very important, because the more light admitted, the shorter the exposure can be. The chief object in using a lens instead of a pinhole is to transmit more light to the film, and the amount of light that is transmitted depends upon the area of the glass in the lens.

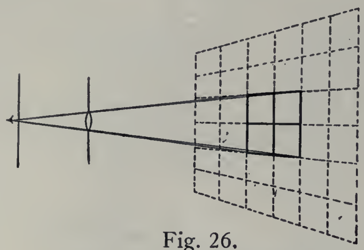


Fig. 26.
Visible Area with Long Focus.

Suppose we place a piece of cardboard, instead of a film, in the back of a camera, and have a pinhole in the card through which we can look at the lens; then point the lens toward a window; the amount of light that reaches the eye through the hole in the card depends upon how much of the light from the window is passing through the lens; that is to say, it will depend on the area of the window which we could see if there was no glass in the lens. Of course, since the visible area of the window is bounded by the edges of the lens mount, we could see more if the lens were of shorter focal length so that the eye was closer to it. With a lens of long focal length only a small part of the window area is visible.

With a lens of half the focal length but of the same diameter as that shown in Fig. 26, four times as much of the window area is visible.

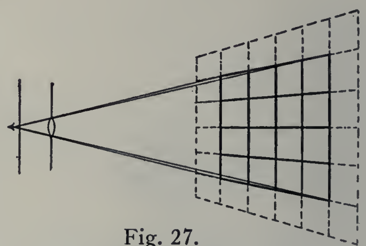


Fig. 27.
Visible Area with Short Focus.

The brightness of the image projected by lenses of the same diameter varies inversely as the square of the focal length of the lens. It also varies as the area of the lens surface (aperture) which admits the light. The greater the lens aperture the more light it admits. Now the area of the lens aperture, of course, is proportional to the square of its diameter, so that all lenses in which the diameter of the aperture bears the same ratio to the focal length will give equally bright images. This means that the brightness of the image is determined not solely by the focal length, nor solely by the diameter of the lens aperture, but by the *relation* that exists between the lens aperture and the focal length of the lens, so that all lenses in which the diameter of the opening is, say, one-sixth of the focal length, will give equally bright images. Thus, in a lens of one-inch aperture and a focal length of six inches, the opening is one-sixth of the focal length, and in a lens of twelve inches focal length and two inches aperture, the opening is likewise one-sixth of the focal length. Both lenses are of the same *f* value. This means that both give an image of the same brightness, and will require the same exposure. Lens "apertures" are, therefore, rated according to the ratio between their diameter and their focal lengths; thus, one in which the opening is one-sixth of the focal length is marked *f*.6; one in which the opening is one-eighth, *f*.8, and so on, and the larger the aperture, the more light the lens transmits, and the more light it transmits the shorter the exposure needed.

But while large lens apertures have the advantage of permitting shorter exposures, they have some disadvantages. In the first place, to get a large aperture we must have a *large lens*, and this means an expensive lens; also, the errors of definition, which are called the "aberrations" of lenses, increase very much as the apertures increase, so that only the very best types of lenses in which these aberrations are removed to as great an extent as possible, can be made of large aperture and still give good definition. Large aperture lenses are therefore costly.

But even when we have a lens with a large aperture we shall have to regard this as a reserve power for use in special circumstances, and we shall not by any means be able to use it at its largest aperture all the time.

From the construction of a lens it follows that only the rays from a mathematical point can come together in a point again, and that the rays from any point nearer or farther than the point focused can not meet in a point image on the film, but must produce a small disc of light instead of a sharp point of light. (See Fig. 21.)

The disc is termed the *circle of confusion*. If the circle of confusion is small enough we shall not be able to distinguish it from a point, and the picture will appear to be sharp.

With what are known as "fixed focus" cameras, such as the Vest Pocket Kodaks and the Box Brownies, no attempt is made to secure a wholly sharp focus for objects at all distances, but the cameras are sharply focused on the nearest point to the camera which will still enable distant objects to appear approximately sharp in the pictures, and in this way objects in the middle distance are perfectly sharp, and near objects are also sharp, provided they are not too near.

The following table of these distances, beyond which everything is sharp when the largest stop is used, may be useful:

| | | |
|---|---|---|
| Vest Pocket Kodak . . . . . | 9 | feet |
| No. 0 Brownie . . . . . . | 9 | " |
| No. 2 Brownie . . . . . . | 13½ | " |
| No. 2A, 2C and No. 3 Brownie . | 15 | " |

If we are using a No. 0 Brownie, for instance, as long as everything is farther off than nine (9) feet we can rely on getting a picture with everything focused sharply.

With the focusing Kodaks we must judge the distance of the object on which we wish the focus to be sharpest and set the scale to that; then we shall find that objects somewhat nearer, and also objects a good deal farther from the camera are also sharp, and the distance from the nearest to the farthest objects that appear sharp in the negative is called the "depth of focus." This depth of focus depends on the focal length of the lens and on the size of stop used in the lens; the greater the focal length the less the depth of focus, and the *bigger the stop the less the depth of focus.* Thus in Fig. 28, we have a lens focusing near and far points at full aperture and producing large circles of confusion. In Fig. 29 a smaller stop is used in the same lens, and the circles diminish in size in proportion to reduction in the size of the stop.

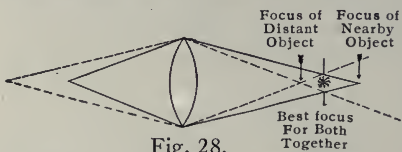



Fig. 28.
Depth of Focus with Full Aperture.

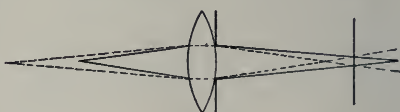


Fig. 29.
Depth of Focus with Smaller Aperture.

Sometimes we have to focus near objects at the same time as distant ones, so that it is necessary to "stop the lens down" to some extent.

Stops are marked in two different systems, though both are based on the fundamental ratio of the diameter to the focal length of the lens. In the one system the stop is expressed simply as a fraction of the focal length; thus F./8 (commonly written *f*.8) means that the aperture is one-eighth of the focal length of the lens; *f*.16, one-sixteenth, and so on. The rectilinear lenses fitted to Kodaks are, however, marked in the "Uniform System" (U. S.) in which the numbers are proportional to the exposure required, *f*.4 being taken as unity, so that the scale is as follows:

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| F. | *f*.4 | *f*.5.6 | *f*.6.3 | *f*.8 | *f*.11 | *f*.16 | *f*.22 | *f*.32 | *f*.45 |
| U. S. | 1 | 2 | 2½ | 4 | 8 | 16 | 32 | 64 | 128 |

The U. S. numbers give the relative exposure that is required with the *f*. system stops, the exposure varying as the square of the *f*. value, so that *f*.11 requires twice the exposure of *f*.8; *f*.16 twice that of *f*. 11 and so on.

Kodaks, Premo and Brownie cameras are listed with several different kinds of lenses, the smaller cameras being listed with either Meniscus, Meniscus Achromatic, Rapid Rectilinear or Anastigmat Lenses. The larger cameras have either Rapid Rectilinear or Anastigmat Lenses, while the Special Kodaks and Graflex cameras have Anastigmats only. The Box Brownies are equipped with Meniscus or Meniscus Achromatic Lenses, while with the Folding Brownies there is a choice between Meniscus Achromatic and Rapid Rectilinear lenses.

Many people do not understand the meaning of these terms, and while it is a safe rule to choose the best lens which can be afforded, certain that the better lens is worth the extra cost, it is still better to understand the properties of the different kinds of lenses and what advantages can be gained from the use of the higher grades.

The simplest lenses which can be used are made of a single piece of glass, the form of the lens being of the type which gives the best definition; that is, a Meniscus or crescent shape, and the lenses are called Meniscus (not Meniscus Achromatic) lenses. Such a Meniscus lens can only be used in a fixed focus camera where the maker of the camera has put it in the correct position for forming a sharp image upon the film, but if such a lens were used in a focusing camera we should find that however carefully we focused the picture on the ground glass the negatives would not be sharp, unless the difference between the focusing point of the visual rays by which we focus, and the chemical rays which affect the film, was provided for.

This is because a non-achromatic lens bends the rays of light of different colors to different extents, so that the yellow rays which we use for focusing do not come to a focus in the same place as the blue rays which affect the film, because the blue rays are bent more than the yellow.

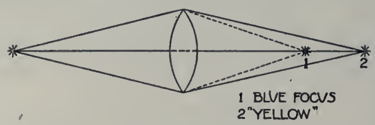



Fig. 30.
Focus of Blue and Yellow Rays.

In 1752, Dollond, an English optician, showed that by combining two different kinds of glass to make a lens he could get the blue rays to focus at the same point as the yellow rays, and lenses made in this way were called "achromatics," from the Greek words "a" meaning not, and "chroma" meaning color. The best shape of achromatic lens to use is shown in Fig. 31, and since this is also of a "meniscus" or crescent shape the lenses are called meniscus achromatics. If a single achromatic lens is used, it is necessary to "stop it down" so that only a small portion of the lens is used, because the rays which come through the edges do not focus together as well as those which come through the center, and so the image is not quite sharp if the whole lens area is used.

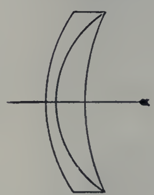


Fig. 31.
Achromatic Lens.

This stopped-down meniscus lens has the effect of producing slight curvature of the edges of the picture, which does not matter in landscape work or portraiture; but if subjects containing straight marginal lines are photographed with such a lens, their outer lines appear slightly curved—so slightly, however, that the effect is negligible unless the image of the subject so crowds the picture area that its outer lines are very near the margins of the picture, as shown by figures 32 and 33, which represent a window sash photographed with a meniscus lens at short range.

If the stop is in front of the lens the curvature is in one direction, and if it is behind the lens the curvature is in the opposite direction, so that if we put two lenses together with the stop between them, the curvature is neutralized and we get a lens which gives no curvature at all.

Such a lens is called a "Rapid Rectilinear"— rectilinear because it gives straight-line images, and rapid because having a focal length half that of either of the component lenses with a stop of the same diameter, it passes four times as much light and only requires one-quarter of the exposure. Rapid Rectilinears are sometimes called by other names, such as "Rapid Aplanats," "Planatographs," and so on. Now, it so happens that the two kinds of glass used in an achromat must fulfill certain conditions to bring the blue and the yellow rays to the same focus, and must

Fig. 32.
Made with Stop in Front of Meniscus Lens

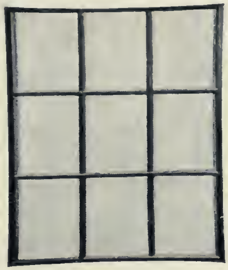


Fig. 33.
Made with Stop Behind Meniscus Lens.

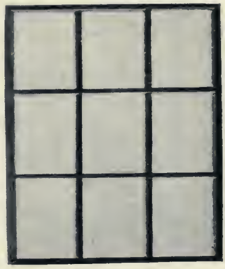


Fig. 34.
Made with Rectilinear Lens

fulfill certain other conditions to get a picture which is flat, that is, a picture that is sharp on a flat plate or film; and the ordinary glasses which are used for making achromats will not fulfill all these conditions at once, so that the lenses made with "old" achromats will not give flat field images, the image being saucer-shaped. These lenses are, therefore, said to be "astigmatic," which means that they do not give sharp-point images of points.

About thirty years ago, Professor Abbe and Otto Schott, working together at Jena, found out how to make new kinds of optical glass from which lenses could be made which would give flat field images with the blue and yellow rays of the same focus.

By the use of these new glasses the opticians have been able to make lenses that give sharp images on a flat field to the very edge of the picture and, therefore, these lenses are called "Anastigmats," meaning "not astigmatic," but this better defining power can, however, only be obtained by the most careful and skilled work in making the lens, this work being of a far higher quality than that employed on the older types of lenses, which accounts for the higher cost of anastigmats.

Anastigmat lenses can be used with larger stops than any of the older lenses, so that if an Achromatic working at *f*. 16 requires a 1/5 second exposure, a Rapid Rectilinear working at *f*.8 will require a 1/20 second exposure, and an Anastigmat working at *f*.6.3 will require a 1/32 second exposure.

To summarize the advantages and disadvantages of the three types of lenses discussed in the preceding pages:

The single lenses (meniscus and meniscus achromatic) must be used with a relatively small stop, which means that they are somewhat slow. They are fast enough for snapshots in good light, the shutters they are fitted with being adjusted for the making of moderately slow "snaps". The very fact that they require a small stop gives them great depth of focus, however, and for that reason errors in focusing are largely compensated for, resulting in a high percentage of successful pictures.

The Rapid Rectilinear Lenses have more speed than the single lenses, and are also better for architectural work.

The Anastigmat, *f*.6.3, lenses are about sixty per cent faster than the Rapid Rectilinear lenses and are corrected for the finest definition (sharpness). When used at their full speed—that is, with the largest opening—they require accurate focusing, although it should be borne in mind that both the length of focus and the stop opening affect this matter of depth of focus. That is why the 3A,the largest of the Kodaks, requires more accurate focusing than the smaller ones, and is why, when we get down to the Vest Pocket size, it is possible to use an Anastigmat lens with a fixed focus.

An Anastigmat lens does not require any more accurate focusing than any other lens when used with the *same stop*. Take, for instance, an average landscape with a prominent object in the foreground. The correct stop would be *f*.16 and, if the sun were shining, the correct exposure 1/25 of a second. This same stop and exposure should be used with a Single lens, a Rapid Rectilinear or an Anastigmat, and the depth of focus with the same focal length of lens would be the same in all cases—no more accurate focusing would be required with one lens than with another.

But when the light is weak and an Anastigmat is used at its full opening, or nearly its full opening, in order to get a well timed snapshot, there will be a gain in speed but a loss in *depth* of focus. The object at the focused distance may photograph even sharper than it would with the Single or Rapid Rectilinear lenses, but objects a little nearer the camera or a little farther away will not be so sharp because depth of focus has been sacrificed for speed. And, of course, this same thing is true in using a large stop in order to arrest the motion of moving objects. With a fixed-focus camera working at a fixed shutter speed, all still objects at, say, fifty feet away, would be sharp and, with a good light, fully timed, but moving objects might show a blur. With an Anastigmat lens opened to *f*.6.3 and a shutter speed of 1/200 of a second, it is possible to arrest moderately fast motion and get a fully timed negative (with good light), but in such case care must be taken to focus accurately.

# CHAPTER IV.

## THE LIGHT SENSITIVE MATERIALS USED IN PHOTOGRAPHY.

AS was explained in Chapter I, the sensitive coating on films and papers consists of bromide or chloride of silver held in a thin layer of gelatine, and thus, photography depends upon the fact that the shiny, white metal silver when combined with certain other substances forms compounds which are sensitive to light and which are changed in their nature when they are exposed to light.

Chemical compounds are formed by the combination in definite proportions of a limited number of *elements*, of which about eighty exist.

These elements may be divided into the two classes of *metals* and *non-metals*, and the metals combining with the non-metals form compounds called *salts*. These salts are not usually formed by the direct combination of the metal and the non-metal but by the agency of *acids*.

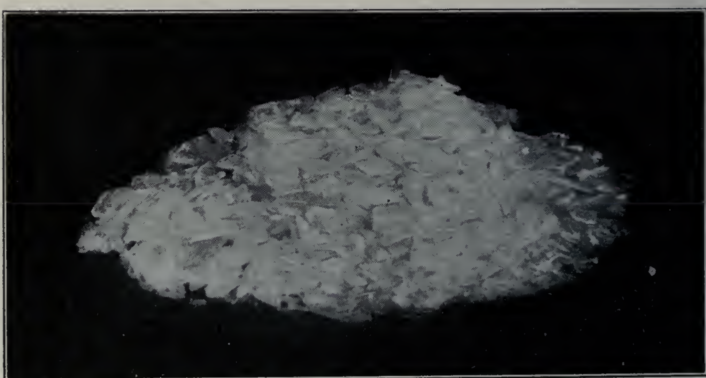


Fig. 35.
Crystals of Silver Nitrate.

Thus, the first step in making a light sensitive compound of silver is to dissolve the silver in nitric acid. After the silver has been dissolved by the acid, and then dried up we get flat, plate-like crystals of silver nitrate. These crystals of silver nitrate dissolve in water quite easily, but if some cooking salt solution is added to the silver nitrate solution, the silver combines with one of the components of the salt, called *chlorine*, and the silver chloride that is produced is not soluble in water, so that it will be visible as a sort of white mud in the solution.

Chlorine is one of a group of elements which, because they occur in sea salt, are called halogens, from the Greek name for the salt sea. Two others of these elements are bromine and iodine, and the silver compounds with these three elements are distinguished by their extreme insolubility in water and their sensitiveness to light. Silver bromide is more insoluble than silver chloride and is pale yellow in colour; silver iodide is still more insoluble and is strongly yellow.

These silver compounds are formed by simply adding a solution of a chloride (such as cooking salt), bromide or iodide to a solution of silver nitrate. If this is done in a water solution, the silver compound will settle down to the

Fig. 36.

Two Flasks Containing Precipitated Silver Bromide: Left, Without Gelatine; Right, With Gelatine.

The flask on the left shows that silver bromide without gelatine settles to the bottom of the solution. The one on the right shows the silver bromide held evenly in suspension by gelatine.

bottom of the vessel, but this may be prevented by adding to the water some gelatine, like that used for cooking.

The gelatine is soaked in water, and then when it is swollen it is dissolved by putting it in warm water and gently warming and shaking until it is all dissolved. Then there is added to this the right quantity of bromide. The bromide dissolves in the gelatine solution just as salt would, and is stirred up to get it evenly distributed. Meanwhile, some silver nitrate has been weighed out so that the right amount is taken to act with the amount of bromide chosen and is dissolved in water, in which it dissolves very easily. This silver nitrate solution is then added slowly to the bromide dissolved in the gelatine, and produces at once a precipitate of silver bromide. This silver bromide is sensitive to light so that before adding the silver nitrate to the bromide and gelatine all the white lights are turned out and the silver is added by the light of a photographic red lamp.

As the silver is added a little at a time, the solution being stirred meanwhile, the gelatine becomes full of the smoothly, evenly precipitated silver bromide distributed through the solution.

If the emulsion of silver bromide in gelatine is coated on the film and then cooled, the gelatine will set to a jelly, still containing the silver bromide suspended in it, and then when this layer is dried, we get the smooth yellowish coating, which is familiar to those of us who have looked at an undeveloped film in the light.

If we look at the silver bromide film through a very high power microscope, we shall find that the silver bromide is distributed throughout it in the form of tiny crystals. These crystals are in the form of flat triangular or hexagonal plates, and careful investigation has shown that they belong to the regular system of crystals. When these crystals are exposed to light, no visible change takes place, but there must be some change because when a crystal of silver bromide, which has been exposed to light, is put into a developer, the developer takes the bromine away from the silver and leaves instead of the crystal what looks under a microscope like a tiny mass of coke, which is, really, the metallic silver itself freed from the presence of the bromine.

It may seem strange that silver, which we always think of as a bright, shiny metal should look black, but when it is divided up in this irregular way, it looks black, although it is the same thing as the shiny metal we are familiar with, just as a black lump of coke is the same thing as the bright gleaming diamond.

If the silver bromide has not been exposed to light, then the developer has no power to take away the bromine from

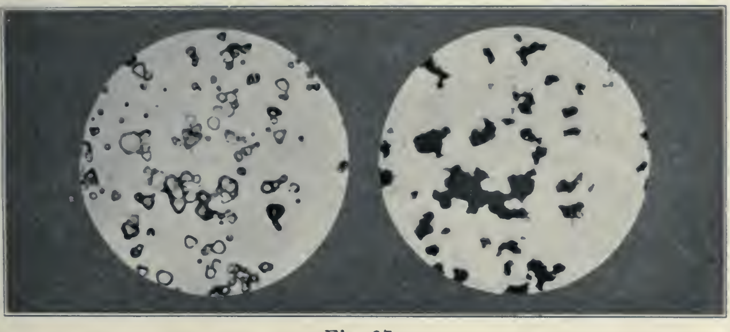


Fig. 37.
Crystals of Silver Bromide before (left) and after (right) Development.

The photographs above, taken through a very powerful microscope, show crystals of silver bromide before development (on the left) and (on the right) some crystals after they have been changed into metallic silver by development. The crystals before development are transparent except where they are seen sideways or where their edges appear darker. After development the clear yellow silver bromide is turned into a black coke-like mass of silver in exactly the same position as the crystal from which it was formed.

the silver and leave the black silver behind, so that we see a developer is a chemical that has the power to take away the bromine from the silver in a grain of silver bromide which has been exposed to light but will not affect one which has not been exposed to light.

Wherever, then, the light in the Kodak acts upon the silver bromide crystals in the emulsion, the developer turns them into black grains of silver and we get an image, and where the light has not acted the developer has no action and no image is produced. The chemical part played by a developer, therefore, is the freeing of the metallic silver from the bromine associated with it.

This liberation of metals from their compounds is the most important chemical process in the history of the human race.

The great thing which has distinguished man from the other animals has been his ability to make and use tools and weapons, and man has progressed step by step from the earliest days when he used a flint fastened to a stick, to the present time, when he employs the marvelous machinery of modern civilization; but the greatest step in all that progress came when men found out how to get metals to use in the place of stone. All the earliest weapons were made of stone, and then men found a way of getting tin from its ores, and found that when this tin was combined with copper, which they found in the ground, they could get bronze, and for a long time all the weapons and tools were made of bronze, and then came the greatest discovery of all—they found that by taking iron ore and heating it with charcoal they could get the metal iron, which made such beautiful tools and weapons; and from the time that men found out how to get iron, they ceased to be savages and began to be civilized.

Iron is got from the ore by heating it with charcoal or coke, which takes away the other components of the ore and leaves the metallic iron free. Metals can be got out of their compounds in different ways. Quicksilver, for instance, can be got by merely heating its oxide. If the red oxide of quicksilver be heated the quicksilver will boil off, and can be collected quite pure at once. Silver is rather easy to get, and, indeed, if we take a solution of silver nitrate and add some iron sulphate to it the metallic silver will be thrown out as a black sludge.

The developers that we use in photography play the same part for the silver that the charcoal does for the iron; they take away the bromine from the silver bromide and leave the metallic silver behind.

The emulsion coated on films and used for making the negative contains silver bromide with a small addition of silver iodide. The different degrees of sensitiveness are obtained by the amount and duration of heat to which the emulsions are subjected during manufacture, the most sensitive emulsions being heated to higher temperatures and for a longer time than the slower emulsions.

If a slow bromide emulsion is coated upon paper, the material is known as bromide paper and is used for printing and especially for making enlargements. The less sensitive papers which are commonly used for contact printing by artificial light, contain silver chloride in the place of silver bromide.

Materials which are to be used with development must not contain any excess of soluble silver, and the emulsion must be made so that there is always an excess of bromide or chloride in the solution, since any excess of soluble silver will produce a heavy deposit or fog, over the whole of the surface as soon as the material is placed in the developer. In the case of Solio paper, however, which is not used for development but which is printed out, a chloride emulsion is made with an excess of silver nitrate, this having the property of darkening rapidly in the light, so that prints can be made upon Solio paper without development, a visible image being printed which can be toned and fixed. Solio paper can be developed with certain precautions, but only by the use of acid developers or after treatment with bromide to remove the excess of silver nitrate.

In the early days of photography prints were usually made on printing-out papers, but at the present time most prints are made on developing-out chloride and bromide papers, which are chemically of the same nature as the negative making materials, and which are coated with emulsions containing no free silver nitrate.

# CHAPTER V.

## THE STRUCTURE OF THE DEVELOPED IMAGE.

THE silver grains which form the developed image are held in a layer of gelatine. This gelatine is used in making the emulsion which is coated on the support to make the sensitive film.

Gelatine is a very interesting substance, and its characteristics are markedly different from those of most other chemical substances. Most chemical substances form crystals, and many of them are soluble in water. When they are dissolved in water, the solution is quite homogeneous, that is to say, alike in its properties in all its parts. Substances generally will dissolve in water to a fixed extent, dependent on the temperature. We say of one material, for instance, that it is soluble to the extent of 30%, meaning that a hundred parts of water will take up 30 parts of the material. If we heat the solution it will usually dissolve more, but then when it cools again the material will crystallize out so that whatever we do we can only obtain the fixed 30 parts per hundred remaining in solution.

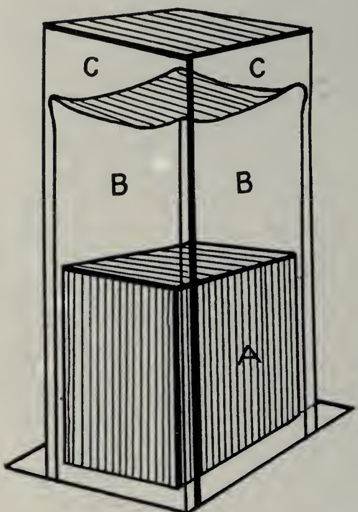



Fig. 38.
Swelling of Gelatine Cube.

Gelatine behaves quite differently to this. In cold water it does not dissolve but it swells, as if, instead of the gelatine dissolving in the water, the water dissolves in the gelatine. If the water is heated, the gelatine will dissolve in it, and it will dissolve to any extent. You cannot say that there is a definite solubility of gelatine in water. The more gelatine is added, the thicker the solution becomes, but there is no point at which the gelatine will refuse to dissolve.

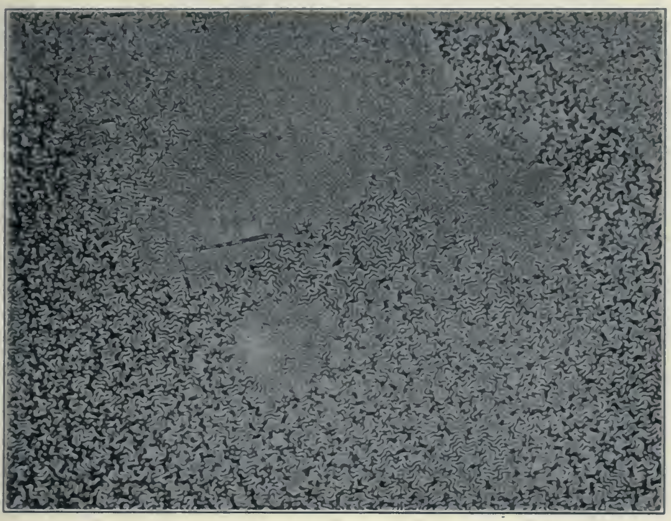


Fig. 39.
Reticulation.

If we heat a gelatine solution it will become thinner and less viscous when hot, and will not recover completely when cool; it will remain thinner than if it had not been heated, so that the heating of the gelatine solution produces a permanent change in its properties. If we cool a gelatine solution, the gelatine will not separate from the solution in a dry state, but the whole solution will set to a jelly, which we might consider a solution of water in the gelatine. If we heat the jelly it will melt again, and we can melt and reset a jelly many times, but in doing so we shall produce a progressive change in the jelly, and if we continue the process too long, sooner or later it will refuse to set and will remain as a thick, gummy liquid.

Gelatine belongs to the class of substances which are called colloids, the name being derived from a Greek word meaning gummy.

When a gelatine jelly is dried, it shrinks down and forms a horny or glassy layer of the gelatine itself, smooth and rather brittle, and this dry gelatine when placed in water will at once absorb the water and swell up again to form a jelly.

An interesting and important property of the drying and swelling of gelatine is that it swells almost entirely in one direction, namely, that in which it was dried. This is illustrated in Fig. 38. In this, *A* represents a small cube cut out of a sheet of gelatine which was originally dried in the horizontal plane when it was made. If this cube is placed in water, it will not swell in all directions, becoming a bigger cube, but it will swell almost entirely in the direction in which it dried down, and will take the form *B* and, finally, the form *C*.

Fig. 40.
Spot on Gelatine
Caused by Moisture.

The explanation of this directional swelling of the gelatine jelly, and also of the fact that gelatine solutions change permanently with heating, lies in the fact that gelatine is not a uniform substance but has an internal structure. Probably, gelatine has a structure somewhat like that of a sponge, but the structure is very small and has not the elasticity of the sponge.

When the gelatine is in the jelly state, it is as though the sponge were full of water, and then it is fairly rigid, because of the water contained in the pores. When the water is dried out, the sponge structure shrinks down, and if it is stretched out in one direction by being coated on film or paper, for instance, it will shrink down vertically just as a sponge without elasticity would fall into a flat mass if placed on the table.

When the gelatine solution is heated and the gelatine dissolves, it seems at first to retain a certain amount of its structure, as if the sponge had disintegrated and was distributed through the solution but the sponge structure had not entirely disappeared. Then, if the temperature is raised, it behaves as if the structure were slowly breaking up and dissolving, so that after a considerable heating at a high temperature the whole solution becomes homogeneous. When this solution is cooled and, finally, set to a jelly, it has to re-establish a new sponge structure, and this will be different to the original one and probably of less strength.

This explanation of the behavior of gelatine, that it has an internal structure which can persist even in solution, seems to account for most of its properties and behavior.

When a gelatine jelly contains only such an amount of water that it still contains a considerable proportion of gelatine, over 10% for instance, the jelly will be strong and tough, but if the jelly contains much less gelatine than this, it will be weak and likely to rupture on any kind of strain. This is a very important matter in dealing with photographic films. When the film is first placed in the developer the gelatine at once commences to swell. As long as it does not swell too much it is easily handled, but if it swells too far, then it becomes very tender and is likely to be damaged by touch, and in extreme cases will swell so much that it will loosen from its support or wrinkle up in what is called "reticulation".

The swelling of a gelatine film is influenced by the temperature of the solution in which it is placed and also by the presence of other substances in the solution. A small amount of either acid or alkali will produce a considerable increase in the swelling, and since the developer is alkaline and the fixing bath is acid, both these solutions have a great tendency to swell the gelatine, especially when they are warm. On the other hand, sulphites tend to prevent swelling, so that an increase in the concentration of the sulphite in a developer or fixing bath will diminish it. An even greater aid in preventing swelling is the hardener in the fixing bath. The hardening agents used in fixing baths are the alums, which not only prevent the swelling of the gelatine temporarily but which permanently harden the structure of the gelatine so that it will not easily swell. The alum is introduced into the fixing

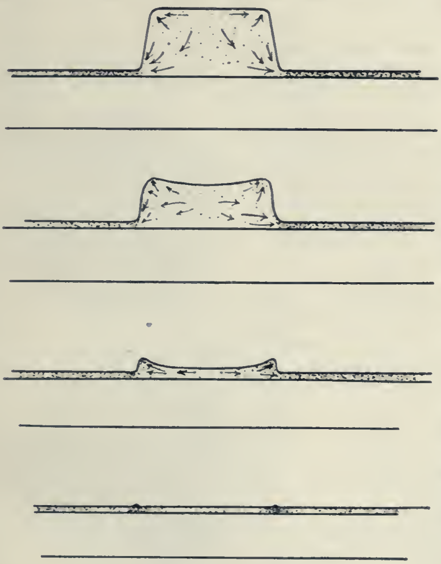


Fig. 41.
The Way a Waterspot Dries.

bath so that after fixing the film will not become soft and disintegrate in washing.

Reticulation is due to local strains in the gelatine, and a sudden change in the temperature of solutions will sometimes produce this effect. If a film is transferred for instance from a cold fixing bath containing a hardener to very warm wash water, the whole film will sometimes pucker into tiny reticulations, a good example of which is shown in Fig. 39. If one part of the film contains much more moisture than another, the silver image itself is liable to become distorted by the movement of the gelatine, and of the silver grains in it. If a drop of water, for instance, falls on a film and this is dried rapidly, it will often produce a curious ring-shaped mark, the middle of the drop being lighter and the edge of the drop darker than the surrounding negative, Fig. 40. The explanation of this is shown in Fig. 41. The gelatine swells up where the spot of water fell on it, and as it dries again a strain is produced by the collapse of the center of the swollen spot, and so the gelatine and silver grains are pulled in to the edges of the spot and there produce the dark ring.

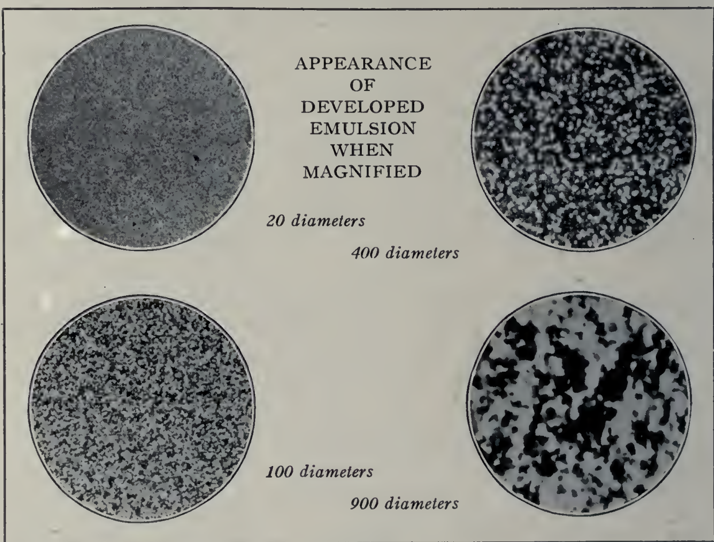
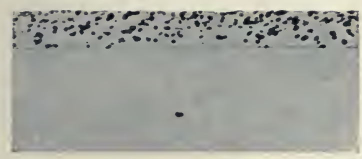



Fig. 42.
Appearance of Emulsion After Development When Magnified.

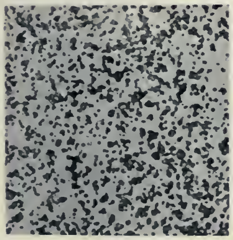
The developed image consists of grains of silver, each grain under sufficient magnification looking like a little mass of coke, replacing one of the silver bromide crystals which were originally formed in the emulsion and keeping the same position. See Fig. 37. When we look at a negative it appears perfectly smooth to the eye, but under a small degree of magnification it begins to show an appearance of graininess.

It must not be thought, however, that with a magnifying glass we can see the silver grains themselves. The silver grains are so small that to make them visible requires powerful magnification. What we see through the magnifying glass are clumps of grains.

Suppose that an aviator is flying over country dotted with occasional woods and clumps of bushes. If he is flying near to the ground, he will be able to distinguish the separate trees and bushes. If he goes higher, he will no longer be able to see them separately but he will see them in little clumps of two and three where they are close together with the spaces where they are farther apart showing between them, and then as he goes higher still, he will no longer be able to see these small clumps, but will be able to see only the large masses of woodland or forest. In the same way when we look at a negative under a low magnification, we see the larger masses of clumps of grains, and then as we increase the magnification we see the smaller clumps of grains, and then finally at a very high magnification we see the grains themselves, Fig. 42.

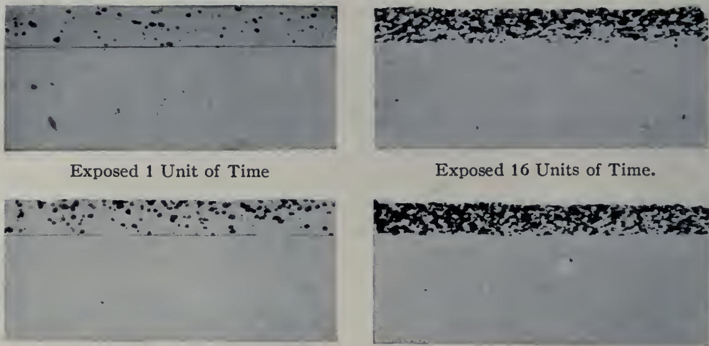


A
Vertical Section Showing Grain Deposit.



B
Horizontal Plan of Same Grain Deposit.
Fig. 43.

These clumps of grains which we can see under low magnification are made up of grains which are not all in the same layer. This can be seen by first of all photographing an image from above and then cutting a section down through it so as to see how the grains lie one below the other. In Fig. 43 A it will be seen that the image is as much as six grains deep so that



Exposed 1 Unit of Time

Exposed 16 Units of Time.

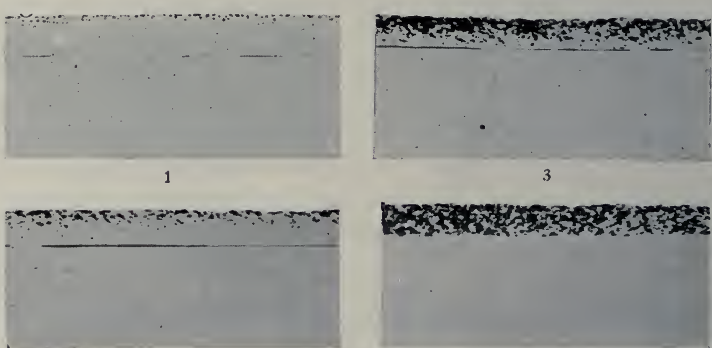
Exposed 4 Units of Time.

Exposed 64 Units of Time.

Fig. 44.

many of the clumps of grains seen in Fig. 43B are not made up of grains in the same layer but of grains in different layers, some on the top and some below.

The distribution of the grains in the depth of the film is interesting. It might be thought that with short exposures the image would be on the top of the film and that as the exposure was continued, the light would penetrate farther and farther into the film, making the grains in the lower layers more and more developable. This sometimes seems to be the case, but with some emulsions it is not so, as is proved by the photographs of sections shown in Fig. 44, which are cut from an N. C. film. These are fully developed so that the effect of development is eliminated, and they show that the grains are exposed at all parts of the film to



1

3

2

4

Fig. 45.

Showing Progress of Development from Surface to Base of Emulsion.

an almost equal extent, though in the second and third prints there is a slight tendency for the image to be more on the top of the film. It looks as though the emulsion contains grains of various degrees of sensitiveness and the more sensitive grains are made developable first. Further, since there is certainly more light at the surface of the film, it


Strong or Concentrated Developer.


Weak or Diluted Developer.
Fig. 46.

must be a fact that the more sensitive grains are found in the lower parts of the film.

During development, however, there is an appreciable effect due to the penetration of the developer into the film. This is shown in Fig. 45, where it is seen that at the beginning of development only the surface of the emulsion is developed, and then as development continues the developer penetrates into the film and develops more and more deeply in it. In the case of a strong developer this effect is accentuated, because a strong developer will develop the surface to good density before it has penetrated through the emulsion, while a weak developer will penetrate at the same rate as the strong developer and will not develop so rapidly, so that with a strong developer there is a tendency for the image to be confined to the surface of the emulsion, and with a weaker developer for it to penetrate through the whole emulsion. This effect is well shown in Fig. 46, where two photographs are shown of the edge of an exposed image, the image being shown as the dark part on the left, while on the right we have the light deposit of grains due to fog. The broad black line at the bottom of each illustration represents the film on which the emulsion is coated. In the upper picture, the image was developed with a very strong developer, while in the lower picture it was developed with a much weaker developer, and it will be noted that the weak developer has penetrated right through the image to the back, while with the strong developer the image has not developed through to the back of the film, although care was taken to develop the images to the same apparent density.

There is a curious effect shown in these photographs at the point marked A, where it is seen that at the edge of the developed image the fog grains are not developed in the lower part of the film; it is as if they had been eaten away. There is no doubt that the reason for this is that the bromide liberated during development of the heavy image has prevented the fog grains close to the edge of the image from developing. In extreme cases this will sometimes surround a dense image with a white line.

# CHAPTER VI.

## EXPOSURE.

IN order to get a satisfactory photograph of any scene it is necessary that the exposure should be correct. The time of exposure required will, of course, depend upon the brightness of the image formed by the lens on the film, and this in turn will depend upon the aperture of the lens used and on the brightness of the scene photographed. The brightness of a lamp is measured in terms of its candle power; that is, a lamp is stated to be equivalent to 1, 5, 10, or 100 candles, the original unit being an actual candle, though nowadays the practical standards used are electric lamps which have been carefully measured and which are kept for use only as standards.

When the light of one candle falls upon an object at a distance of one foot, the brightness falling on the object is said to be one foot-candle. When we have 3 candles at a foot distance, the brightness would, of course, be 3 foot-candles, and if we use a 25 candle power lamp, the brightness will be 25 foot-candles. (Fig. 47). If we change the distance, the brightness will vary inversely as the square of the distance, because the cone of light which covers one square at a foot will embrace 4 squares of the same size at 2 feet, 9 squares at 3 feet, and so on; and since the same light that falls on one square at one foot is spread over 4 squares, at 2 feet distance, it is naturally ¼ of the strength, so that a 25 candle power lamp at one foot dis-

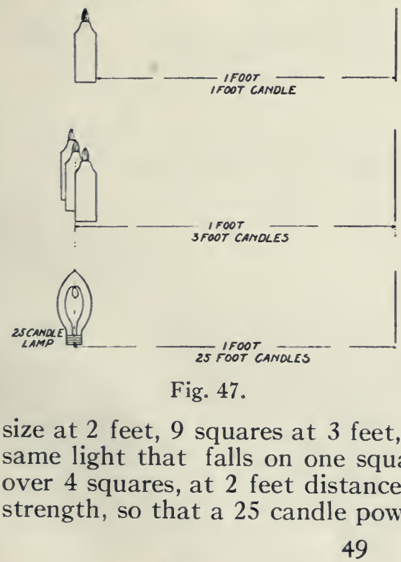


Fig. 47.

tance gives a brightness of 25 foot-candles, and at 5 feet distance it gives only one-foot-candle brightness (Fig. 48).

The brightness of natural objects can be measured by means of a photometer, in which the brightness is matched with a lamp of known brightness. A convenient form of the instrument is shown in Fig. 49. In this, the scene is viewed through a hole in a piece of white paper, and the white paper, which must be backed on metal so that it is opaque, is illuminated by a small movable lamp of which the distance from the paper can be varied. In order to use the instrument, it is held up to the eye so that the brightness to be measured can be seen through the hole in the paper, and then the lamp is moved until the brightness on the paper is the same as that seen through the hole. Now, the brightness which the lamp throws on the paper can be calculated from the distance of the lamp, and consequently we can read on the instrument the brightness of the object to be measured.

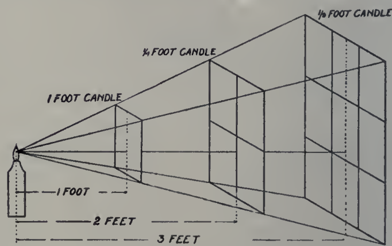


Fig. 48.

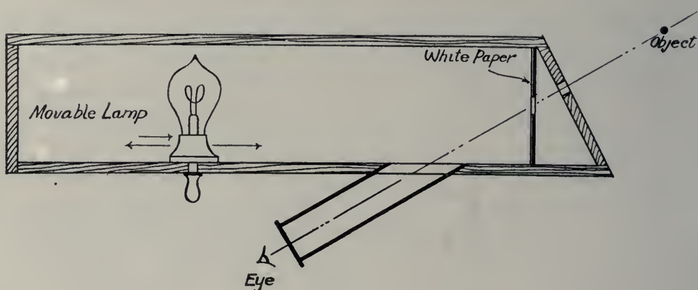


Fig. 49.
Photometer to Measure Relative Brightness.

In Figs. 50 and 51 are shown two landscapes which were photographed and at the same time were measured with the photometer, and it will be seen that the sky in these has a brightness of about 1500 foot-candles, while the deepest shadows in the foreground have a brightness of about 60 foot-candles.

It is often believed by photographers that the range of light intensities occurring in natural objects is very great, and that in an ordinary landscape, for instance, the sky will be enormously brighter than the shadows, but this idea


Fig. 50.

is quite incorrect. In a bright landscape with heavy shadows, the sky is only about 30 times as bright as the deepest shadows, while in the case of open landscapes in which there are no close objects in the foreground, the range of intensities will be much less than this, the sky often being only 5 or 6 times as bright as the shadows. The range of light intensities, therefore, with which it is necessary to deal in ordinary photography will vary from, perhaps, 1 to 4 at the least up to 1 to 50 as a maximum, and the brightest part of a landscape—the sky—will have a brightness of from 1000 to 3000 foot-candles. This is the photometric brightness of the sky itself; but when we take a photograph, we are concerned not with the brightness outside but with that inside the camera; that is, with the brightness of the image which falls upon the film. This brightness depends upon the aperture of the lens, and we can calculate it from the fact that at an aperture of *f*.8 the photometric brightness of the image is about 1/100th of the brightness of the object outside, so that the light from the sky falling upon


Fig. 51.

the film will have a brightness of, at most, 30 foot-candles, and the shadows will be represented by a brightness of about one foot-candle in a photograph of a landscape having a brightness range of 30 to 1.

Now, let us consider how much time of exposure will be required for the film to reproduce the shadows, of which we see that the image formed on the film has a brightness of one foot-candle. In order to do this, we must know how much exposure is required by a film to make it developable. We can find this by exposing the film to a candle at a fixed distance and giving it a series of different times of exposures. It is convenient to have each of these exposures double the next one, so that one part is exposed for one second, the next for 2 seconds, the next for 4, and so on. If, now, we develop and fix the film, and then after it is dry find out how much silver per square inch we have produced in each exposed part we shall find that each time the exposure was doubled we added almost the same amount of silver (Fig. 52.)

It is rather hard to measure the amount of silver by actual analysis, but it can easily be done optically by measuring

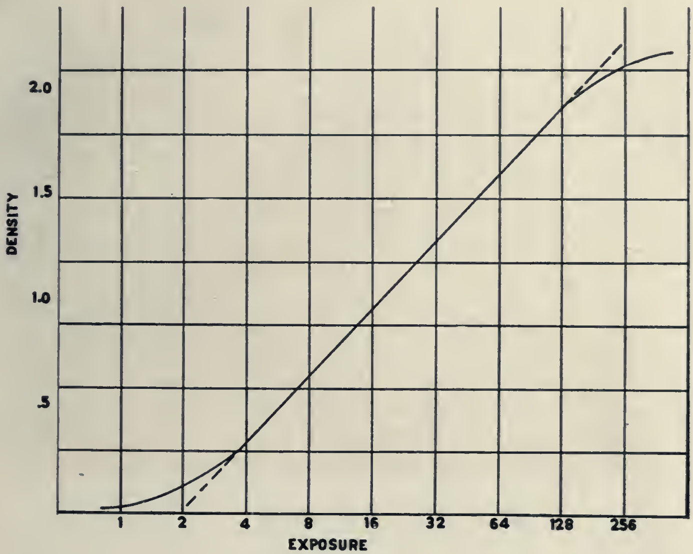



Fig. 52.

the blackness of the deposit, and this measurement of the blackness, which is proportional to the amount of silver per square inch, is called the "density". A density of unity is taken as the standard and represents the blackness of a deposit which lets through only 1/10th of the light; it corresponds to a very small amount of silver—only about 1/100th of a grain per square inch.

The relation between the density and the exposure of the plate can easily be represented as a curve, and for most of this curve the density is increased proportionally as the exposure is doubled (See Fig. 53). This condition is that which produces a correct rendering of the original in the print, and for that reason the parts of the curve for which it is true is known as the region of *correct* exposure. But at the beginning and the end, the curve is not straight; at the beginning, the density increases more rapidly; this is known as the region of *under-exposure*, and at the top of the curve the density falls off and finally fails to increase at all when the exposure is increased; this is the region of *over-exposure*. We may note that in the example taken the under-exposure region persists while the exposure increases from unity to three and one-half units; then we have correct exposure until the exposure becomes about one hundred and twenty-eight units, and then the over-exposure region appears, differences in exposure failing to grow in density after about five hundred units of exposure. For a rapid film, the point marked unity on this curve represents an exposure of about 1/50th of a candle-foot-second; that is, this film requires an exposure of 1/50th of a second to a candle at one foot distance in order to give the first visible trace of deposit.

When photographing a landscape, we want to obtain in our negative just a trace of deposit for the shadows, and we have already seen that the image of the shadows on the film will have a brightness of one foot-candle, so that the correct exposure time to give for such a landscape will be 1/50th of a second with the lens working at an aperture of *f*.8. The exposure given for such a landscape will therefore vary from 1/50th candle-foot-second in the shadows to 30/50th or 3/5th of a candle-foot-second for the sky.

This reasoning applies to an ordinary film, but photographic materials are of various speeds, and we can clearly define the speed according to the exposure required to give an impression upon it. The shorter the exposure required, the "faster" the film; and from the exposure which we find to be required, we may calculate a number which will represent the "speed" of the film.

A film might be said to have a speed of unity which requires the exposure of 1/50th of a second to give a deposit equal to that given by the light of an intensity of 1 foot-candle, such as is reflected from the darkest shadows of a landscape. But it would be inconvenient to choose unity as the speed of our film, because the speeds of all slower materials would have to be expressed in fractions, and in practice such a film is said to have a speed of 250 in the units generally used by photographic workers.

We see, therefore, that for a film of speed 250 at *f*.8 which reduces the light by about 100 times, we shall require an exposure of 1/50th of a second if the light reflected from the darkest portion is about 100 foot-candles. If the light reflected from the darkest shadow of the object is one foot-candle, we shall require an exposure of 1 second on a film of speed 500, or 500 seconds with a film of speed one. Or, generally, if $L$ is the light intensity from the darkest part of the subject, $P$ is the speed of the film or plate, and $E$ is the exposure at $f.8$, then

$$E = \frac{500}{L \times P}$$

$E$ being exposed in seconds, $L$ in foot-candles, and $P$ in the usual speed units.

It will be seen that this method of calculating exposures assumes that the exposure is made for the shadows, and in practical photography this is almost always true; one exposes to get shadow detail and trusts to the latitude of the emulsion being sufficient to render the whole scale of gradation of the subject.

If, instead of a landscape with foreground, we photograph a quite open landscape with sea or open country in the distance, then the darkest part of the picture will reflect perhaps 1/5th of the sky light or about 500 foot-candles. Using a film of speed 250, we should have to give an exposure of only 1/250th second at $f.8$ or about 1/60th of a second at $f.16$.

Using this line of reasoning, let us consider what the shortest exposures practicable for figures in rapid motion are likely to be. The range of contrast when taking a photograph of an athlete jumping, for instance, will be much smaller than in our typical landscape, and probably 1 to 10 would be a fair approximation; if the scene is in sunlight, the shadow detail may be represented by 250 foot-candles. Using the most rapid lenses available for such work, we may reckon on having 3 times as much light as a lens at $f.8$ will give, and we can use a Seed Graflex plate of speed 500; the exposure required will therefore be 500/250 x 3 x 500 or 1/750th of a second. We see, therefore, that unless the light conditions are of the very best, the use of such high shutter speeds will involve some degree of under-exposure, and this fact illustrates the advantage well-known in practice of taking very rapidly moving objects as silhouettes against the sky.

When photographing in the streets of cities, a considerably greater exposure is permissible than in landscape work, because there are always deep shadows outside the main range of contrast, in which an increase of exposure will give detail at the expense of the highlights, and an increase of exposure therefore means a shifting of the center of the scale of gradation from the highlights to the shadows. In practice topographical views are usually made at the shorter exposures, while the pictorial photographer prefers the longer exposures which concentrate interest on the lower-toned portions of the picture.

When using color filters, their factors must be allowed for in considering exposure; thus, taking the speed of film as 250, the use of the color filter requires an increase of five times in the exposure, so that for our typical landscape when using a color filter at *f*.8 we shall need an exposure of 1/10th of a second.

### POSITIVE PRINTING.

When printing positives either on paper or on plates for lantern slides, working conditions are somewhat different, no camera being used and the object reproduced being a negative instead of the original subject. The range of contrast in negatives is frequently much greater than in natural objects, but the exposure is governed by the same conditions as those which apply in the negative making. Such an exposure must be given that the greatest opacity which it is desired to print through at all just produces a visible deposit. Usually the highest light of all should be printed free from any deposit, and the next tone to this should be taken as the one to be printed through.

Turning to the curve shown in Fig. 53 and considering a bromide paper, this will have a speed of about 5 on the speed scale, so that it is 50 times slower than the film which we considered first and the point marked 1 on the exposure axis corresponds to an exposure of a candle-foot-second. Now the highlight which we shall want to print through in an average negative will let

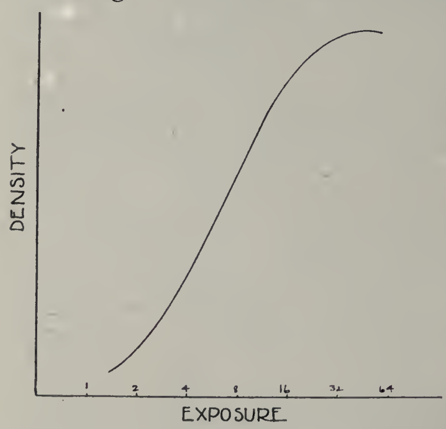



Fig. 53.

through only about 1/20th of the light, so that we shall have to give such a bromide paper an exposure of 20 candle-foot-seconds behind such a negative, and for a paper or plate of any speed we may write

$$E = \frac{5 \times O}{P}$$

where $P$ is the speed of the paper and $O$ is the opacity of the highlight in the negative which it is desired to print through. If the highlight in a negative lets through 1/20th of the light, then the opacity of that negative is said to be 20. If it lets through 1/100th, it is 100, and so on.

## CHAPTER VII.

### DEVELOPMENT.

IN chapter IV we saw that the chemical process of development consists of the removal of the bromine from the silver bromide in the emulsion so as to leave the grains of silver behind.

There are many chemicals which will remove bromine from silver bromide in this way, but in order to act as a developer, it is necessary that a chemical should be chosen which has the power of turning the exposed silver bromide into metallic silver, but which will not act on unexposed silver bromide, since, if the developer acted on the unexposed, as well as on the exposed grains, we should not get an image at all, but the whole film would go dark when put in the developer, just as if it had all been fogged by exposure to light. Only a very limited number of chemicals have this power of distinguishing between exposed and unexposed grains of silver bromide and, consequently, there are only a few substances which are suitable for use as developers.

The chief of these developing substances are pyrogallol, or "pyro" as the photographer calls it, hydroquinone and elon, all of which are chemically related to aniline, which is used as the base of coal tar dyes. Hydroquinone and elon, indeed, are made by the same methods as those used for making dyes, but pyro is made by distilling gallic acid, which is produced by fermenting gall nuts, so that, although pyro is really a cousin of hydroquinone, it is made quite differently, from a vegetable product, while hydroquinone itself is made from aniline.

Now, if we take a solution of one of these chemicals, let us say pyro, and put an exposed film into it, we shall get no development at all; the developing agent by itself having no power to develop. In order to make it develop we must add a little alkali to the solution. Any kind of alkali will make it develop, but the most convenient one to use is carbonate of soda which, in its crude form, is called sal-soda and is used to make water alkaline for washing. If, then, we take a solution of pyro and add some sodium carbonate to it it will develop our exposed films; but a solution containing only pyro, carbonate and water will not keep and, if we leave it in the air, it will very soon darken and lose its developing power.

In order to make it keep, there is added to the developer some sulphite of soda because the developer is spoiled by taking up oxygen, and sulphite is so greedy for oxygen that it will take it away from the oxidized pyro or take it in preference to the pyro, and thus protects the pyro from the oxidizing action of the air and enables it to keep its developing power, although the sulphite itself has no developing power at all.

The essential constituents of a developer therefore are: The developing agent—pyro or hydroquinone or elon or Kodelon which is a relative of elon—the alkali, which is generally carbonate of soda, and the preservative, which is sulphite of soda. Very often a developer which contains only these constituents will prove difficult to handle. It will tend to give fog, that is, to develop unexposed silver bromide as well as exposed silver bromide, and so, in order to regulate it, there is put in a little potassium bromide to act as a restrainer.

The various developing agents behave somewhat differently. Suppose, for instance, that we make up two developers, one with hydroquinone and the other with elon, and start to develop a film in each at the same time. In the elon developer the image will appear very quickly on the film and will appear all over the film at the same time, the less exposed portions which, of course, were the shadows in the picture, appearing at the same time as the highlights. On the other hand, with the hydroquinone the image will appear more slowly, and the most exposed portions, or the highlights, will appear first, so that by the time the shadows have appeared on the surface of the film the highlights will have acquired considerable density. If development is stopped as soon as the whole image is out, then the negative developed in elon will be very thin and gray all over, while that developed in hydroquinone will have a good deal of density in the highlights. Thus, of these two developers we may say that elon gives detail first and then slowly builds up density, while with hydroquinone the detail comes only after considerable density has been acquired. It is for this reason that these two developing agents are used in combination; the hydroquinone gives the density and the elon the detail, and together they make a well balanced developer.

These differences in the behavior of developing agents are due to a property of the developer which can be explained very easily by an analogy. Suppose that we had two automobiles of the same kind, one of 20 horse power and the other of 100 horse power. What would be the difference between them? Naturally, the high horse power automobile would be able to go faster than the other; but in a city, at any rate, either of them would be able to go as fast as was safe, and no one would wish to use the higher horse power for increased speed; but the advantage of the high horse power would be found whenever the automobiles were used against adverse circumstances, as, for instance, against high winds, in snow or in climbing hills, when the high-power machine would be able to keep up its speed against the difficulties, and the lower power machine would be slowed and might even be unable to get ahead. The difficulties which affect development in a manner corresponding to the effect of hills or winds for an automobile are cold and bromide. The addition of bromide has the same effect on a developer that a hill has on an automobile —it slows it down; but bromide has far more effect on a low power developer like hydroquinone than it has on a high-power developer like elon; the effect of bromide on elon is very small, while on hydroquinone it is very great. In the same way, hydroquinone develops very slowly when it is cold, while elon is not nearly so much affected by temperature.

The analogy between the horse power of the automobile and the power of the developer is really very close. The high horse power automobile will start from rest very much more quickly than the machine of lower horse power, just as the elon developer forces out the image all over the film much more rapidly than the hydroquinone developer. Just as the horse power of an automobile could be measured by the effect of a hill on its speed so the power of a developer can be measured by the reduction of density produced by the addition of bromide, and just as one would not wish to have an over-powered automobile, hard to handle and always picking up speed very rapidly, so it is difficult to use the very high-power developers, and elon, for instance, is rarely used alone, but is generally adjusted by admixture with the slower hydroquinone.

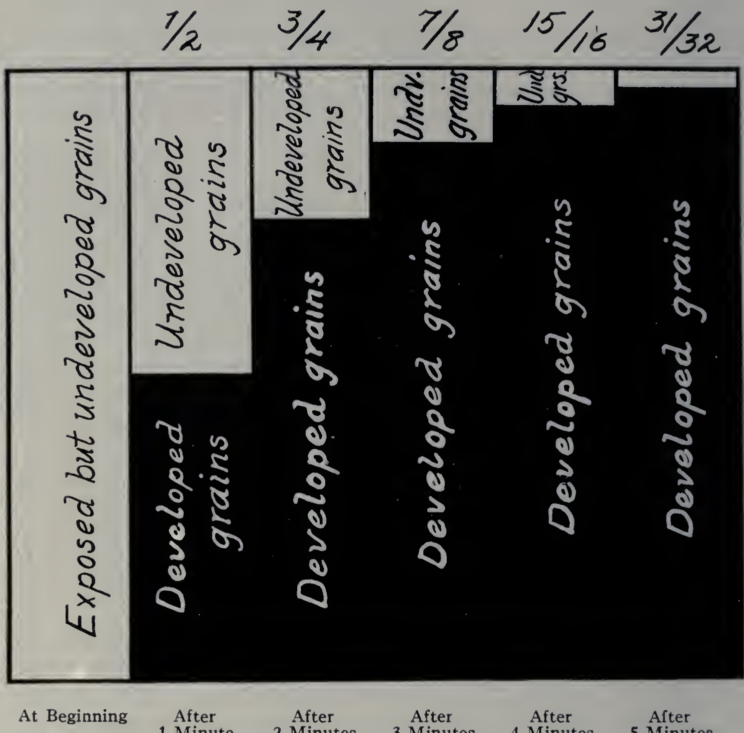
Pyro is an almost ideal developer for negative making. Owing to the fact that the pyro is changed during development into a yellow colored substance, some of which remains with the silver in the image, pyro tends to give a slightly yellowish or brownish image. The yellowish stain is prevented from forming by sulphite, so that the more sulphite there is in a developer the less tendency to warmth the deposit will show. Pyro is not used for papers, for which the blue-black image obtained with elon and hydroquinone is preferred.

When a film is developed, it is only the grains of silver bromide which have been changed by the action of light that are affected by the developer. The grains that have not been changed are not affected; at the beginning of development there are a great many exposed grains ready to be developed, and then as development proceeds, these exposed grains are turned into grains of black silver, so that the number of developable grains decreases during development until at last there are no developable grains left; all those which can be developed have been acted upon, and development ceases.

The rate at which the development proceeds can best be understood by an analogy from fishing. Suppose one went out fishing and found a pond where there were about four hundred fish. In the first day's fishing one might catch half the fish in the pond, or two hundred fish, but the second day one would not expect to catch the other half; all one could expect to catch would be the same proportion of the remaining fish, that is, half of what were left, or one hundred fish, and the third day one might catch half of what were left again, or fifty fish, and the fourth day half of what were left again, or twenty-five fish, and so on, the catch growing smaller as the number left decreased, until finally no fish were left to catch, or more probably until one got tired of trying to get the few remaining fish.

This is what happens in development. The rate at which the grains develop depends upon the number of undeveloped grains left, and as the grains are developed up and the number of undeveloped grains remaining become less, fewer and fewer grains develop in each minute, until finally, it is not worth while to prolong the development in order to get any more density. (See Fig. 54.)

If the development is prolonged beyond the point at which all the exposed grains are developed, then there is a danger of developing some of the unexposed grains, which produces a veil over the whole negative—exposed and unexposed portions alike—and this veil is known as fog.




*Development of exposed grains in a film which is half developed in one minute.*

Fig. 54.

The growth of the image during development is referred to as a growth of density, that is to say, the density is a measure of the number of grains of silver which are produced at any given point because these grains of silver, after the film has been cleared by the fixing bath, obstruct the passage of light through the film. We have seen that the density of an image is measured in units which are based on the amount of silver which will let through 1/10th of the light, so that if only 1/10th of the light falling on the negative gets through a certain part of it, that portion of the negative is said to have a density of 1. The blackest part of a negative may have a density of perhaps 2, the middle tones 1 or less, and the shadows, perhaps 1/10th. (Fig. 55.)

The difference of density between the darkest portion and the lightest portion of the negative is called its *contrast*. In most negatives the shadows are nearly clear so that the contrast depends chiefly on the density of the darkest portion, but this is not necessarily so because an over-exposed negative, or one taken of a very flat subject, may have no clear portion in it and may be even very dense owing to over-exposure, and yet not contrasty at all because there is very little difference between the density of the most exposed portion and that of the least exposed portion, the negative being very dense all over. It is necessary to keep clearly in mind this difference between the density and the contrast.

Since the *contrast* depends chiefly upon the *density of the highlights*, it grows during development just as the density does. It grows rapidly at first, when there are many grains to be developed, and then more slowly until, finally,

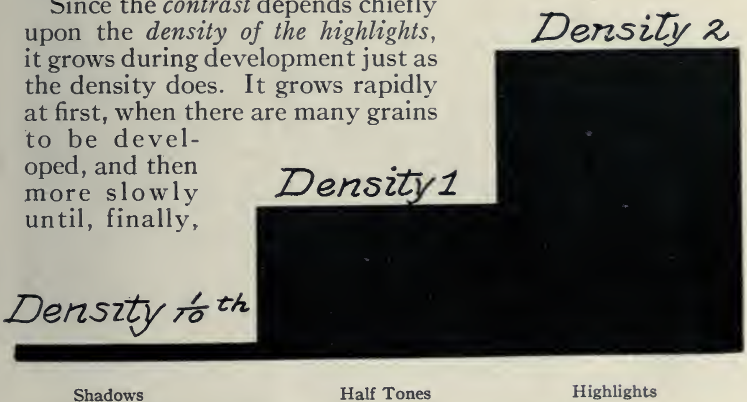


Fig. 55. Densities of Various Parts of a Negative.

when the grains are all developed, the negative will not give any more contrast however long development may be prolonged, and a continuation of development will only result in the production of fog. (Fig. 56.)

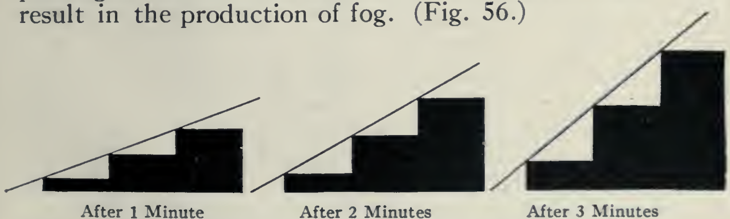
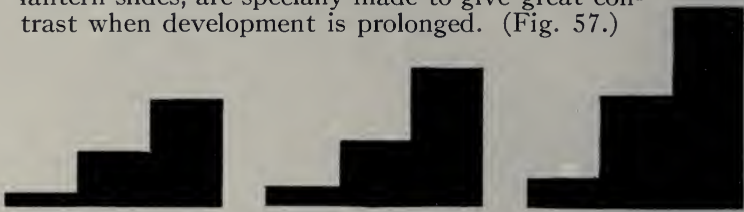


Fig. 56. Growth of Contrast During Development.

The final contrast which can be obtained depends upon the kind of emulsion used. The fast emulsions, such as the film emulsions, give moderate contrast, but the slow emulsions, such as those used for copying purposes or for making lantern slides, are specially made to give great contrast when development is prolonged. (Fig. 57.)



Highly Sensitive Film | Medium Speed Plate | Slow Lantern Plate

Fig. 57.
Greatest Contrasts With Different Emulsions.

It would be convenient if the manufacturer could make the film so that it would be impossible to over-develop it, but this is not practicable. It would be possible if a film developed at an even rate and then stopped developing when it was correctly developed as is shown in Fig. 58, where development is supposed to go straight on for a given time and then stop altogether, the film not changing after that time. But the film does not develop like this; the growth of the image gets slower as time goes on but it takes a very long time indeed to stop completely, so that the growth of the image occurs as shown in Fig. 59. If

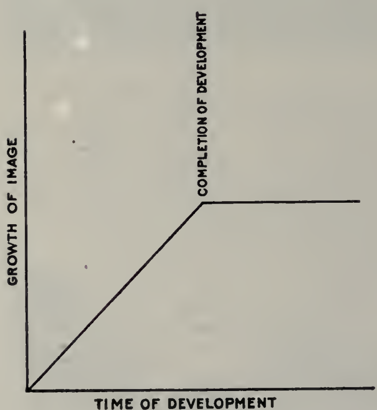



Fig. 58.
Growth of Image During Development
(to be desired)


Fig. 59.
Growth of Image During Development
(actual)

a film were made so that we had to develop it as far as we could, it would take too long to develop, and therefore it is necessary to make a film that is capable of giving more density than is required in order that it may be developed in a sufficiently short time; this means that we must be able to stop development at the right time to get enough density and contrast, the density being the blackness of the image and the contrast.

Old-time photographers used to take pride in the accuracy with which they could judge the progress of the development of negatives, and it was regarded as quite wrong when, in recent years, people insisted that negatives could be developed just as well by timing the development as by watching it, and that it was better for the negatives not to be watched.

The customary way of judging the progress of development in a negative is to hold it up to a lamp and look through it, but unless one has had a lot of experience he is very likely to be deceived because the apparent density of a negative held up to a light is very difficult to judge. The emulsion which has not been developed makes it appear stronger than it really is, and beginners almost always under-develop negatives if they try to judge when to stop development. If for some reason it is necessary to judge the progress of development by inspection (and this applies particularly to lantern slides), the best way is to turn the emulsion side to the light and look through from the back. This is much less misleading than if they are examined from the front.

There is no doubt, however, that the best method of judging development is simply to develop for a fixed time.

Films are best developed in a film tank, and the time of development, at a temperature of 65° for the tank developer, is 20 minutes. This time depends on the temperature. If the temperature is lower than 65° the time must be increased, and if it is higher than 65° the time must be reduced.

Instructions for development are furnished with each Kodak or Premo tank. It might be thought that if the film were over-exposed and so gave density easily it should be developed for a shorter time than if it had received less exposure, but this idea is quite wrong, because what is wanted in a negative is not correct density, which only affects the time of printing, but correct contrast, and the contrast is controlled by the time of development. An over-exposed film will tend to have too little contrast, and if the development is lessened the contrast will be still further reduced and the negative will be flat. On the other hand, an under-exposed film tends to be too contrasty, and must not be forced in development or it may be unprintable, and so whatever the exposure, the best result will be obtained by the use of the normal time of development. Of course, the best negative can only be obtained by correct exposure as well as by correct development, and it is a mistake to think that we can correct errors in exposure by deviation from the correct time of development.

# CHAPTER VIII.

## THE REPRODUCTION OF LIGHT AND SHADE IN PHOTOGRAPHY.

PHOTOGRAPHY is the art of making representations of natural objects by mechanical and chemical processes. These representations deal with differences of brightness, color being ignored, except in color photography, and the object of the photographic process is to translate, as accurately as possible, the degrees of brightness which occur in natural objects into corresponding degrees of brightness in a photographic print.

It is not possible to convey any impression in a photograph of the brightness of an object of even brightness; a piece of black velvet seen in bright sunlight is brighter than a piece of white paper in a dark room, so that it is impossible to speak of the brightness of paper or the blackness of velvet unless there is some standard of comparison by which it can be measured. If black marks are made on the white paper and then photographed, the resulting print will reproduce the relative intensity of the black marks and of the white paper.

When a representation of a natural object is made on a flat surface, the form can be represented only by differences

Fig. 60.
Two Tones.

Fig. 61.
Three Tones.

of brightness or color. Shape is only possible in sculpture. The painter uses differences of brightness and of color, while the black and white draftsman uses only the differences of brightness. Except in the special branch of color photography, photographs deal only with the reproduction of objects in their degrees of brightness.

The different degrees of brightness are spoken of by artists as "tones." If a piece of white paper on which black marks have been made is photographed the result will be a picture in two tones (Fig. 60). Between these extremes are other tones spoken of as halftones. Figs. 61, 62, and 63 show the effects of additional tones. In Fig. 64 the six tones complete the representation of a solid object, from which it will be seen that form and substance are shown by degrees of brightness. In the mind the forms of natural objects are comprehended by the degrees of brightness that occur in them. It is the business of photography to reproduce these different degrees of brightness, which may vary from white to black.

Differences in brightness which occur in nature may

Fig. 62.
Four Tones.

Fig. 63.
Five Tones.

Fig. 64.
Six Tones.

Fig. 65.
Front Lighting (Flatness).

Fig. 66.
Side and Top Lighting (Tone Graduations).

be produced by differences in the illumination of the object. If a plaster cast is lighted directly from the front the outlines will be visible but there will be no variation in tone. It will have a flat, even appearance (Fig. 65). If the cast is lighted from one side shadows will be formed, there will be variations in illumination, and in this way tones will be produced by shadow (Fig. 66).

The brightness of an object depends not only upon the illumination falling upon it, but also upon the reflecting power of the object itself. Things differ very much in reflecting power. If a piece of white paper represents a reflecting power of 80%, a piece of gray paper may reflect only 44% of the light falling upon it, and so on down the scale, a piece of black paper reflecting only about 5%. The brightest thing known is white chalk, which reflects 90% of the light falling upon it; that is, of all the light falling on the white chalk 90% is reflected back. Snow does not reflect quite as much light as chalk. The ordinary red brick wall reflects only about 20%. Good black printers' ink reflects about 10%, and the blackest thing, black velvet, will reflect about 1% or 2% of the light falling upon it.

Since in natural scenes both the reflecting power and the illumination vary, some parts of a landscape consisting of clouds in sunlight, and others of dark rocks in the shade, the range of contrast is often very considerable. For photographic purposes a scale, or contrast of 1 to 4, in which the brightest thing is only four times as bright as the darkest, is very low, and such a subject would be called flat; a contrast of 1 to 10 is a medium soft contrast; 1 to 20 a strong contrast; 1 to 40 very strong and 1 to 100 an extreme degree of contrast. All these degrees of contrast occur in subjects such as landscapes, street and seashore scenes.

Since the more nearly we can reproduce in our picture the range of brightnesses which were present when the picture was taken, the better the picture will represent the original scene, our object in photography must be to get an accurate reproduction of the various tones or brightnesses which occur, keeping each tone in its same relative position in the scale as it occupied in the subject which was photographed. This is, of course, easier to do if the range of brightnesses is small than if it is very great.

When we make a photograph we do the operation in two separate steps. We first make a negative upon a highly sensitive material and obtain a result in which all the tones of the original are inverted, the brightest part of the subject being represented by a deposit of silver in the negative which lets through the least amount of light, while the darker parts of the subject are represented by transparent areas in the negative which let through the most light. This negative is then printed upon a sensitive paper, in which operation the scale of tones is again reversed so that the bright parts of the subject which were represented by heavy deposits in the negative now appear as the light areas of the print and the dark portions of the subject which were transparent in the negative are represented by dark deposits in the print.

In order to find out how closely the tones of the print follow those of the original subject we must follow the changes of these tones through both steps: we must study first how far the negative reproduces in an inverted form the tones of the subject and then how accurately the printing paper inverts these again to give a representation of the original.

Any silver deposit in the negative will let through a certain proportion of the light which falls upon it. A very light deposit may let through half the light, a dense deposit one-tenth, a very dense deposit one-hundredth or even only one-thousandth. The amount of deposit through which one can see depends, of course, upon the brightness of the scene at which one is looking, but it is interesting to note that one can see the sun through a deposit which lets through only about one-twenty-billionth of its light.

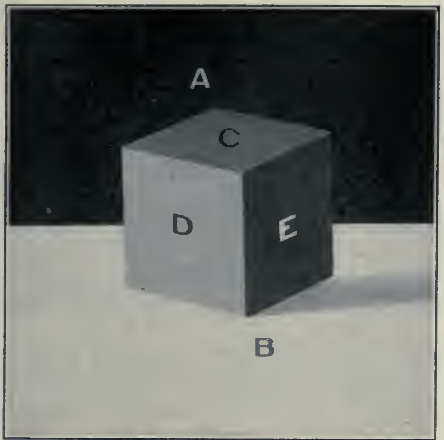


Fig. 67.
Five Toned Block.

These fractions of the light which are let through are referred to as the "transparency" of the deposit, and the inverse of the transparency is called the "opacity", the opacity, therefore, being the light-stopping power of the deposit. A deposit which lets through half the light, for instance, is said to have a transparency of ½ and an opacity of 2. Similarly, one which lets through one-tenth of the light has a transparency of 1/10 and an opacity of 10.

If the negative is to be the exact inverse of the scale of tones of the subject,

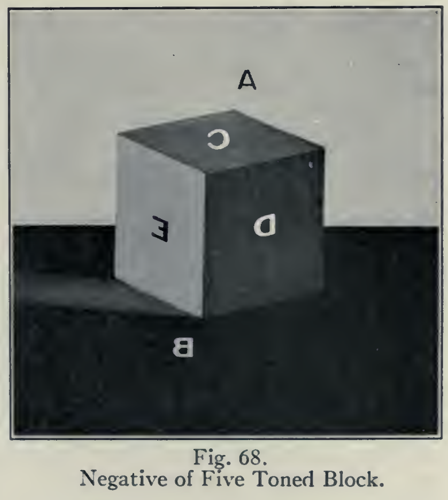


Fig. 68.
Negative of Five Toned Block.

then the opacities of the different areas must be in proportion to the brightnesses of the parts of the subject which produce them. In Fig. 67 we have a subject in which if we take the black background as having a brightness of 1, the brightest portion will have a brightness of 10, and the other portion will be in proportion. Then when we make a negative of this we shall get the picture shown in Fig. 68, and in this, if we measure the opacities of the negative, we ought to find them exactly inverse to those of Fig. 67, so that the *transparency* of the background, A, would be ten times that of the table, B, or the *opacity* of the table, B, will be ten

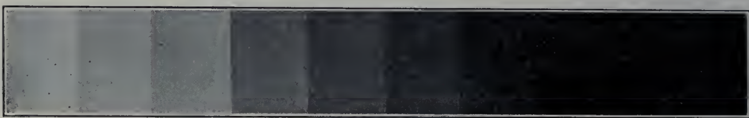


Fig. 69.
Graded Strip of Exposures.

times that of the background, A. Not only this, but the relative opacity of the deposits in the areas C, D and E should also be the same as the brightnesses of C, D and E in the original subject.

It will be seen by the foregoing, therefore, that a technically perfect negative will be one in which the opacities of its different gradations are exactly proportional to the light reflected by those portions of the original subject which they represent.

Let us now consider how far we can fulfill this condition and what must be done to obtain such a perfect negative of any subject.

Suppose that a photographic plate or film is exposed to a series of known brightnessess; for instance, that we photograph a scale made up of steps of different reflecting powers so the brightness of each step is doubled with regard to the next one.

The result that such a series of exposures will give has already been discussed in Chapter VI, but we must now look into the matter somewhat more carefully. We shall get a negative which will look like Fig. 69. Now if the rendering is technically perfect, the opacities of this negative should be the same as the brightnesses of the different steps of the original; that is to say, as each step is twice the brightness of the next step, the light let through each step of the negative should be half the amount of the step next to it.

This would be attained if each step in the negative added the same amount of silver to the deposit, so that if we could represent the silver for each step as altering the thickness of the silver deposit (it does not do this really, of course; it adds to the number of grains in the same layer) and then could cut an imaginary section through


Fig. 70.
Heights of Silver Deposits (diagram).

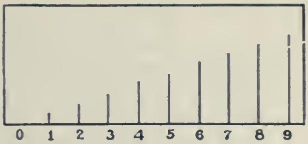



Fig. 71.
Heights of Silver Deposits. (Line Diagram).

the negative so as to show the height of the deposit of silver, it should look like Fig. 70; and if we draw a diagram in which the amount of silver is represented by the height of a vertical line, the diagram showing the amount of silver for the different steps might look like Fig. 71.

If we actually try this experiment, however, we shall find that the silver does not rise quite uniformly in this way as the exposure is increased through the entire scale, but that instead we get the diagram shown in Fig. 72, and this diagram, which represents the actual relation between the silver deposit in a photographic material and the increase of exposure, requires careful study.

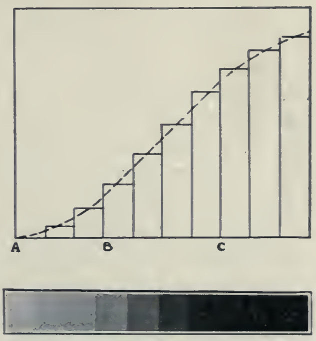



Fig. 72.
Diagram of Actual Increase and Graded Strip.

Starting at A and proceeding to B we notice that at the beginning, in the lower exposures, the steps are marked by a gradually *increasing* rise, and, therefore, in this part of the exposure scale there will be *too great* a gain in opacity for each given increase of exposure. A negative, the gradations of which fall in this period, will yield prints in which an increasing contrast is shown between tones of uniform increase of brightness; that is to say, it will appear what we term "under-exposed." From this period at B we pass imperceptibly into the period where the densities show an equal rise for each equal increase of exposure, and here we have our technically perfect negative, that is, one in which the opacities are exactly proportional to the light intensities of the subject. This is termed the "period of correct exposure," and only through this period of the curve where the opacities are directly proportional to the exposures and where the densities show an equal increase each time the exposure is doubled shall we get a perfect rendering of the original subject. From the point C onwards we have a gradually *decreasing* rise in the steps with increase of exposure until, finally, the increase of density with further exposure becomes imperceptible. This period is the period of "over-exposure," in which the opacities of the negative fail to respond to increasing amounts of exposure and the correctness of rendering is again lost. It will be seen at once, then, from this curve that only through the period of correct exposure where equal increases of exposure are represented by equal rises in density can tones of the original subject be correctly reproduced in the print.

If we join all these points together instead of representing them as a staircase effect, as is shown by dotted line in Fig. 72, we get a smooth curve, Fig 73, of which the straight line portion (B to C) represents the period of correct exposure, while the more or less curved portions at the beginning and end of the curve correspond to the periods of under-exposure and over-exposure.

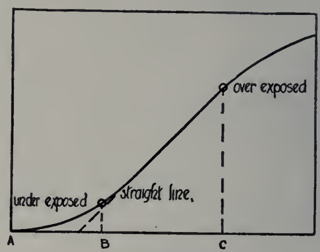



Fig. 73.
Curve Showing Under, Correct and Over-exposure.

It must be realized that no ordinary negative can show the whole range of exposures from beginning to end of this curve. This is because the range of brightnesses covered by the whole curve is much greater than that which occurs in ordinary subjects and consequently it is quite possible to represent an ordinary subject entirely in the period of correct exposure, avoiding both the period of under-exposure and the period of over-exposure. If, therefore, we wish to obtain a technically perfect negative, we must expose so that the subject which we are photographing falls into this period of correct exposure, when we shall obtain a negative in which there will be no wholly transparent film, since this would mean that we had entered the period of under-exposure, and there will be no blocked up masses of silver since this would mean that the negative was over-exposed. The capacity of a photographic material to render the scale of tone values correctly is, therefore, entirely a matter of the length of the straight line portion of the curve, and it is the length of this straight line portion in the case of Kodak film which gives its well-known "quality" to the material. By the use of a material of this kind which has a long straight line portion to the curve, and of an exposure which will place the scale of intensities on that straight line portion we can correctly translate the tones of the subject into corresponding opacities in the negative and obtain a technically perfect negative.

When we come to the second step of the process, however, and make a print from this negative, we find that however carefully we choose our exposure and development *perfect* reproduction in the print is unobtainable. For a negative material the relation between the silver deposit and the increase of exposure is given by a curve similar to that shown in Fig. 73, and in this curve the straight line portion (B to C) represents the period of correct exposure, so that to obtain perfect reproduction in the negative we must expose so that the whole range of brightnesses in the subject falls within this period of correct exposure, none of the tones being represented by densities in the negative which fall on the curved portions at the beginning and end of the curve corresponding to the periods of under and over-exposure.

When we make a print, however, we cannot do this because in a print we are forced to use the whole range of reflecting power of the printing paper; we must have highlights which are almost white paper, and shadows which are as black as the silver deposit will give. This is necessary because the total range of tones which can be obtained by reflected light is none too great for the reproduction of natural subjects, while in negatives, where the light is transmitted instead of reflected, the available range is enormous and we need make use of only a small portion of it. This is also true in the case of transparent positives such as lantern slides and motion picture films, which give the best rendering of any printing material.

We can try the effect of an increasing series of exposures upon a printing paper in exactly the same way as upon a film, that is, we can give a first exposure just sufficient to get a barely perceptible image after development, then expose another portion for twice the time, another for four times, and so on. Now instead of measuring the light transmitted by the various densities, as we did in the case of the film, we must measure the light reflected from them. We get a series of "reflection densities" on paper corresponding to the transmission densities of the film and we can express the result in the form of a curve just as we did in the case of the film.

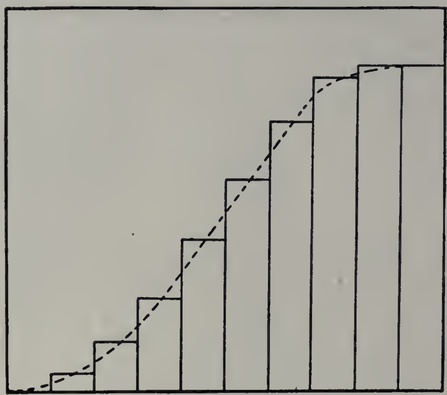


Fig. 74.
Curve of a Printing Paper.

Thus in Fig. 74 we see that the densities increase gradually at first, as shown on the lower portion of the curve, then grow in equal steps for equal increases of exposure, as with the film, and then the increase not only grows less, but very soon stops altogether, as shown by the upper portion of the curve. This result only occurs with a film with very great exposures indeed, since after a film begins to be over-exposed there is still a considerable range of exposures before the increase of density with exposure actually ceases. Therefore, a paper is seen to differ from a film in that we rapidly reach a point where we have obtained the maximum blackness of deposit which the sensitive emulsion is capable of giving and where no further increase of exposure will enable us to obtain a more intense black.

The reason for this is that with the paper we are dealing with reflected light, and not with transmitted light, as in the case of the film, and the light is reflected from three surfaces—from the surface of the gelatine, from the surface of the silver deposit, and that which is not absorbed in passing through the silver deposit is reflected from the paper beneath.

The rule for correct rendering of tones on the paper is the same as for the negative; that is, the tones which fall on the straight line portion of the curve are rendered correctly, and those which fall on the top and bottom portions of the curve do not reproduce the tones of the negative in their correct position. As has already been said, however, the difference is that in the negative we can generally confine the scale of the subject to the straight line part of the curve, while in printing we are forced to use the whole curve, including those portions which cannot give a perfectly correct rendering of the tones of the negative.

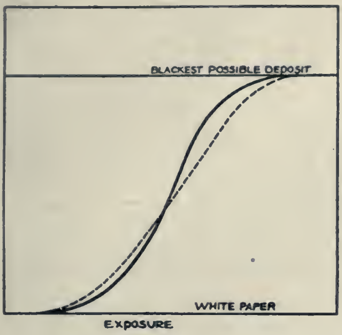



Fig. 75.
Curves Showing Good and Poor "Quality" in a Printing Paper.

Different papers sometimes show very different curves; thus in Fig. 75 we see the way in which two different papers give their scales of tones; both give the same range of tones, both require the same range of exposures to give the entire range of tones, but in the one the deposit grows evenly with the increase of exposure while in the other the curve is scarcely straight at all. The paper showing the even growth of deposit will give a correct rendering of the tones of the negative throughout the greater part of its curve (shown by dotted line in Fig. 75) and it is generally said that such a paper has good "quality" while the paper with the uneven growth (solid line Fig. 75) has poor "quality". For papers, therefore, as well as for negative-making materials, quality depends upon the proportion of the curve which is a straight line, and the straighter the curve the better the quality.

## CHAPTER IX.

### PRINTING.

A GREAT number of different processes have been used at one time or another for printing negatives. The earliest printing processes depended upon the fact that silver compounds darken in light, and the first printing paper to be used generally was made by soaking a sheet of paper in a solution of table salt and washing this over with a solution of silver nitrate so as to convert the salt into silver chloride. Paper so prepared was known as "salted" paper on which, after exposure to light behind a negative, a print was obtained which could be toned by the deposition of gold from a solution and then fixed with hypo. A better paper was made by using albumen obtained from the white of eggs. After adding salt to it the albumen was spread over the surface of the paper and then sensitized by treatment with a solution of silver nitrate.

After the gelatine process for negatives was discovered gelatine emulsions were applied to printing papers. Gelatine paper was made by emulsifying silver chloride in gelatine with an excess of silver nitrate and then coating it on paper just as films are coated with the sensitive negative emulsion. The typical gelatino-chloride paper of this type is Solio.

To use Solio, the negative is put in a printing frame, and the paper is put with its coated side in contact with the emulsion side of the negative and pressed into contact by closing the back of the printing frame. The frame is then exposed to daylight and the image printed on the paper, which darkens to a brownish-red colour. From time to time the depth of the printing is observed by opening the back of the frame. The image must be printed to a somewhat darker colour than will be required in the finished picture. When printed the paper is removed in subdued light and the print is toned by immersing in a solution containing gold so that the metallic gold is deposited on the print, giving it a purple colour. After toning, the print is fixed in a hypo solution and washed. A toning process is necessary with all printing-out silver papers, such as Solio, albumenized paper, or salted paper, because if the printed-out silver image is fixed without toning, the fixing bath changes it to an ugly yellow color and a very poor-looking print results. The gold toning produces a rich-looking, permanent image which varies in color from brown to purple; these colors, indeed, used to be regarded as the only satisfactory colors for photographs.

The chief use for printing-out papers at the present time is for the making of photographers' proofs. For this purpose the negatives are printed, but the prints are not toned or fixed, and, while they are satisfactory for examination, they cannot be kept, because they darken in the light, the photographer supplying them only as samples to show the pose and expression, and making permanent prints to order later.

Quite early in the history of photography it was discovered that many substances besides the salts of silver are sensitive to light. One process of printing, the platinum process, is founded upon the sensitiveness to light of iron salts. If paper is coated with ferric oxalate, which is a green soluble salt of iron, and this is exposed to light, the ferric oxalate is changed into another oxalate of iron, ferrous oxalate, which is insoluble, so that a sheet of paper thus prepared and printed will, after washing, give a faint image consisting of ferrous oxalate. If, to the ferric oxalate with which the paper is prepared, a solution of a platinum compound is added and then, after printing, the faintly visible image is put into a solution of a soluble oxalate, the ferrous oxalate is dissolved and attacks the platinum salt, which is not affected by the ferric oxalate, precipitating metallic platinum on the paper so that an image is obtained consisting of black metallic platinum.

Another process depends upon the fact that gelatine containing bichromate becomes insoluble in water on exposure to light, and this process is known as the "pigment" process or more commonly as the "carbon" process, the name being derived from the fact that the gelatine used in the early days of the process contained finely divided carbon or lamp black to act as a pigment. The printing paper is made by coating the paper stock with a thick gelatine solution containing finely divided pigment suspended in it. The pigment is chosen according to the color of the print required. For a black image it may be lamp black, for a red image red ochre or burnt sienna, and for images of other colors any permanent and stable pigment of the color desired which can be finely powdered. After the coated gelatine has been dried the paper is immersed in a solution of bichromate of potash or ammonia and again dried. This bichromated gelatine is quite soluble in hot water, but if it is exposed to light it becomes insoluble where the light has acted upon it. The bichromated gelatine is, therefore, printed under the negative in the same way as a Solio print. No visible image is produced, and to get the visible print it is necessary to wash away the soft gelatine. The gelatine, which has been hardened by the action of light, is on the surface of the print and the soft gelatine is at the back, so in order to develop the print it is put face down on to another sheet of paper and placed in hot water. After a short time the soluble gelatine begins to ooze out at the edges of the print and the whole of the original paper can be pulled off, leaving the image covered with a sticky mass of partly dissolved gelatine on the paper to which it has been transferred. This image is then washed in hot water until all the soluble gelatine has been washed away, leaving a clear image of the pigmented gelatine on the paper.

All these printing-out processes require a long exposure to strong daylight, and they have become more or less obsolete owing to the trouble of working them and especially the difficulty of judging the correct exposure with such a variable illuminant as daylight. They have been displaced by printing processes in which the paper used is coated with an emulsion very similar to that used for making the negative, but of considerably less sensitiveness. This paper, known as development paper, is exposed behind the negative and is then developed, in the same way as a negative, to give a visible image.

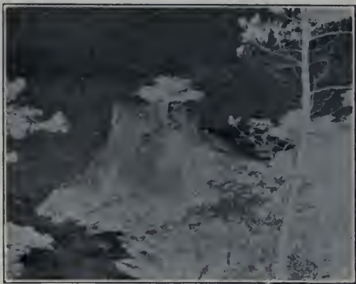
The oldest of these development papers is bromide paper. This paper is coated with an emulsion very similar to the ordinary negative emulsions but of somewhat less sensitiveness. The paper is very sensitive to light and must be worked by red or orange light only. The exposure for printing is, of course, very short and the paper is, in fact, mostly used for enlarging, the image of the negative being thrown upon the sensitive bromide paper by a projection lantern so as to obtain an enlarged picture from the negative.

About 1894 Velox paper was introduced and was an entire novelty, since while it was similar to bromide paper in that it is exposed to an artificial light and then developed and fixed, it is so much less sensitive than bromide paper that it can be worked in a room lighted by a weak artificial light and does not require a special darkroom, from which fact it is known as "gaslight" paper. Since the introduction of Velox other gaslight papers have been made and at present almost all prints made by contact from negatives are made on gaslight papers, though Velox is still the best known of all. Velox is about a thousand times slower than bromide paper so that it can be handled safely in any subdued light. It requires an exposure that ranges from about 2 seconds to about a minute and a half, depending on the density of the negative and the grade of Velox used, at one foot from a 25-watt Mazda lamp, and it is characterized especially by the extreme rapidity and ease of its development, from which its name is derived, Contrast and Regular developing fully in 15 to 20 seconds and Special Velox in about 30 seconds. It is consequently possible by using Velox to make prints in comfort and with great rapidity, the old troubles of judging the extent of the printing, and the difficulties with toning baths being entirely absent with this simple and convenient printing medium.

Fig. 76.
Degrees of Light Intensities.

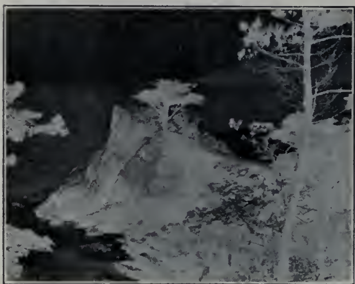
Velox paper is made in three grades of contrast to fit different types of negatives. The paper was originally made in the Regular grade only, but it was found that many negatives were too contrasty to print well on this paper and Special Velox was manufactured for use with such negatives, while recently Contrast Velox has been put on the market for use with negatives so lacking in contrast that they will not give good prints even on the Regular grade.

If we make three negatives of the same subject in succession, giving each exactly the same exposure, and then develop these for different lengths of time so that the first will be underdeveloped the second correctly developed, and the third over developed, the first negative will have a short range of contrast, the second a medium range, and the third a long range. If we then print the first negative on Contrast Velox, the second on Regular Velox, and the third on Special Velox, we shall get almost identical prints on all three papers



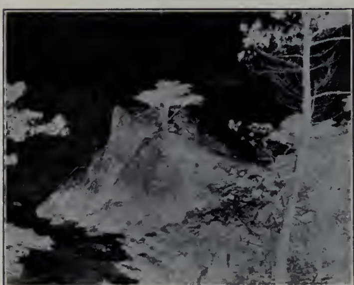
Soft Negative of Little Contrast.

Print from Opposite Negative on Contrast Velox.



Average Negative of Medium Contrast.

Print from Opposite Negative on Regular Velox.



Hard Negative of Strong Contrast.

Print from Opposite Negative on Special Velox.

Fig. 77.

provided that the contrasts of the negatives just fit the various grades of the paper. This is shown in Fig. 77.

We might think that Contrast Velox would always give more contrasty prints than Regular Velox; it will if both papers are printed from the *same* negative, but if the Contrast Velox is printed from a flat negative and the Regular Velox from a normal negative, then the Contrast Velox will compensate for the flat negative and give a *normal* print, just as the Regular Velox gives a *normal* print from a normal negative, and the Special Velox a *normal* print from a contrasty negative.

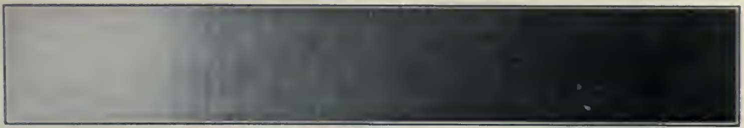


Fig. 78. Range of 44 Distinct Tones.

All the grades of Velox give the same range of reflecting powers in the print provided that they are used with negatives which will enable this range to develop. Suppose we take a black wedge which contains all the degrees of light intensities, from absolute opacity at one end to absolute transparency at the other end and make a print of it. We should get the result shown in Fig. 76. This shows the entire range of reflecting power of which the paper is capable, the range varying from white paper at one end to the blackest silver deposit which the paper can give, at the other.

With any "velvet" surface paper, such as Velvet Velox, we shall find that the white paper will reflect about twenty-five times as much light as the deepest silver deposit. The number of distinct tones which are included in this range from white to black depends, of course, on the ability of the eye to distinguish them. The eye can actually see about one hundred distinct tones in such a range.

Contrast Velox — Regular Velox — Special Velox

Fig. 79.

In Fig. 78 is shown a range of tones made up, not as a continuous wedge, but of forty-four distinct tones. The number which can be seen in the illustration is less than the number which the eye can distinguish in a print because of the limitations imposed by the process of half-tone

Fig. 80.
Print Showing Empty Highlights.

Fig. 81.
Print Showing Blocked Shadows.

re-production. If the full one hundred tones which the eye can distinguish in a print were reproduced by the half-tone process the halftone illustration would look like a continuous wedge.

In Fig. 79 the same wedge has been printed on all three papers, and it will be seen that Contrast Velox has reached its full blackness only a short distance up the wedge, Regular Velox has gone further, and Special Velox has gone the farthest of all, so that while all three papers will give the same range of tones, this range is impressed on Contrast Velox with only a short range of densities in the negative; for Regular Velox a longer range is needed, and for Special Velox a still longer range.

Fig. 82.
Gray, Flat Print.

The range of densities required in a negative to just print out the full range of tones on a paper is called the "scale" of the paper and this is measured by trying an increasing series of exposures until the range of exposures which will just give the whole range of tones on the paper is found; that is, if an exposure of one second to the bare paper with no negative will just give the first perceptible difference from white paper, so as to show the first trace of tint on the paper, and an exposure of twenty seconds will give the deepest black the paper is capable of rendering, so that no increase of exposure will produce any denser black, then we should call the scale of the printing paper 1 to 20.

Thus the word "scale" applied to a printing paper does not refer at all to the range of tones in the print. It indicates the range of contrast in the negative which should be printed on that paper. A paper with a scale of 1 to 20 will require a negative in which the densest part lets through 1/20 of the light transmitted by the clearest part, because if this negative is printed on that paper the print will just have the whole range of tones from white to black completely printed out, each tone in the print corresponding to a density in the negative, and there will be no differences of density in the negative unrepresented by differences of tone in the print.

Special Velox has a scale of about 1 to 20 and is suitable for printing from contrasty negatives. Regular Velox has a scale of about 1 to 10 and is suitable for printing from negatives of moderate contrast, while the very flattest and least contrasty negatives, which are the result either of excessive over-exposure or underdevelopment should be printed on Contrast Velox, which has a scale of about 1 to 5.

It is important to choose the grade of paper correctly for the negative. If the paper is too contrasty for the negative; if, for instance, we print a hard negative (one that has strong contrast) on Contrast Velox, then we shall have to sacrifice a part of the scale of the negative; either we shall get the highlights empty and white, as shown in Fig. 80, or we shall get the shadows blocked up, as shown in Fig. 81. On the other hand, if the scale of the paper is too long for the negative and we print a soft negative (one that has little contrast) on Special Velox, for instance, when we should have used Regular Velox, then we shall get a gray, flat print, as is shown in Fig. 82.

With paper, as with film, the density of the picture is controlled by the duration of the exposure and the development, but whereas with films the contrast is dependent upon the time of development, the contrast increasing as the development is continued, with paper the contrast is fixed by the maker, and after a few seconds the development does not change the contrast of the print at all but only affects the density of the deposit. This is illustrated in Figs. 83 and 84.

In Fig. 83 we see that with increasing time of development, a film shows an increase in contrast, while in Fig. 84 that by prolonging development it is clear after reaching a certain stage in the development of a print there is only an increase in total density and no increase in contrast.

If a print is over-exposed, it can be taken out of the developer before it is fully developed, and if under-exposed, it can similarly be forced in development, though there is some risk of yellow stain if development is continued too long. The best results can, of course, only be obtained by getting the exposure right and giving the normal time of development, which is from 15 to 20 seconds for Contrast and Regular Velox, and about 30 seconds for Special Velox.

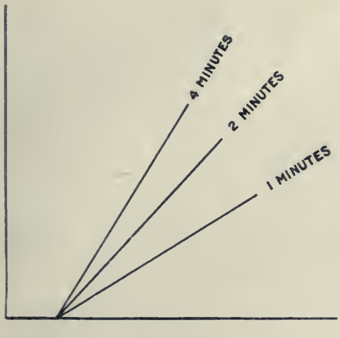



Fig. 83.
Growth of Contrast with Development, Eastman N. C. Film.

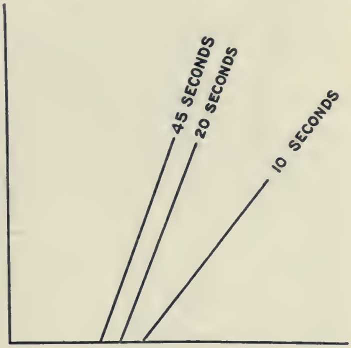



Fig. 84.
Increase of Density with Development, Velox Paper.

The matter of greatest importance for getting really first-class prints, therefore, is to give them the right time of exposure.

Before starting to print a number of negatives they should be classified for contrast so as to choose a suitable grade of paper for printing them; that is to say, put the negatives in three envelopes according to whether they are to be printed on Special, Regular or Contrast Velox. Now take the negatives in each of these envelopes and divide them again into three more classes—normal negatives having average density, thin negatives, and dense negatives. When printing, if we take the exposure for the normal negative as standard, then the thin negatives will require half this standard exposure and the dense negatives will require twice, while sometimes we may possibly meet an exceptional negative—very thin or very dense—which may require one-fourth or four times the standard exposure. Having classified our negatives in this way, in order to get our exposures right we need know only the exposure on each grade of Velox paper for our standard negatives, and if we print with a 25-watt tungsten lamp at a distance of one foot, we shall find that the exposure for a standard negative will be about 20 seconds for Special Velox, about one minute for Regular, and one and a half minutes for Contrast. These figures are to be taken only as a guide, and when a new light or a new package of paper is used for the first time, trial exposures should be made with the standard negative, giving, say, 15, 20 and 30 seconds exposure, so as to select the exposure which develops to the right density with the correct time of development.

It is best always to use the same standard negative for testing a new paper or a new printing lamp and any other new conditions that may arise in printing, as more useful information will be gained by making tests with one negative only than if a different negative is selected each time a test is to be made.

If the subject of exposure is dealt with in this way, if the negatives are classified for density before printing, and a test is made on a standard negative, it will be found easy to print a large number of negatives on several grades of Velox paper and get a very high percentage of first-class prints with normal development.

With regard to development and after-treatment of the print, there is very little to say, since the matter is fully explained in the instruction sheet that accompanies each package of Velox paper. It is best to buy the ready prepared developers such as Velox Liquid Developer or Nepera Solution and to follow the directions given.

When fixing prints, take care that they do not lie on top of one another in the fixing bath without change so that each print will get its supply of fresh acid hypo.

## ENLARGING.

While contact prints are satisfactory to show one's friends, a time comes when we want to attempt something more ambitious and to make photographs which we can hang on our walls or submit for exhibition, and then we feel that we want something more than an ordinary print and something more than an enlarged print; we want to make a picture. The difference between a picture and a print is of course, not a matter of size; it is a matter of composition and balance, of judgment in the choice of subject and of the moment of exposure, and of finish and quality in the result.

The possibility of using a very great degree of enlargement is shown in Fig. 85, where the small image in the corner represents a contact print from the original negative.

Fig. 85.
Extreme Enlargement.
Original in lower right hand corner.

In this case the negative was a portion of a motion picture film which was taken to get the utmost sharpness of definition and was then enlarged to about a thousand times its original size, the definition in the finished enlargement being still quite good. Such work as this is rarely wanted, but the great value of enlarging is that parts can be chosen from a negative and enlarged to make very pleasing pictures, where the whole negative if printed as a contact print would be by no means satisfactory. The print shown in Fig. 86, for instance, is an enlargement of a film negative. This negative was taken at the seashore as a snapshot exposure, the figures being very small and in the corner of the negative so that if the negative were printed as a whole it would be very unsatisfactory. While a contact print trimmed as is shown in the enlargement was not much larger than a postage stamp, an enlargement of the figures in it, however, made a pleasing picture.

Another illustration of what can be done in enlarging is shown in Fig. 87, where two negatives have been enlarged together to make a combined picture. The lower half of the original scene, of which the church and trees form the upper half, consisted of a plowed field, so that the foreground in the original negative was very unsatisfactory. By taking another foreground, however, taking care, of course, that the lighting was the same, and shading the foreground of the first negative so that it did not print in enlarging, then changing the negative in enlarging and substituting the foreground negative, the two have been printed into one another with the result shown. Some photoghraphers are very clever at making these combined enlargements.

Fig. 86.
Enlargement of Part of a Snapshot.

There are two practical methods of making enlargements; those involving working in a dark-room, and those in which no dark-room is employed for the enlarging itself. For the latter purpose the Brownie Enlarging Camera is suitable, this being simply a cone-shaped box with a holder for the paper at the large end and a negative holder at the small end. The lens is fitted inside the cone, at just the right distance to insure a sharp focus so that the camera is always focused, and sharp enlargements are certain if the negatives are sharp. This enlarger is exposed to daylight. The disadvantage with this camera is that the degree of enlargement is fixed and that consequently it is not easy to select a small portion of a negative and enlarge it to a considerable extent.

Another good arrangement is that shown in Fig. 88, where the film or glass negative is put into the negative holder of the Kodak Enlarging Outfit. With this arrangement the negative is projected on to an easel or wall on which the bromide paper can be pinned, and since the distance of the enlarger from the easel or wall can be regulated, any degree of enlargement can be obtained and a small part of the negative can be selected and enlarged to any required size.

### TONING.

In the earlier printing processes used by photographers—those in which the image was obtained by the continued action of light and which were toned by the deposition of gold from a toning bath—the prints obtained were in various shades of purple and brown, and these shades became so associated with photographs in the minds of the public that when the black and white prints made on Velox and bromide papers began to displace the earlier Solio and Aristotype prints, the general public would scarcely recognize them as "photographs" at all, and a demand soon arose for some method of toning the black images of bromide and Velox prints to a brown or sepia similar to that of the gold toned printing-out papers.

Fig. 87.
Combined Enlargement from
Two Negatives.

It seems to be characteristic of mankind to want what they have not got, and it is interesting to note that with the earlier printing-out processes which easily gave warm tones, chemists were anxiously working to get methods of obtaining black and white prints, while with the developing-out processes, which naturally give good black and white prints, photographers desire to obtain warm sepia and brown tones.

The processes for obtaining sepia prints from the black developed-out images all depend on one chemical reaction;

namely, that by which silver bromide is converted into silver sulphide. Silver sulphide is a dark coloured, almost black, substance well known to the housekeeper—if not by name— as the tarnish which appears on silverware after it has been some time in the air, the surface of metallic silver being attacked by sulphur compounds in the air, which generally come from the products of combustion of gas in the cooking range.

Now, when any chemical substances *can* be produced by the interaction of two other chemical substances in solution the question as to whether it *will* be produced depends upon whether it is more or less soluble than the substances which

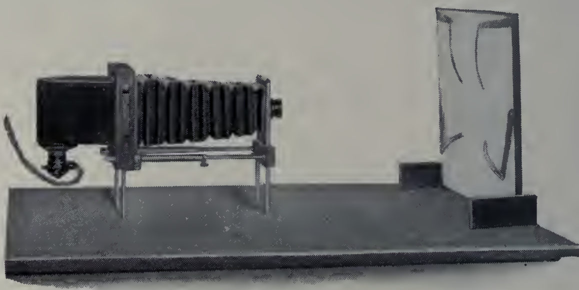


Fig. 88.
Brownie Enlarging Camera.

can form it. Silver sulphide is less soluble than silver bromide so that when silver bromide is treated with a solution containing sulphur in a free form it is changed into silver sulphide and the silver sulphide is deposited in its place. On the other hand, metallic silver, such as that which forms the image in a developed print, is less soluble than silver sulphide and consequently we cannot change it into silver sulphide by simply treating it with a solution containing free sulphur, but if in this solution we have some substance which will dissolve metallic silver, then we can change the metallic silver itself into silver sulphide. It is on these principles that the sulphur toning processes are based.

One toning process depends upon changing the silver image of the print back into silver bromide. Now, we know that silver is obtained from silver bromide by reduction, just as iron is got out of iron ore, and therefore we can get back silver bromide from silver by oxidation, which is the reverse process to reduction. If we use any solution which will oxidize silver and have potassium bromide present in the solution, the silver image will be turned into silver bromide.

The usual way to do this is to treat the black print after fixing and washing with a solution containing potassium ferricyanide, which is an oxidizing agent, and potassium bromide, and this turns the black silver image into a yellowish-white image of silver bromide which is scarcely visible, so that the process is called "bleaching" since the black silver turns into white silver bromide, and then after washing, this silver bromide is treated with a solution of sodium sulphide, which turns it into the brown silver sulphide which gives us our sepia toned print. So, to make a sepia Velox print by this method, we treat it with the "bleaching solution," which turns the silver into silver bromide, and then "redevelop" this, as it is called, in a solution of sulphide, which converts the silver bromide into silver sulphide and gives us our sepia print.

There is another method of obtaining sulphide toned prints which is somewhat simpler. We have seen that we cannot turn silver directly into silver sulphide by a solution containing free sulphur unless we have a solvent of silver present in the solution. Now, it so happens that hypo is to some extent a solvent of silver, and also that with a weak acid, hypo gives free sulphur. Alum behaves chemically like a weak acid and it also has the valuable property of hardening the print, so if we put the print which we wish to tone into a solution containing hypo and alum, the silver will slowly be changed into silver sulphide and the print will be toned brown. This change goes on very slowly at ordinary temperatures, but by heating the solution it goes much more rapidly, so that if we heat a bromide or Velox print in a solution containing hypo and alum, we shall get a good sepia tone at the end of ten or twenty minutes without any further difficulty, the only objection being that the bath, like all baths containing free sulphur, and like the sodium sulphide used for redeveloping in the other toning process, smells rather unpleasantly.

Equally good results in sepia toning cannot be got with all papers, but a great deal depends on the development of the print. To get good sepias, development should be full; an underdeveloped print will always give weak, yellowish tones when compared with one in which development has been carried out thoroughly, which will give a strong, pure sepia. It is important to remember this, as two prints which may look alike as black and white prints will tone differently if they have not been developed to the same extent.

## CHAPTER X.

### THE FINISHING OF THE NEGATIVE.

AFTER development, the undeveloped silver bromide is removed by immersion of the negative or print in what is called the "fixing bath". There are only a few substances which will dissolve silver bromide, and the one which is universally used in modern photography is sodium thiosulphate, which is known to photographers as hyposulphite of soda, or more usually as hypo, though the name hyposulphite of soda is used by chemists for another substance.

In the process of fixation the silver bromide is dissolved in the hypo by combining with it to form a compound sodium silver thiosulphate. Two of these compound thiosulphates exist, one of them being almost insoluble in water, while the other is very soluble. As long as the fixing bath has any appreciable fixing power, the soluble compound only is formed.

Fixing is accomplished by means of hypo only, but materials are usually transferred from the developer to the fixing bath with very little rinsing so that a good deal of developer is carried over into the fixing bath, and this soon oxidizes in the bath, turning it brown, and staining negatives or prints. In order to avoid this the bath has sulphite of soda added to it as a preservative against oxidation, and the preservative action is, of course, greater if the bath is kept in a slightly acid state. In order to prevent the gelatine from swelling and softening it is also usual to add some hardening agent to the fixing bath so that a fixing bath instead of containing only hypo will contain in addition sulphite, acid and hardener.

Now, if a few drops of acid, such as sulphuric or hydrochloric acid, are added to a weak solution of hypo, the hypo will be decomposed and the solution will become milky, owing to the precipitation of sulphur. The change of thiosulphate into sulphite and sulphur is reversible, since, if we boil together sulphite and sulphur we shall get thiosulphate formed, so that while acids free sulphur from the hypo, sulphite combines with the sulphur to form hypo again. Consequently, we can prevent acid decomposing the hypo if we have enough sulphite present, since the sulphite works in the opposite direction to the acid. An acid fixing bath, therefore, is preserved from decomposition by the sulphite, which also serves to prevent the oxidation of developer carried over into it.

Since in fixing baths what we require is a large amount of a weak acid, the best acid for the purpose is acetic acid. Citric or tartaric acids can also be used.

In order to make sure that the films are properly fixed they should be left in the fixing bath twice as long as is necessary to clear them from the visible, white silver bromide. If considerable work is being done, the best course is to use two fixing baths, transferring the films or prints to the second clean bath after they have been fixed in the first. Then, when the first bath begins to work slowly, it can be discarded and replaced by the second bath, a fresh solution being used for the second bath. These precautions are necessary because, as has already been said, silver forms two compound thiosulphates, the first of which is almost insoluble in water but is transformed into the second, which is soluble, by longer treatment with hypo. Consequently when a film first clears, it still contains the first insoluble thiosulphate of silver, and if it is taken out of the fixing bath and washed some of the silver will be left behind and not washed out. Then, on keeping, this silver thiosulphate left in the negative will decompose and produce stains. If a negative or print is properly fixed and washed it will be permanent.

The actual rate of washing may be understood by remembering that the amount of hypo remaining in the gelatine is continually halved in the same period of time as the washing proceeds. An average negative, for instance, will give up half its hypo in two minutes, so that at the end of two minutes half the hypo will be remaining in it, after four minutes one-quarter, after six minutes one-eighth, after eight minutes one-sixteenth, ten minutes one-thirty-second, and so on. It will be seen that in a short time the amount of hypo remaining will be infinitesimal. This, however, assumes that the negative is continually exposed to fresh water, which is the most important matter in arranging the washing of either negatives or prints.

If a lot of prints are put in a tray and water allowed to splash on the top of the tray, it is very easy for the water on the top to run off again, and for the prints at the bottom to lie soaking in a pool of fairly strong hypo solution, which is much heavier than water and which will fall to the bottom of the tray. If the object is to get the quickest washing, washing tanks should be arranged so that the water is continuously and completely changed and the prints or negatives are subjected to a continuous current of fresh water. If water is of value, and it is desired to economize in its use, then by far the most effective way of washing is to use successive changes of small quantities of water, putting the prints first in one tray, leaving them there for from two minutes to five minutes, and then transferring them to an entirely fresh lot of water, repeating this until they are washed.

The progress of the washing can be followed by adding a little permanganate solution to the wash water after the prints are taken out of it in order to see how much hypo is left in it, the presence of hypo being seen by decoloration of the permanganate. An even simpler test is to taste the prints. Six changes of five minutes each should be sufficient to eliminate the hypo effectively from any ordinary material.

## REDUCTION.

Sometimes negatives are obtained which are so dense that they are difficult to print. Other negatives are so contrasty that they give harsh prints. In order to improve these negatives recourse may be had to the process called "reduction," that is, to the removal of some of the silver by treatment with a chemical which dissolves the metallic silver of the image.

It is unfortunate that the word "reduction" is used in English for this purpose. In other languages the word "weakening" is used and it is undoubtedly a better word because the chemical action involved in the removal of silver from a negative is oxidation, and the use of the word reduction leads to confusion with true chemical reduction such as occurs in development.

In order to produce the best results it is necessary that the reduction should be suitable for the negative which is to be treated. Thus, in the case of a negative which is too dense all over it is necessary to remove the density uniformly, while in the case of one which is too contrasty what is required is not the removal of the silver from highlights and shadows alike, but the lessening of the deposit on the highlights without affecting the shadows.

In Fig. 89 we see a diagram which represents a negative originally dense from which by the removal of an equal amount of silver from shadows, halftones and highlights,

Fig. 89.
Diagram Showing How Cutting Reducer Acts.

there can be obtained a negative of proper gradation. A reducer which effects this uniform removal of density is generally called a "cutting reducer". The typical "cutting reducer" is that known as Farmer's reducer, which is made by preparing a strong solution of potassium ferricyanide, otherwise known as Red Prussiate of Potash, and adding a few drops of this to a solution of plain hypo until the latter is yellow. This reducer will not keep when mixed so that the ferricyanide must be added to the hypo only when required for use. It is especially useful for clearing negatives or lantern slides and is often used for local reduction, the solution being applied with a wad of absorbent cotton to the part which is to be lightened. Another cutting reducer is permanganate, which is supplied under the name of the "Eastman Reducer." Permanganate, however, tends to act more proportionally on the highlights and shadows than is the case with ferricyanide.

Proportional reducers are those which act on all parts of the negative in proportion to the amount of silver present there. They thus exactly undo the action of development since during development the density of all parts of a negative increase proportionately. A correctly exposed, but over-developed negative should, therefore, be reduced with a proportional reducer. This effect is shown in Fig. 90 where it is seen that the contrast of the negative is far too great owing to over-development, and that by removing the same proportion of the silver from the shadows, halftones and highlights, a negative of correct contrast can be obtained.

Fig. 90.
Diagram Showing How Proportional Reducer Acts.

Unfortunately there are no single reducers which are exactly proportional in their action but by mixing permanganate, which is a slightly cutting reducer, with persulphate, which is a flattening reducer, a proportional reducer may be obtained.

Flattening reducers are required for negatives which have been under-exposed and then over-developed. In these cases the negative is much too contrasty but it is important not to remove any of the deposit from the shadows, since owing to the under-exposure, there is already insufficient deposit in the shadows.

What is required in this case is shown in Fig. 91, where a large amount of deposit is removed from the highlights, a smaller amount from the halftones, and very little or none from the shadows. This can be accomplished by the use of ammonium persulphate. Ammonium persulphate attacks silver deposit with the formation of silver sulphate and this attack is increased by the silver salt which is produced, the rate of attack increasing as the attack goes on. Such chemical actions are called "auto-catalytic," a "catalyst" being a substance which increases the rate of a chemical

Fig. 91.
Diagram Showing How Flattening Reducer Acts.

*a* *b*

Fig. 92.

*a.* Negative too dense all over.
*b.* Result of using Farmer's Reducer.

action without actually taking part in it, and an auto-catalytic action being one in which the rate of action increases of its own accord. Since the action of ammonium persulphate is auto-catalytic it acts most rapidly where the greatest amount of silver is present, and consequently it attacks the highlights far more energetically than it attacks the shadows of the negative and is, therefore, suitable for the reduction of under-exposed, over-developed negatives. (Whether any silver will be removed from the shadows will depend on how long the reducer is allowed to act.) Because it is auto-catalytic in its action, however, it is very likely to go too far and get out of control so that it is not by any means an easy reducer to handle, and it is not recommended that it be used upon a valuable negative unless the user has had considerable experience of its action.

For some time after ammonium persulphate was introduced as a reducer for negatives its action was very

*a*

*b*

Fig. 93.

*a.* Correctly exposed but over-developed negative.
*b.* Result of reducing with a Proportional reducer.

*a*

*b*

Fig. 94.
*a.* Too dense in highlights, deep shadows not clear.
*b.* Effect of the Eastman Reducer on such a negative.

uncertain; some samples would reduce silver while others would not. When this peculiarity in its behavior was investigated by the Research Laboratory of the Eastman Kodak Company the reason was found to be a chemical difference in some of the samples tested.

INTENSIFICATION.

Sometimes we get negatives which are too thin and weak to print even on Contrast Velox; if we developed them in the tray perhaps we were deceived in judging the density

*a*

*b*

Fig. 95.

*a.* Negative with dense, blocked up highlights.
*b.* Shows that a Flattening Reducer removes much silver from the Highlights, less from the Halftones and little or none from the Shadows.

and we under-developed them, or possibly the subject itself was very flatly lighted, as often happens when the subject is an extremely distant landscape or a view across a large body of water, and from such negatives we cannot get a bright print, even on Contrast Velox.

Sometimes, also, we may not have Contrast Velox on hand and may wish to use Special or Regular Velox. In

Original. Strongly Intensified. Less Intensified.

Fig. 96.

Showing Effect of Intensification.

all these cases it is convenient to have a means of increasing the contrast of the negative, and the method by which this is done is the chemical process commonly called "intensification."

In order to increase the contrast we must, of course, increase all the separate steps of density occurring in the negative, and not only must we increase them but the increase must be proportional to the steps already existing; that is to say, we must multiply them all by the same amount if we are to retain correct gradation. Fig. 97 shows a number of different steps of density before and after intensification, all the densities having been multitiplied by the same amount or increased in the same proportion.

In order to produce this increase of density we must either deposit some other material on the silver, so as to add something to the image or we must change the color of the image so as to make it more non-actinic and capable of stopping more of the light which affects the printing paper.

There are many different substances which can be deposited upon the image. If, for instance, a negative is treated with a silvering solution suitably adjusted, the silver will be deposited on the image and will increase its density, but this is very difficult to do, and it is more practical to intensify negatives by depositing, not silver, but mercury upon them.

The Eastman Intensifier is a solution containing mercury which will be deposited

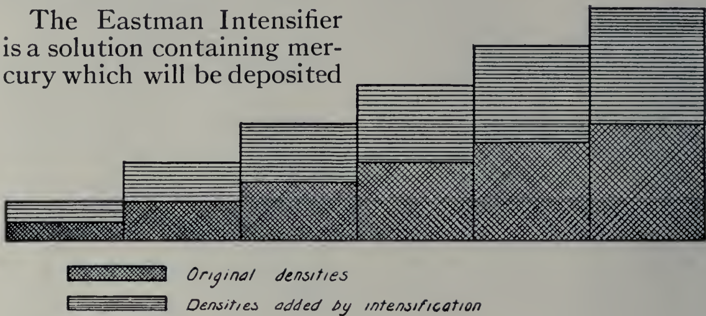



Fig. 97.
Densities Added By Intensification.

upon the negative immersed in it, and since the deposition is regular, it can be watched and the gain of density observed so that the intensification can be stopped at the right time.

While the mercury method is still the most popular for intensifying negatives it has never been wholly satisfactory, because mercury intensified negatives are apt to undergo changes that affect their quality after a time.

Another method of intensifying a negative is to bleach it in the Velox re-developer and then re-develop the bleached image with the sulphide solution used for obtaining sepia-toned prints. By this method the image is changed from silver to silver sulphide, which has a brownish-yellow color and is much more opaque to actinic light than the original silver image, so that a negative treated in this way will show much more contrast than before treatment. This method has proved very satisfactory and it is believed that re-developed negatives will prove as permanent as re-developed Velox prints.

It must be understood that intensification is only suitable for the increase of contrast, it cannot improve a negative which is seriously under-exposed; no amount of intensification can introduce detail which is not present before the intensification is commenced; but occasionally intensification will enable us to adjust the scale of contrast of a negative so that better prints can be obtained than are possible without the intensifying treatment.

# CHAPTER XI.

## HALATION.

Sometimes in a photograph there appears to be a blurring of the bright parts over the dark parts of the picture, and if lamps or other very bright lights are included they may appear in the print as bright spots surrounded by a dark ring beyond which is another bright ring. This curious effect, which is called "halation" is well illustrated in the photograph shown in Fig. 98.

Fig. 98.
Halation in Print.

Halation is caused by light which passes completely through the emulsion and also through the glass on which the emulsion is coated and is then reflected back into the emulsion from the back of the glass. The simplest form of such reflection is shown by the diagram, Fig. 99, where we see a ray of light falling on the emulsion at A. Most of this light is absorbed by the emulsion but some of it passes through to the glass and is reflected from the back of the glass, so that it reaches the emulsion again at B.

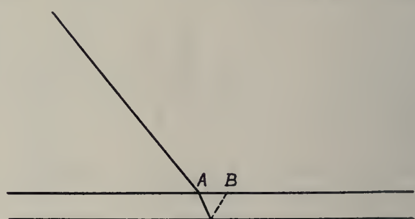



Fig. 99.
Simplest Form of Reflection.

But this simple diagram does not account for the appearance of the lights in Fig. 98, because if a ray of light had fallen on the plate squarely at right angles and had passed through the emulsion at right angles it would be reflected straight back and the halation would not be spread beyond the image, whereas, the halation is just as bad in the center of the picture where the light fell squarely on the emulsion as at the edges. Also, it does not account for the ring which is shown around the lights.

As a matter of fact, light falling on a photographic plate does not go straight through in this simple way. When a narrow ray of light falls on the grains of silver bromide it is reflected from them and scattered about.

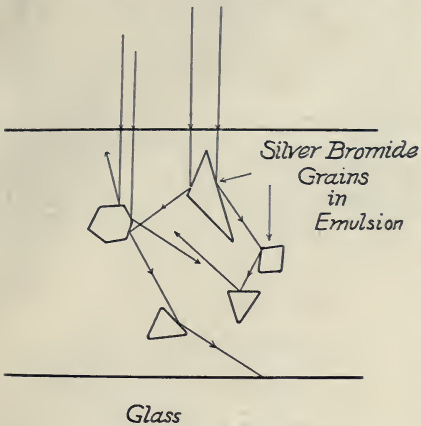



Fig. 100.
Scattered Reflections.

So we must imagine that if we could examine a magnified section through the plate, we should see the light falling on the emulsion scattered in all directions, so that a narrow beam of light is spread out into a kind of blur, the size of the blurring being very minute but still appreciable, Fig. 101; this effect of the light spreading in the film is called irradiation.

We see then that the light which passes through the emulsion of the photographic plate is traveling in all directions, whatever may have been its direction before it reached the emulsion, and if we follow the light into the glass, we shall find that most of the rays pass out of the glass again into the air but that some of them are reflected back into the emulsion.

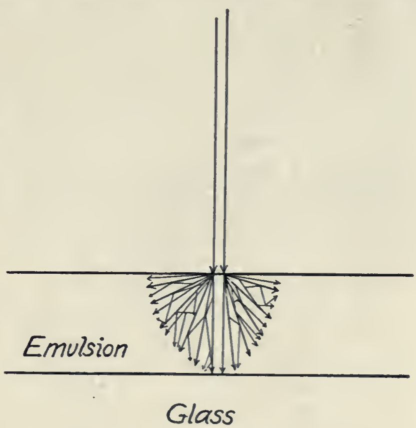



Fig. 101.
Irradiation.

In order to understand this we must look at the way in which different rays of light travel through glass. (See chapter III.) When a ray of light passes from air into a block of glass, it is bent

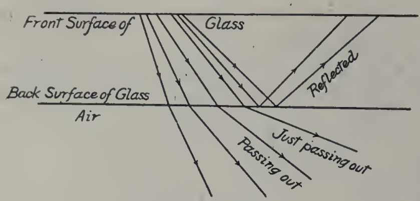



Fig. 102.
Rays in a Block of Glass.

by the glass which is a medium of different density, and when it leaves the glass again it is bent back so as to travel along a path parallel to that along which it entered the glass, but if a ray leaving the glass meets the surface at too big an angle, it cannot go out and it will be totally reflected back again. See Fig. 102. It is these totally reflected rays which produce the ring of halation.

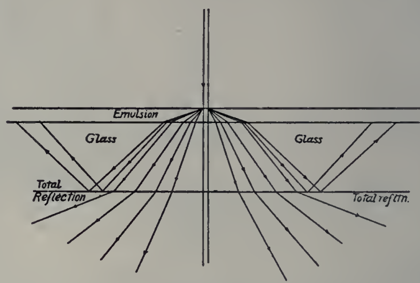



Fig. 103.
Rays in Photographic Plate.

When the image of the lamp falls on the emulsion and enters it, the rays are spread out by irradiation, so that we get a small spot at the center of the lamp, then this scattered light passes into the glass of the plate, and the rays which are near the center pass out into the air from the glass and we get a dark ring, but when suddenly the angle of the rays to the surface of the glass gets too big to get out they are reflected back and produce a sharp ring of halation around the center of the image, and then as they go farther and farther from the image the light gets weaker and the halation fades away again. Thus we can account completely for the rings of light shown in the picture.

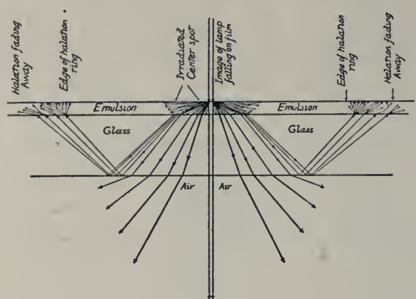



Fig. 104.
Complete Diagram of Halation.

If we coat the back of the glass with some substance into which the rays would pass directly from the glass and which would completely absorb them, we should wholly prevent the halation and if we choose this "backing", as it is called, so that it is of the right kind and almost completely absorbs the light, allowing very little of it to be reflected, then it will be quite effective in reducing halation, but in practice it is not altogether easy to get a satisfactory backing and to apply it correctly. The photographer tried a "backed" plate, but although he got rid of the sharp rings of halation his lights are still obscured by irregular blotches of light reflected from the back of the glass. (Fig. 105).

Fig. 105.
Print from Backed Plate Negative.

The best way of avoiding halation is not to have any glass at all. If we take the photograph on film, the support is sothin that the light has very little room to spread and we get only a very small spreading of the light rays. This spreading in fact is no greater than that necessary to give a correct representation of the effect of the light on the eye since there really is a spreading of the light in the eye and we do not actually see a bright light on a dark night as perfectly sharp, but as having a small amount of blur around it. So that in Fig. 106, which was taken on Kodak film, we get a result which gives a very good idea of the scene as it appeared.

Fig. 106.
Print From Negative Taken on Film.

## CHAPTER XII.

### ORTHOCHROMATIC PHOTOGRAPHY.

IF we take a piece of blue cloth and put an orange on it and then photograph the combination we shall find that instead of the orange being lighter than the cloth, as it looks to the eye, the photograph (Fig. 107) shows it as being darker. This difficulty in photographing colored objects so that they appear in the print in their correct tone values, as they are seen by the eye, has been well known to photographers from the earliest days of the art.

In order to understand the cause of it we must consider the nature of color itself. When we speak of a colored object

Fig. 107.
Picture of an Orange on Blue Cloth.

we mean one which produces a distinct sensation, which we call the sensation of color. This, of course, is due to a change in the nature of the light which enters the eye and causes the sensation of sight, and this change is produced in the light by the colored object so that the light after reflection from the colored object is different in composition from the beam of light before reflection.

In Chapter II we have seen that light consists of waves, and that these waves are of various lengths, the color of the light depending upon the wavelength.

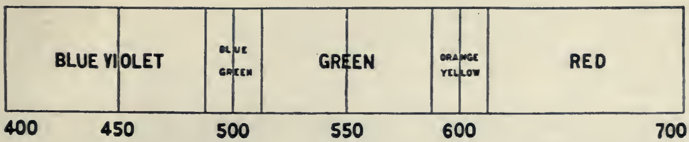



Fig. 108.
Divisions of Spectrum.

In white light there are waves of all lengths and if white light is passed through a spectroscope it is spread out into a band of various colors which is called a spectrum. The various colors of the spectrum correspond to definite lengths of light waves and if we measure their length in the very small units which are used for measuring waves of light we shall find that the red waves are 700 millionths of a millimeter, the yellow ones are 600, the green 550, the blue-green 500, the blue 450, and the violet waves, the shortest which we can see, are 400 millionths of a millimeter long (Fig. 108). Thus, we can scale the spectrum by the length of the light waves of which it is composed (Fig. 109).

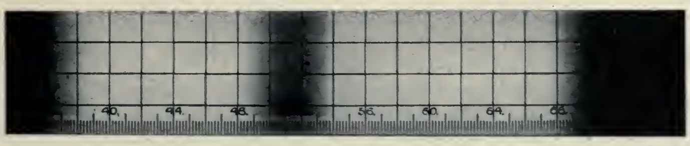


Fig. 109.
Pink filter passing violet, blue, yellow, orange and red rays but absorbing green.

If we take a piece of colored glass or gelatine, say pink gelatine, and hold it in front of the spectrum, we shall find that the pink gelatine will not let some of the waves of light through; it will stop them completely, while it will let the other waves through without any difficulty. The pink gelatine, in fact, cuts out or absorbs the green light (Fig. 109). *This is because of its pinkness;* that is, it has the property of absorbing green light from the white light and of letting through the other light which is not green, that is to say, to a less degree this pink film sorts out the light just as the spectroscope does, but instead of separating the waves of different lengths it stops some of them and lets the others go on, and the eye, missing those which are stopped, records the absence as a sensation of colour.

If, instead of having a transparent substance like film, we have an opaque colored object, like a sheet of orange paper, and let the spectrum fall on it, we shall find that the

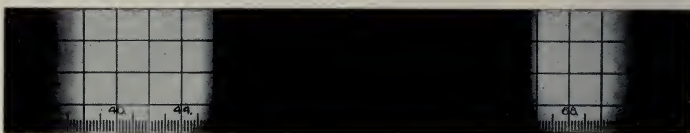


Fig. 110.
Purple filter passing violet and red, but absorbing the blue, green, yellow and orange.

orange paper will reflect the red and yellow and green light but will refuse to reflect the blue light; it absorbs it, and its orangeness is due to the fact that it absorbs the blue light and refuses to reflect it. All objects which are colored are colored because they have some selective absorption for some of the waves of light; they do not treat them all alike but reflect some and absorb others, and the modified light which reaches the eye we call "color." Any object which treats all the waves of light alike, which absorbs them all or absorbs them equally or reflects them all in equal proportion, is not colored. If it absorbs them all it will be


Fig. 111.

dead black since it will reflect no light. If it absorbs them to a small extent, but equally, it will be gray; if it reflects them all it will be white, but if it absorbs some of the wave lengths and not others, it will be colored.

If we try a series of experiments in our spectrum we shall find that things which absorb red light are colored blue, and those which absorb green light are colored pink or magenta, or if they absorb a great deal of the light, purple (Fig. 110). Those that absorb blue-green light are orange, and those that absorb blue-violet light are yellow. We see, then, that to each color there corresponds a region of the spectrum which is absorbed.

If we look at a spectrum we shall see that the brightest part of it is the yellow-green and yellow (the position of the yellow in the spectrum being between the yellow-green and the orange) so that the eye is most sensitive to the yellow, yellow-green and red rays and least sensitive to the blue and violet rays. (Fig. 111.) But if, instead of looking at the spectrum, we use a piece of bromide paper so that the


Fig. 112.

light of the spectrum may fall on it, and then make a positive print from this negative image, we shall find that the photographic action on the print is not produced in the region that is bright to the eye, but in the region which the eye can scarcely see, and, indeed, there is a strong action in the part of the spectrum beyond the visible spectrum, showing that there are waves which are shorter than the violet waves, which were discovered when the spectrum was first photographed and are called the *ultra-violet* waves. (Fig. 112.) This explains at once why when we photographed an orange on a blue cloth the orange was dark in the photograph and the blue cloth was bright, which is the opposite to the way they appear to the eye. The bright orange absorbs the blue light to which the film is sensitive and the blue cloth reflects it, so that although the cloth looks dark to the eye, it is bright in the photograph, and the orange which reflects very little blue and violet light is dark in the photograph. Fortunately, this defect, for defect it is, of photographic materials can be remedied to a considerable extent.

If dyes are incorporated with the emulsion the dyes sensitize the emulsion for the part of the spectrum which they absorb, so that if we put a pink dye of the right kind in the


Fig. 113.

emulsion the film will not only be sensitive to the blue light, to which it is naturally sensitive, but will also become sensitive to the yellow-green light, which the pink dye absorbs, and if we take a photograph of the spectrum on this sensitized film we shall get a photograph which appears as is shown in Fig. 113. Film made sensitive in this way is called *orthochromatic*, and in photographing colored objects the use of an orthochromatic film is a great advantage.

The orthochromatic film is still not sensitive to red, which to the eye is a bright color, and so red objects are still rendered too dark in a photograph, but this is not a great disadvantage for most work, and we have the very great advantage that the film can be developed in a red light.

Emulsions can be treated in such a way as to make them *panchromatic*, that is, sensitive to all colors, but such panchromatic materials cannot be handled by the light of an ordinary dark room lamp; they have to be used either in total darkness or by means of a very faint green light. For amateur photography it is therefore better to be content with orthochromatic film unless special subjects are to be photographed. A full account of photography with panchromatic plates and of the use of light filters in general is given in "The Photography of Colored Objects," published by the Company.

Fig. 114.
Made Through a Yellow Light Filter.

Great care is taken to make Kodak NC film as orthochromatic as will confer satisfactory color sensitiveness upon it without sensitizing it so far that it will be difficult for the user to handle or that there will be danger of fog when developing it.

While the sensitizing with dye makes the film sensitive to the yellow and green light, it is still much more sensitive to the blue and violet waves, as is shown in Fig. 113, and consequently it will still photograph blue objects much lighter than they appear to the eye. This is a disadvantage in some photography, and especially in landscape photography where we have blue sky with white clouds. White clouds are much brighter to the eye than the blue sky, but if they are photographed on the film in the ordinary way the blue sky appears too light and the clouds are lost against it. In order to overcome this and to enable orthochromatic film to represent most of the colors in their correct tone values light filters are used which absorb the excess of blue light and prevent it from reaching the film.

These light filters are, of course, yellow in color, since yellow absorbs blue light and thus, by the use of yellow light filters, which are sometimes called color screens, the excess of blue light can be absorbed and a much improved rendering of sky and clouds can be obtained. (Fig. 114.)

When light filters were first introduced it was thought that any yellow glass would be satisfactory, and light filters were made of brownish yellow glass, which really are of no advantage at all. The reason for this is that they transmit the ultra-violet light, which lies out in the spectrum beyond the violet. This ultra-violet light is quite invisible, but produces a strong impression upon the photographic plate, and in order to get satisfactory action from a filter it is very important to remove the ultra-violet light as completely as possible. The ultra-violet light is far more easily scattered by traces of mist in the atmosphere than visible light, and since it is this mist which so often makes objects in the distance invisible in photographs that are taken without a filter (Fig. 117a) it is necessary to use a filter that will cut out this ultra-violet light in order to show the distance well. (Fig. 117b.)

Modern light filters are made by dyeing gelatine with carefully chosen dyes and then cementing the dyed gelatine between optically prepared glasses.

Some yellow dyes, while removing violet light quite satisfactorily, transmit a great deal of the ultra-violet light and only a few dyes cut out the invisible ultra-violet satisfactorily. One of the best of these dyes is the dye used in

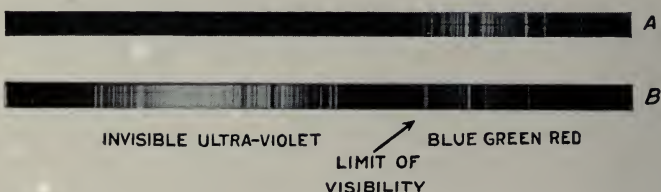



Fig. 115

Photograph of the spectrum, through two yellow Filters, which are of almost the same color to the eye, showing (A) that the K Filter cuts out the ultra-violet, while (B) the other Filter does not.

the Wratten K filters and the Kodak Color Filters. In Fig. 115 are shown two photographs of the spectrum—the one taken through a filter made with a dye of a type often used for filters, but not cutting out the ultra-violet, and the other the same spectrum taken through a K filter.

The K filters were made with a dye produced in Germany, and during the war the requirements of the aerial photographers in the army made it necessary to prepare a new dye which could be made in America and which would cut the mist even more sharply than the K filters. This presented a problem which was solved in the Kodak Research

Laboratory by the discovery of an entirely new dye which was named "Eastman Yellow," with which special filters are prepared for aerial photography.

Since a yellow light filter removes the ultra-violet and much of the blue-violet light, it necessarily increases the exposure, because if we remove those rays to which the film is most sensitive, we must compensate for it by exposing the film for a longer time to the action of the remaining rays, and the amount of this increased exposure will be dependent both on the proportion of the violet and the blue rays which are removed by the filter and also on the sensitiveness of the film for the remaining rays (green, orange and red) which are not removed by the filter.

The number of times by which the exposure must be increased for a given filter with a given film is called the "multiplying factor" of the filter, and since the factor depends both upon the depth of the filter and upon the color sensitiveness of the film, it is meaningless to refer to filters as "three times" or "six times" filters without specifying with what material they are to be used.

It is always desirable that we should be able to give as short an exposure as possible; what is required in a filter is that it should produce the greatest possible effect with the least possible increase of exposure, so that a filter will be considered most efficient when it produces the maximum result with the minimum multiplying factor. To a certain extent the multiplying factor depends upon the result that is wanted; thus in order to get exactly the same proportional exposure when using a Kodak Color Filter with Kodak NC Film, as that obtained without it the necessary increase of exposure is ten times, but in fact the Color Filter is generally used for distant landscapes where haze is to be cut out, and for clouds against the sky, and under such conditions an increase of three times the normal exposure that would be correct for an ordinary landscape will give the most satisfactory results.

Fig. 116.
Kodak Sky Filter.

For many purposes, however, the Kodak Color Filter is too strong; the exposure when using it is so prolonged that it is not

*a*

*b*

Fig. 117.

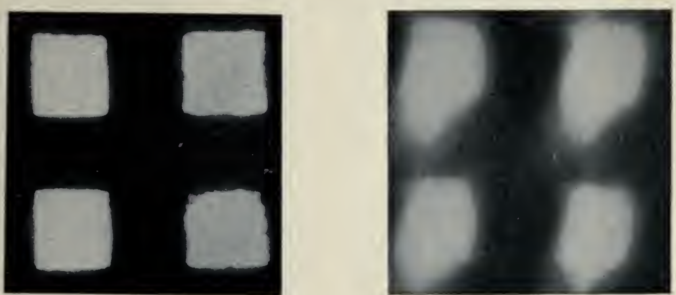
*a.* Made without a filter.
*b.* Made with a Wratten G filter.

practical to use the Kodak without a tripod, and to meet these difficulties the Kodak Sky Filter has been introduced. (Fig. 116.)

In this filter only half the gelatine, which is cemented between the glasses, is stained with the yellow dye, the other half being clear, and the filter is placed on the lens with its stained half on top so that the light from the sky will pass through the stained half and the light from the landscape through the clear half of the filter. In this way the yellow dye reduces the density of the sky in the negative without greatly affecting the exposure of the foreground and enables us to get a rendering of clouds in a blue sky by cutting out a part of the very strong light that comes from the sky, while the exposure necessary is increased only to a small extent.

The sky filter is not suitable for the cutting of haze since its colored half does not cover the landcsape, which is the part of the field where the haze occurs. Its use is confined to that suggested by its name.

When it is desired to make blue photograph somewhat darker than can be done with the Kodak Color Filter the Wratten K2 should be used, and for recording still more contrast, which is sometimes wanted in pictures of extremely distant landscapes that are under haze, the Wratten G filter is very valuable. Thus, distant mountains and all other distant landscape scenes (Figs. 117a and 117b) may be photographed through a strong yellow filter by giving the necessary increase of exposure, with a Kodak mounted on a tripod. The K2 will require an increase of exposure of about twenty times and the G of one hundred times on the Kodak Film.



*a* *b*

Fig. 118.

*a.* Original Definition.

*b.* Definition after screwing up tightly in cell.

In order that filters may not spoil the definition it is important that the glasses between which they are cemented should be of good optical quality. This is very carefully controlled in the case of the Kodak and Wratten filters, which are all measured by an instrument specially built for the detection of optical errors introduced by filters. The filters have to be mounted in the cells so that they cannot be strained by pressure being put upon them, since if they are squeezed the balsam with which they are cemented together will be displaced and the definition will be spoiled. (Fig. 118.)

Filters should be treated with care equal to that accorded to lenses. When not in use they should be kept in their cases and on no account allowed to get damp or dirty. With reasonable care in handling they should never become so dirty as to require other cleaning than can be given by breathing upon them and polishing with a clean, soft piece of linen or cotton cloth. A filter should never be allowed to become wet under any circumstances, because if water comes into contact with the gelatine at the edges of the filters it will cause the gelatine to swell and so separate the glasses, causing air to run in between it and the glass.

The dyes used for the Kodak and Wratten filters are quite stable to light, and no fear of fading need be felt. The filters, however, should be kept in their cases when not in use in order to protect them.

FINIS