THREE-DIMENSIONAL PHOTOGRAPHY

Principles of Stereoscopy

by

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TO

my principal assistant
who is also my wife,

FRANCES A. McKAY

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INTRODUCTION

DURING THE TWO YEARS since the first edition of this book appeared, there has been a profound change in the status of stereo in the United States. Then it was confined to a relatively small number of specialists, today it promises to become the number one medium for amateur photography. The change has been aided by the introduction of small, convenient cameras using 35mm film; it has been given great impetus by the introduction of color; it has been made easier by the simplification of mounting and the introduction of commercial mounting services. However, the greatest force of all has been an aggressive publicity campaign sponsored by the makers of the equipment used.

This does not mean that the popularity is artificial. Not at all. A brief wave of success could be produced by such means, but the campaign has served only to introduce stereo to the public. Once that introduction has been made, stereo continues to advance by its own merit.

Owners of stereo cameras are familiar with one expression which, although it varies widely in actual wording, always remains the same in meaning. It is heard from those who have been familiar with photography all their lives in the way that every American is familiar with it; printed reproductions, casual use of an inexpensive camera, collections of family snapshots. When such people see their first modern stereo they almost always say (1) "I never saw anything like it!" (2) "That's the only kind of photography I'd be interested in." (3) "Where can I get a camera to do that kind of work?"

I am not a salesman, and do not even try to interest people in the purchase of equipment, yet I have "sold" over 100 stereo cameras and almost half that many projectors of which I have definite record (although one dealer or another made the profit incident to these sales!). The fact is mentioned only to show that interest aroused is so deep that those interested are not satisfied until they, too, are making stereos.

It is sometimes difficult for an oldtimer, steeped in the tradition of the older stereo, to keep up with the modern pace. The old rules and laws, except the few which are sound, have been thrown overboard—and stereo does not seem to have been harmed by the fact. Stereo used to be reserved for very carefully made exposures of subjects selected with equal care, the new stereographer blithely shoots 30 or 60 shots in an afternoon.

All of this has a most important bearing upon the development of the new art, and certainly it must affect our approach to the subject in any kind of discussion. Photography is one of the most conservative of the common arts, foolishly so most of the time. The writer can remember the senseless struggle of the glass plate advocates (which means about 99 percent of the serious photographers, professional and amateur) against the encroachment of the sheet film. Today we see the stereo Old Guard tearing their hair and clad in sackcloth and ashes as one after another of their cherished idols falls under the onslaught of the enthusiastic "new stereographer." But with this Old Guard numbering considerably under 1000 and with the new legion growing at about 20 to 30 thousand every year, the newcomers, fortunately for all concerned, are going to have things their own way.

The stereographer was once very proud of his theoretical knowledge, whether it was accurate or not, and he used stereoscopy only as a stepping stone to elementary, very elementary stereogrammetry, and to him "stereo" was far more grammetric than scopic.

Stereoscopy as practised in stereography is a matter of producing a desired visual effect. The *appearance* is the ultimate goal of the whole process. Therefore, as far as stereography is concerned, errors, mistakenly called "distortions," if they are invisible simply do not exist. I recall one enthusiastic young mathematician who wrote about 20 pages pointing out that a certain stereo technique was not distortionless as claimed, but involved two serious distortions. "Of course," he added, "these two distortions neutralize each other and so are not apparent, but they are there as I have proven!" He simply could not understand that stereoscopically, the invisible is non-existent. He was delving into the realm of stereogrammetry.

Another, this time a stereogrammetric technician, produced an involved mathematical dissertation proving the inevitability of distortion produced by the "magnification" of the viewer. He could not understand that in ortho-stereo the final magnification is unity, that is, it does not exist visually.

Therefore, in this volume we shall deliberately disregard all of these fascinating mathematical complexities and treat our subject from the only rational, stereoscopic point of view; that is, with the visual appearance as the standard. *If you can't see it, it isn't there.*

At the same time, most readers will have sufficient curiosity to want to know "why" now and then. Also a superficial knowledge of stereo theory will often be of assistance in producing better work, so a certain amount of theory is necessary. However, it will be kept as elementary as possible. In any event, just remember that you do not really have to know even this simple theory to enable you to make excellent stereograms.

As a matter of fact the writer personally knows two stereographers who cannot even load their cameras, but have the dealer do it, yet they both make perfectly satisfactory stereograms and often produce really beautiful slides!

The extent to which you delve into theory is a matter of your own personal choice. But above all remember that stereography is the easiest type of photography, and it can be mastered with little effort. In fact it is just as easy to operate the stereo camera successfully as it is to use the familiar box camera.

Stereography is the automatic photography that produces the kind of pictures you have always dreamed of but never really expected to see.

The word *stereoscopy* is compounded from the Greek *stereos* (solid or firm) and *skopos* (the act of vision). Thus *stereoscopy* means the act of seeing "solid," or actually, seeing in all three dimensions.

Stereoscopic photography is the only medium known by which the appearance of an object or scene may be reproduced in every detail so that the image appears to the eyes exactly as did the original object. At first this does not seem to describe more than the ordinary photograph until we stop to recall that the best of conventional photographs falls far short of reproducing "every detail." The ordinary or planar photograph does not reproduce definite size or distance, it does not distinctly separate every plane, it does not definitely exhibit the depth contour of an object. In short, it does not reproduce more than a fraction of the essential visual detail of any object.

When the stereoscopic photograph is a motion picture in color and with sound, the picture will often deceive the spectator as to its reality. One inherent factor of true stereo, or "orthostereo" as it is called, is that all objects, regardless of the size of the "print," are reproduced *in their full natural size and at their full natural distance.* Only those who have enjoyed looking at some well-made stereograms can appreciate the startling realism of these easily made photographs.

Any camera may be used for making stereographic negatives; and a simple viewer may be made at home in a few moments by using two inexpensive magnifying lenses. The negatives involve nothing more than making two of them instead of one. That is the sum and substance of elementary stereography. A great deal of very beautiful and costly apparatus has been produced for stereographic purposes, but it is not actually essential. These things, both simple and elaborate, will be discussed each in its proper place.

While a poor photographic print may pass muster, the poor stereogram had better not be exhibited. The first requisite is that the stereographer have the ability to make a really good photograph. More than this, the fundamental aspects of stereography comprise:

1. Two negatives are made of the same scene but from slightly separated points of view.

2. The positives must be transposed, exchanging the right and the left print.

3. The dual print or stereogram is produced by mounting these two prints so that their bases as determined by the camera, shall lie in a common line.

It is possible to make the two exposures freehand, but because the positives must later be aligned according to the relative lens positions during the two exposures, this method is one for emergency only. The beginner will find it advisable to provide a tripod with some kind of top which limits the scope and direction of the camera movement. These may be obtained in elaborate form, or you can make a simple sliding base in a few moments from a board and three strips of wood. You will find herein instructions for making even more elaborate shifting bases which may be made at home.

Black-and-white stereo films may be processed by any commercial finisher if you choose, but in that case you will have to do the work of mounting for stereo viewing. On the whole it will be found more satisfactory if you do all of the processing for yourself. When color is involved, few amateurs will care to attempt the processing.

Experienced stereographers often dispense with the viewer, but the beginner will find it extremely difficult to obtain correct visual fusion without it. The viewer need be nothing more elaborate than two of the simple magnifiers obtainable at most novelty and stationery stores. These are attached to one another so that the centers of the lenses are about two and a quarter inches apart. Viewed through these lenses, the stereogram will fuse into a single, solid picture.

Later you will want a better viewer and a better camera, but these simple pieces of apparatus, to be more fully described later, are the only actual essentials in addition to normal photographic equipment.

The opinion has become widespread that some special knowledge or experience is essential for making stereograms. This is wholly erroneous. Anyone who can make a photograph can make a stereogram. If his skill is such that he makes a poor photograph he will make a poor stereogram, and if he can make a good photograph he can make a good stereogram. The only thing involved here is that stereoscopy enhances the effectiveness of any photograph, so if it is poor it seems very poor indeed in stereo, but if it is good then in stereo it becomes excellent.

Curiously enough, the very essence of nonentity in the form of black shadows and white highlights forms a considerable part of the modern planar photograph. Such elements seriously detract from the quality of, the stereogram. Hence stereographic technique must be such that they are avoided. Ordinarily the stereographic negative will be better if the normal exposure is increased and the negative development decreased.

The stereographic composition is not limited to one plane, therefore classic pictorial composition loses much of its force when applied to the stereogram, and often that which produces an excellent planar picture simply ruins the characteristic value of the stereogram. A new form of composition must be used, in fact it must largely be devised in the future, if we are to have esthetically pleasing results.

The planar photographer need have no extensive knowledge of the principles of human vision to produce pleasing pictures, but the stereographer can never approach the ultimate possibilities of his art unless he has a working knowledge of the principles of stereoscopic vision. For that reason, it has been necessary to include somewhat more theory in this volume than should be found in the usual photographic reference book. Much of this theory, however, is subject to highly interesting experimental demonstration, so that the process of working through the theoretical considerations will be found to provide quite as much pleasurable activity as actually making the stereogram. The theoretical considerations have in so far as possible been incorporated with the practical procedure. Not only does this make the theory easier to grasp, but at the same time it simplifies the process of acquiring stereoscopic skill.

Stereography is now undergoing a revival of popularity, and we are convinced that once the amateur has experienced the deep pleasure of seeing his photographs in the incredible realism of three dimensions, he will thereafter give to stereography his full enthusiasm.

Three-Dimensional Photography

CHAPTER 1

ELEMENTARY STEREOGRAPHY

WHAT IS STEREOGRAPHY? Stereography is a photographic technique which enables you to realize your dream of photography—reproduction of the original just as you saw it. You can easily imagine, when looking at a stereogram, that you are looking through a window at the real scene. Color, size, space, depth and distance are as clearly perceptible as when viewing the original.

Is it difficult? It has been repeatedly demonstrated that a beginner, knowing nothing whatsoever about photography, will have a greater degree of success in stereo than in conventional photography.

Is any special skill required? Definitely no! Anyone of average intelligence can begin to make good stereograms without special knowledge or the use of any special technique.

Is special equipment required? Strictly speaking, no, because even a box camera may be used for making stereograms. But practically it is highly advisable to use the regular two-lens stereo camera which is in reality two cameras built into one body.

Is it expensive? No. The film roll that will provide 20 exposures for the conventional miniature camera will provide 16 or 17 stereo pairs. The added cost will not exceed 10 percent.

With one camera (Personal), the 20 exposure magazine will provide 36 or 38 stereo pairs.

Is color film essential? No. Color does add greatly to the value of the stereogram, just as it does to any photograph. However stereography has been practised for more than a century, so naturally most of it has been in black and white. You can use any sensitive media you choose.

What are the limitations? None. The normal stereo negative may be used for making single enlargements, for example. Stereo may be applied to photomicro, macro, telephoto, portraits, records, figure study, landscape, flowers, and of course to motion pictures. Stereo may be applied to any form of photography, not even excepting stroboscopic studies and X-ray.

Color films are as limited in application as any color film.

Why should stereo be chosen rather than conventional photography? Much of this volume is devoted to the answers to this question, but to sum it up, it may be said that the stereogram accurately reproduces the original. In the stereogram you see just what you saw with your naked eyes. In short, in conventional

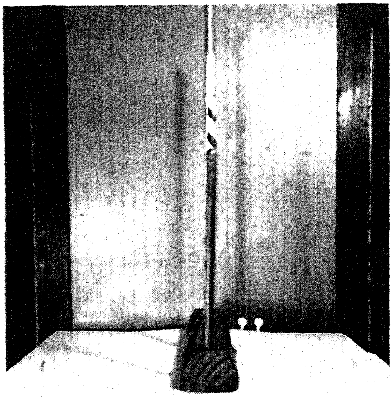

Fig. 1–1A. How It Works. An ordinary photograph of three posts set up in a row as seen by the one-lens camera set directly in front of the row.

photography you must have years of experience before you can predict the appearance of the final print; in stereo "What you see, you get." Stereo never disappoints, it always gives you just what you expect.

Moreover the utter, incredible realism makes conventional photographs appear as artificial as a wood engraving.

How is it done? Load the camera, set the exposure, focus with the rangefinder, sight the subject in the finder, press the button. Repeat until the film is exposed. When the film is removed it is factory processed as usual, and if you do not care to mount the films yourself, they are mounted for you. You drop the stereogram into the viewer (or place it in the projector) and enjoy it. The headaches have all been removed. There is nothing more than this that is absolutely essential. You will discover a great deal that is fascinating in this renewed art, and while you will never fully master all of its intricacies, you have the solace that you will be making excellent stereograms right from the start. That fact seems paradoxical, but it is the paramount reason for the tremendous rise in stereo popularity during the past two years.

Stereoscopy is based upon the simplest of principles. We have two eyes which are separated by a distance of 65mm, more or less. It is obvious that, inasmuch as the two eyes are in different positions, we have an individual point of view for each eye. It also follows that the aspect of any scene must be slightly different from these two points of view, even though the amount of difference is so slight as to be hardly noticeable.

If two photographs are made from two points of view separated by a distance similar to that between the eyes, two photographs will be obtained, and these two will respectively correspond to the visual image of each of the two eyes. If these two images are then viewed in such a manner that each eye shall see its own image and not the other, then we have the conditions of direct stereoscopic vision duplicated, and instead of seeing the two images as such, we shall see the single, three-dimensional image of normal direct vision.

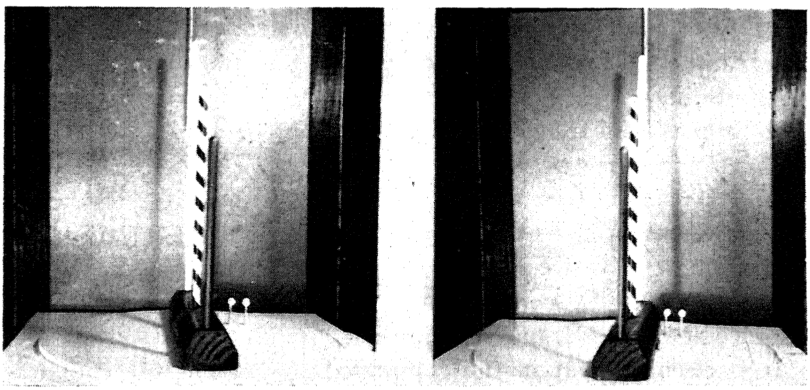

Fig. 1–1B. How It Works. The same three posts as seen by a stereo camera. Note that the two lenses each being at one side, show all three posts, but they "see" the two opposite sides of the row. Viewed in a stereoscope, the posts are seen in a straight line, but in depth.

Our problem then is two-fold. We must make the two photographs from separate points of view, and we must so look at these pictures that each eye sees only its corresponding picture. To that end the whole art of stereography is directed.

There are refinements of technique, and there are limitations which are rigidly enforced under certain circumstances, but for the present we shall ignore them and proceed to make the simple stereogram.

THE SIMPLE CAMERA.—A stereoscopic camera or a stereoscopic adapter for a standard camera serves but one purpose, that of making the two exposures simultaneously. This permits stereograms to be made of moving objects, but except for that purpose, any camera, including the simplest box type, may successfully be used for stereography. If you have a camera which you ordinarily use, you can make stereograms of motionless objects with it.

THE POINTS OF VIEW.—Theoretically, the two exposures should be made with the optical axes parallel and with a distance of 65mm between the points of view. We shall see that even in the best of technical stereography these factors are often ignored, but for the present we shall accept them as a working standard. In this connection it is interesting to note that the interpupillary distance varies with individuals, and that while 65mm has long been the accepted standard in the metric system (with both 60mm and 65mm as occasional competitors), 2½ inches is the accepted standard in U. S. measurement. Therefore, the two exposures will be made by moving the camera approximately 2½ inches between exposures.

CONTINUITY OF BASE.—The open frame in the rear of the camera against which the film lies and which frames the negative, has a position relative to the lens axis which is mechanically fixed. This means that the optical center of the image is always the same distance above this frame baseline.

It is essential that in the completed stereogram the common base of the two positives must be parallel to this camera base, and that the two exposures must be made under the same conditions.

Thus if the two exposures are made freehand, as is not uncommonly done by an expert stereographer, one of them with a slight tilt to the right and the other with a similar tilt to the left, there is no original continuity of base, and the prints must be aligned by stereoscopic analysis, a task for the experienced stereographer. Therefore, while freehand exposures are often made successfully by the experienced stereographer, the beginner will almost inevitably be disappointed if he tries it.

THE STEREO SHIFT-HEAD.—To avoid the condition just described, some kind of stereo tripod adapter or shift-head should be used. The simplest consists of a board with a raised border or frame around three sides. (Fig. 1-2). Let us assume that the camera to be used is a box camera three inches wide and five inches

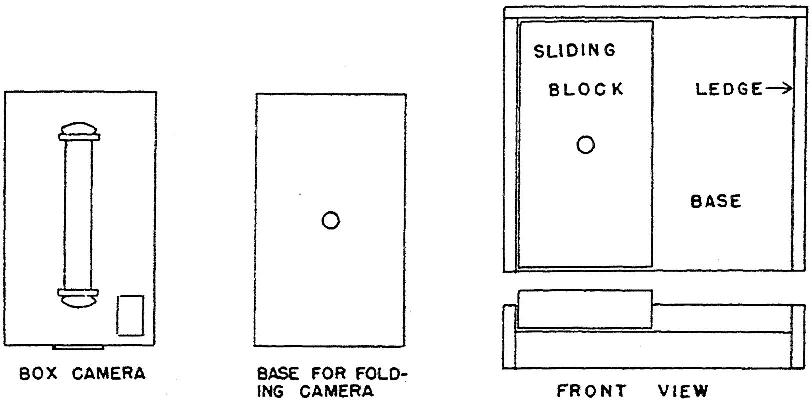

Fig. 1–2. Simple sliding base for making stereograms with any camera.

long. A board of this size would just be covered by the camera. It is desired that the camera be moved sidewise 2½ inches. If we add this to the width of three inches, we have 5½ inches, so the baseboard will be cut 5x5½ inches. This board should be from a half to three-quarters inch thick.

Along the two five-inch sides and along one 5½-inch side, thin strips of wood are nailed, rising perhaps an inch above the top of the board.

It is of the greatest importance that the baseboard be cut absolutely square, and that the two ends be accurately parallel. Perhaps it should be stated that these terms of accuracy are intended for the amateur workman. An error of one degree, while undesirable, is not too serious.

This board may be provided with a screw socket so that it may be mounted upon a tripod. In any event, some means should be provided for holding the board motionless during the two exposures. Otherwise the care spent in making the board accurately will be wasted.

Making the Exposure.—The board is attached to the tripod and the camera aligned as in making an ordinary photograph, but care is taken to make sure the camera rests solidly against one of the side rails and against the rear rail. In other words, the camera is pushed into one corner of the rails. The exposure is made as usual, erring if at all upon the side of overexposure. The camera is then pushed sidewise until it rests firmly in the opposite corner, and the second exposure is made.

As the negatives must later be cut apart and rejoined to establish the correct spacing, it is immaterial which exposure is made first.

Other Types of Base.—Stereo shifting bases are obtainable from many dealers. They may be the simple sliding type, as for

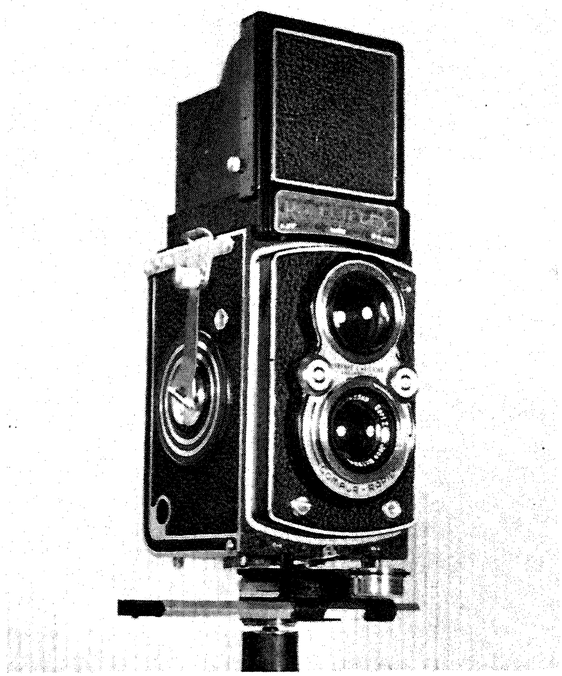

Fig. 1–3. A Rolleiflex camera mounted upon a Rolleiflex stereo slide bar for making stereograms by successive exposure.

example that sold for use with the Rolleiflex camera (Fig. 1-3), or it may be the parallel-arm type made popular in Germany. An examination of the latter shows its construction so clearly that no further description is necessary. This type may also be made at home, although more care is needed than in the construction of the board type.

STEREO REFLECTORS.—The disadvantage of all "successive" types of stereo exposure is that the object must be quite motionless during the whole interval of both exposures. Because even the slightest sway resulting from a breeze will effectually ruin the result, this method is hardly practical for most exterior subjects.

The alternative of a stereoscopic camera is not alway feasible because of the necessarily greater cost of such instruments. To meet this need, the stereo reflector was invented by F. A. P. Barnard in 1853.

The stereo reflector is an arrangement of four reflecting surfaces which are set before the lens of any standard camera. This divides the negative area into two portions, each of which receives one of the stereo images. In the cheaper forms, the device is made up of four mirrors, while the more elaborate types have two prisms, each of which provides two reflecting surfaces. The prism-type is fixed for one set of optical factors as embodied with some given lens and camera, while the mirror-type may be so designed that it may be adjusted for use with a variety of cameras and lenses.

The Leica Stereoly is an excellent example of the prism reflector designed for use with the Leica camera, but easily adapted to any miniature camera using a two-inch lens. The Stereotach (Fig. 1-4) is an example of the mirror reflector of fixed adjustment. Unfortunately there is no adjustable reflector available at the present writing, although the Rexo stereo adapter which had a full range of adjustment was sold about 1915.

These devices are attached to the camera lens in much the same way that a filter or sunshade is attached. They require some increase in exposure, the exact amount depending upon the design of the reflector used. Ordinarily, a three- or four-times exposure is about right. Care should be taken that the mirror division is exactly vertical and that it exactly bisects the lens. Other than this, operation is normal and the results are highly effective.

There has been a great deal of criticism offered regarding these attachments. Tests of all types mentioned have indicated

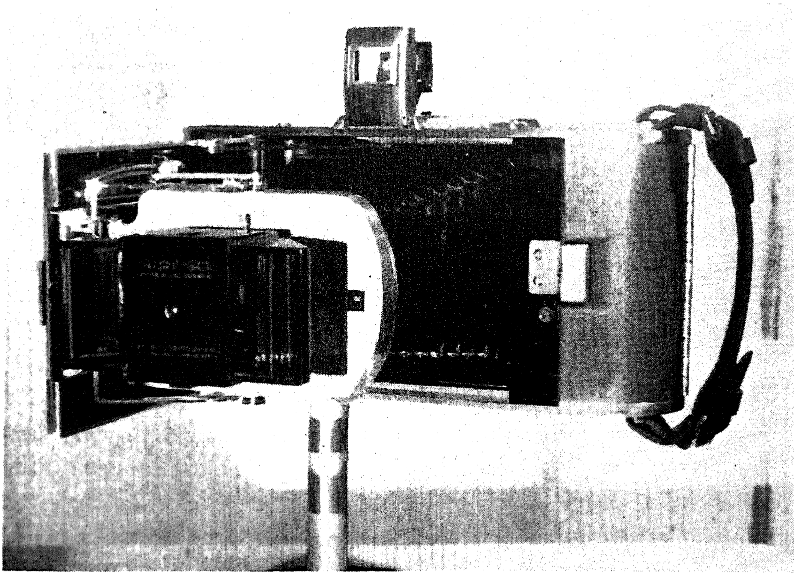

Fig. 1–4. For instantaneous stereograms, the Stereotach is applied to the Polaroid-Land camera.

that when properly used, the results are satisfactory. Inasmuch as the negatives may be printed or color films viewed just as they come from the developing laboratory, without transposing, they provide an ideal equipment for the beginner in stereography. It is only fair to add, however, that the resulting quality is not as good as that obtained with a conventional stereo camera.

When a high precision reflector is used, such as that advised for motion picture work, the quality is better. But as such a reflector costs as much or more than a good stereo camera, its use is pointless for still work.

PHOTOTECHNICAL CONSIDERATIONS. (BLACK-AND-WHITE).—In making the exposure, give full attention to the brightness range of the subject and do not attempt to make an exposure without compensation if this range is excessive. It is desirable that the meter be used to obtain a differential reading, and that the exposure given be that demanded by the shadow areas. This is no longer a question of the shadows "which contain desirable detail," but of the deepest shadow included, regardless of whether it is important or not. Any shadow lacking detail will later be seen as a formless smudge. Therefore, give that exposure demanded by the deepest included shadow of significant size.

This exposure will very often be from two to three times the average exposure, (which is in addition to any factor used because of the reflector, if used) and the differential reading will show that the highlights are being seriously overexposed. It will be necessary to compensate during development, often to the extent of using only half the normal time. In stereography the best results are obtainable only by going back to the old principle of exposing for the shadows and developing for the highlights.

It is difficult to imagine an exterior scene which can be stereographed successfully without a filter. An extensive series of filters is not needed, but the set should contain the medium or dark yellow, yellow-green, medium orange and tri-color red. Of these the medium orange will probably be the most often used.

DEFINITION.—As a rule the stereogram should be visually sharp throughout. Any obvious unsharpness, or hint of softness, is usually unacceptable.

It has been repeatedly suggested that the stereo depth be enhanced by softening the definition of the background. Such a suggestion indicates a lack of knowledge of the most elementary stereoscopic principles.

The stereogram duplicates in every way the appearance of the original. When this stereogram is viewed, assuming it to be needle sharp throughout, the eyes see sharply only that object upon which they are focused, and as the vision shifts from object to object, other objects in the field of vision take on exactly the degree of unsharpness they would have in real life. This fact is one of the fundamental principles of stereography. Therefore, any attempt further to simulate the characteristics of direct vision only introduces an unnatural effect and a loss of stereoscopic acuity.

It is therefore advisable always to use the smallest aperture compatible with other essential factors. When a large aperture is essential, try as far as possible to avoid any great depth in the field, and focus carefully to include as many planes as possible within the field depth.

MOVING OBJECTS.—This, of course, refers only to the use of the simultaneous exposure either with reflector or double camera. Strangely enough, a slight blur caused by the moving object is less objectionable than loss of definition by poor focus. It is desirable to avoid all blur, of course, but if conditions necessitate a compromise between small aperture and motion-stopping exposure, it is advisable to favor the small aperture even at the cost of a *slight* blur of motion.

On the other hand "follow shots," in which the exposure is made while swinging the camera to keep up with a moving object, are often surprisingly successful. If the object is sharp and the background is sufficiently blurred to rob it of identity, the stereogram may be very good indeed. So if you blur the background, blur it a lot!

INTERRELATION OF FACTORS.—Field depth demands a small aperture. Motion demands fast shutter speed. Shadow detail demands full exposure. Exterior scenes demand the use of a filter. All of these combine to limit the possible exposure somewhat rigidly. Often compromises must be made. The first thing is to use a lighter filter, or perhaps no filter, although this is undesirable. Next sacrifice some speed even at the expense of motion blur. Then manipulate the aperture, even to losing definition in the far background. Finally, rather than sacrifice shadow detail, either go to a faster film or try the same subject later when the light is more favorable. With experience you will learn to compromise these factors so that with hardly any discernible loss you will find it possible to make a good stereogram of any normal subject.

When color film is used, its slow speed further complicates the problem.

EMULSIONS.—In stereography, differences which are so subtle as to escape notice altogether in planar photography, become painfully obvious. Therefore, it is desirable that the positives have the greatest possible photographic quality. In fact, real success will never be achieved by the amateur until he has learned to make good transparencies. The print should be brilliant and full toned, with detail in the darkest shadows and the brightest highlights.

Ordinarily, while our most sensitive emulsions are perfectly satisfactory for routine planar photography, it will be found that emulsions of somewhat less than the greatest sensitivity will give the best satisfaction. The ideal emulsion is a slow, fine-grained panchromatic, but because of the antagonistic factors we have already discussed, a moderately high sensitivity is often very valuable in stereography. The popular panchromatic emulsions rated at approximately ASA 50 are perhaps the best all-around stereo emulsions. It is to be understood that like all generalizations, this is subject to variation for any of the many special types of subjects constantly encountered in stereoscopic work.

Of course the ideal material is color film. There is much to be said in favor of monochrome planar pictures, nothing in favor of monochrome stereo because color is an active stereo factor aside from its esthetic weight.

When the 35mm camera is used, the shorter focal length makes it possible to use larger apertures. Therefore the slower speed of color film loses its significance, and in such miniature cameras stereography with color film becomes as easy as, or in fact easier than, black and white with a larger camera.

FACTORS OF DEPTH PERCEPTION.—There are several factors involved in our sense of visual depth perception, all of which can be used to good advantage in stereography, but as these belong to the division of advanced work, we shall leave a discussion of them for a later chapter.

CHAPTER 2

STEREOSCOPIC CAMERAS

TWO OR THREE YEARS AGO any discussion of stereoscopic cameras necessarily included a number of obsolete models simply because there were so very few current models available, and among these only one of modern type. Today the situation is wholly different. The cameras follow the modern trend of stereoscopic technique, namely, the use of 35mm, natural color film. Of course there are hundreds of larger cameras in use, hundreds which make black and white prints as a rule. Obviously any camera can be used for color, but in practise the 35mm camera is largely devoted to color work; larger sizes to monochrome.

Nothing new has yet been introduced without meeting a host of objections, a few justifiable, but most of them made simply because the product is new. The miniature camera had a difficult time for years, but that precedent did little to win favor for the 35mm stereo camera, although the latter involves far less actual change of existing conditions than did the former.

In stereo, the vital viewing factor is visual angle—the angle from the center of the pupil to the extreme corners of the positive image. It is obvious that if a smaller picture is viewed nearer the eyes, the same angle is filled; and assuming, as we may, that the image structure (grain and the like) is such that the image definition is retained, there is no limit to the smallness of the image which is satisfactory. The sole limitation is image breakdown. This is more than being merely satisfactory. If the viewers are masked so that only the lenses show, there is nothing to indicate size. Under such conditions, spectators who have volunteered for the experiment repeatedly state a 3x6 inch or 6x13cm transparency to be the smallest of a group which includes both 35mm and 16mm films. Size *per se* offers no advantages, no disadvantages in stereo. Naturally the one who uses some particular size will rise in arms to defend his favorite. That is always true in photography, but disinterested experimenters have demonstrated the impossibility of distinguishing among sizes by viewing the images in normal viewers. The apparent size depends upon the sole factor of visual angle.

This point has been discussed at length simply because it often becomes the most important consideration when buying a stereo camera, when in fact, it is the least important. Certainly the smaller the picture the cheaper it is to make. For example, if you take a 20 exposure magazine of film, depending upon the camera you use, you may obtain 10, 12, 15, 16 or 38 exposures upon that film. If the operating cost is not a factor, then there is a second one, namely, that at the present time there are certain accessories which are available for the original 35mm size which are not as yet available for some others.

For example, rigid cardboard mounts are available for the five-perforation frame width, so wider films must be cut down for use in such mounts. In the case of the European models this amounts to a considerable loss of film area.

So the intending purchaser should study the salient points of each camera available, and make his choice by deciding which best meets his specific requirements. Among the three domestic cameras offered, the choice will be so guided because in the matter of results all three will afford performance beyond criticism. The European cameras include the most costly of all, the Verascope, which is truly de luxe, and the Continental wide frame with the traditional French or German design details will appeal to many users who are accustomed to Eureopean cameras.

Because of the wide use of 35mm (at least 100 to one), we shall limit our description of the larger cameras to the one which is the prototype of all de luxe stereo cameras and which will serve every need of the photographer who prefers the larger format.

There is no matter of preference involved in the order in which the cameras are described. It is convenient to start with that making the smallest picture, after which logical transition indicates the order in which the remaining cameras are discussed.

PERSONAL CAMERA (Sawyer's Incorporated). This camera has been introduced by the makers of the widely known "Viewmaster," and the finished films are mounted in the familiar "reels" of seven pairs each, for viewing in the Viewmaster. It is only fair to point out that inasmuch as the Personal films are direct camera images, they are even more satisfactory than the commercial reels which are, of necessity, copies.

The Personal camera is particularly attractive to those who are

Fig. 2–1. The Sawyer Personal Camera.

unfamiliar with photographic technique, because it needs no exposure meter, no calculating, no bother. The exposure control has been integrated with the camera controls so cleverly that all you have to do is to set one dial to the speed you wish to use and a second one to the light conditions, then press the button. To those who are skeptical about the practicability of such a device, I will only say that I made more than 100 exposures following the system and without benefit of meter and then gave the camera to a novice who exposed some 70 frames. The novice's films exhibited a better average of good results than the usual amateur photographer of normal competence will obtain in conventional photography. I obtained 96 percent with an additional 2 percent within consideration.

Unlike most cameras, the whole unit is self contained. The lenses lie within the body, and the filters (when used) lie in the body wall, retained by the standard Series V retaining ring. The body is oblong with rounded ends, 6 inches long, 3¼ high and 2 thick. It weighs, loaded, one pound, nine ounces. The finish is black and chrome, and is provided if desired with a good eveready case.

The lenses are of only 25mm focal length, a fact which makes it possible to dispense with focusing adjustment. Satisfactorily sharp pictures at a distance of 28 inches have been made, indicating the entire practicality of the fixed-focus lens when the focus is so short. The lenses have a maximum aperture of f/3.5 and are coated.

The shutter is of the time proven guillotine type which cannot possibly get out of synchronization and is speeded 1/10 to 1/100 with Bulb. A flash synchronizer for five millisecond delay (SF/SM bulbs and most portable strobe units) is built in and couples for all speeds.

The picture size is 12x13mm upon a 12x18mm film. The extra 6mm in length provides a tab which is indexed in the camera to indicate right or left and also forms a "handle" so that the film surface never need be touched in mounting. A 20-exposure magazine of standard 35mm film provides 38 stereo pairs. The method of adapting the so-called 16mm size to the 35mm film is unique. During the first 19 exposures, the lenses are opposite the top half of the film and the exposures extend to the midline of the film. When 19 exposures have been made, a dial on the front of the camera is turned. Then the lenses are opposite the lower side of the film, the film travel is reversed and 19 more exposures are made along the bottom of the film. When the last exposure has been made the film is already rewound ready to be removed from the camera.

The release is located at the lower, right corner of the camera (in operating position), and is pressed back into the camera. This provides a natural squeeze motion which is unlikely to produce camera bounce.

To make mounting easy, a special film punch is provided which punches out both films simultaneously, thus providing mechanically positive alignment between the two films. The camera apertures have small notches in one edge. One is semi-circular, the other square. These are the right-and-left indicators. The blank reels have 14 pockets. One is numbered 1, with a semi-circle, the opposite one is numbered 1 with a square mark, and so on for seven pairs. You do not even need to know which is right or left. You simply take the punched film which has the circular mark and place it in the pocket bearing the same mark.

The companion picture with the square mark is placed in the pocket bearing the same number but with the square index, and the pictures are mounted correctly. The punch and the reels are precision made so that correct alignment is assured with no possibility of obliquity.

The final measure of a camera, however, is the quality of result. In making well over 1000 exposures with the Personal camera, over a period of almost a year, the writer found it to be wholly satisfactory in every respect. For those who distrust their ability to cope with the intricacies of photographic exposure, the simplicity of this camera will prove most attractive. No focusing, no rangefinder, no exposure meter. Preset one dial which is rarely disturbed; set the other and shoot. It is as simple as that yet quality has not been sacrificed to simplicity.

The finder is a direct optical finder. No rangefinder is used with the fixed-focus lenses of course. The film transport and shutter setting are linked to prevent double exposure.

STEREO VIVID CAMERA. This camera is sold by the makers of the widely known Stereo Vivid projector. A glance at the two illustrations will show a certain similarity between this camera and the Personal. The same foolproof exposure control is used on both cameras, while the built-in shutter and "squeeze" release upon the front panel are common to both. In the Stereo Vivid, the shutter is placed behind the lenses, instead of in front of them, and lies almost in the focal plane. The shutter has the same positive synchronization as the true guillotine shutter.

The Stereo Vivid is a 5.5-perforation camera. That is the film is advanced 5.5 perforations for each picture instead of the five normally used. This gives a picture roughly two millimeters wider than the five-perforation advance, or a bit more. This gives one less picture for each 20-exposure magazine, but provides a picture which is fully square instead of being somewhat narrower than its height. This is a feature which will appeal to many stereographers who have turned to the extra wide European frame to avoid having a picture narrower than its height. This is a matter of personal choice. There is no basis for saying that any of the three is "best," but it does make it possible for the purchaser to choose among three picture widths.

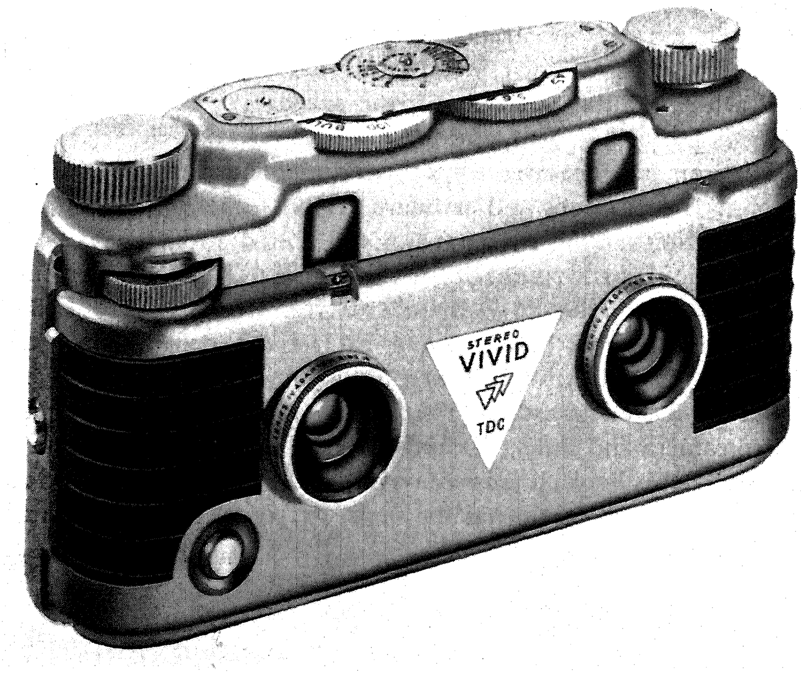

Fig. 2–2. The Stereo Vivid Camera.

The lenses and filters are set into the wall of the camera so there are no protrusions other than the filter retaining rings. The exposure dials and film winding knobs are aligned to provide a smooth, almost flat top to the camera so it has remarkably few projections.

Focusing is provided by moving the film aperture within the camera, giving increased steadiness to the lens mounts, a desirable feature. The focusing knob revolves in a horizontal plane upon a vertical shaft and is built back into the body with only an operating edge protruding. Focus is controlled by a rangefinder built into the top of the camera, immediately beneath the exposure dials. Both finder and rangefinder have the same eyepiece so shifting is avoided. The rangefinder windows lie at approximately the same distance apart as the lenses so the rangefinder parallax is within the stereo parallax, while the finder itself shows a field which lies within the stereo field. A level is visible in the finder when in use.

The focusing dial incorporates an easily read depth of field scale, a feature of importance in all stereo work.

The coated lenses of f/3.5 aperture and 35mm focus are coupled with a shutter with automatic speeds 1/5 to 1/150. This range is more than adequate for most stereo work.

The camera measures 6¼x3⅛x2¼ inches and is provided with neck cord loops and standard tripod socket.

Note: Neither the Personal nor the Stereo Vivid is available at the time this is written, but it is planned to have both cameras ready for the market in well under a year from the date of the publication of this book (1951). In fact the Personal may be available very shortly after our publication date.

STEREO REALIST CAMERA. This is the original, American, 35mm stereo camera and in fact the only one to be described in the first edition of this book. It is more conventional than the two models just described in that it has the usual stereo coupled blade shut-

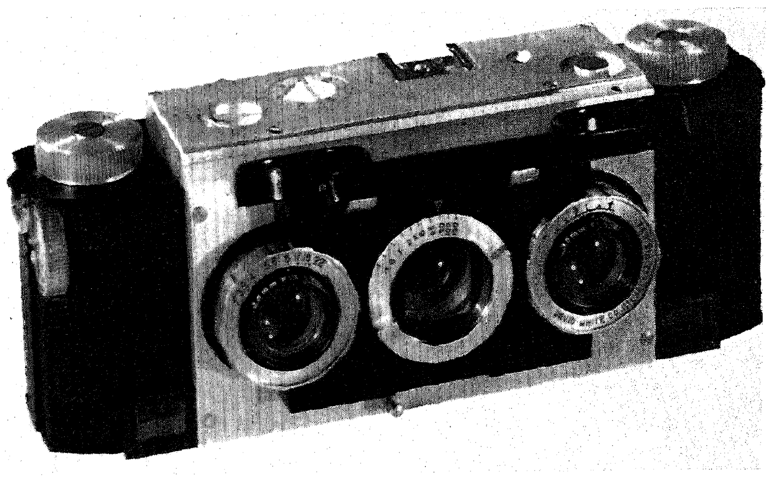

Fig. 2–3. The Stereo Realist Camera.

ters, and the shutter setting is independent of the film transport so the camera may be used for space control, hyperstereo or (by capping one lens) for single color exposures if desired.

The camera measures 6¾x2½x2 inches exclusive of sunshades. It is finished in black with chrome satin trim.

The two 35mm, f/3.5 coated lenses are rangefinder controlled. The finder is a brilliant optical finder with its objective set midway between the taking lenses. Both the rangefinder and finder eye-lenses are set at the bottom of the rear side of the camera so that the camera may be rested squarely against the forehead in making the exposure. The actual focusing is achieved by moving the film aperture within the camera, which results in greater steadiness for the lens mounts.

The shutter has automatic speeds from one second to 1/150 and has Time and Bulb in addition. The timing ring forms a rim for the central finder lens.

On top of the camera there is a small aperture under which a red signal appears when the shutter is tripped, thus warning the user that the film in the aperture has been exposed. This effectively prevents double exposure despite the fact that the shutter is not coupled to the film transport.

The Realist is a five-perforation camera, giving about 16 exposures to a 20-exposure magazine. It will be understood that the actual number of exposures depends upon the care with which the film leader is wound on. On the other hand too much crowding often results in the loss of a frame in processing, so it is best to be content with a smaller number of exposures and to be sure of getting all of them safely back from the laboratory.

There are many accessories available for the Realist, and most makers of mounts and the like have worked to the five-perforation size up to the present time. These accessories include: flashgun, for which the camera provides synchronization, sunshades to take Series V filters, eveready case and the like. There is also a complete mounting outfit which includes a film cutter, distribution box, mounting jig and heater for the irons which heat-seal the films to the prepared masks. This makes stereo mounting very easy.

Until the present year, the Realist has been the only domestic 35mm stereo camera available, and without it we should not have had the present tremendous revival of interest in stereo photography. When the camera was described in the first edition of this book it was a new and untried instrument. Since then many thousands of users have found it completely satisfactory. The writer has used his first Realist for many thousands of exposures and it has not failed once, a record of which any camera should be proud.

Now before we go on to the imported cameras, there is one inevitable question which must be answered here. There are now three high-quality domestic cameras available. Which is the best?

The one which you choose and use.

Look at all three, handle them, examine their features. Then choose the one which appeals to you the most. All will give excellent results. No matter which you buy, by the time you have given it a thorough tryout you will be ready to swear that it is by all odds the best stereo camera ever made. The writer has used a Realist for some three years and a Personal for almost a year, and has no criticism to offer regarding either. Both are excellent cameras. No doubt the same could be said of the Stereo Vivid were it not for the simple fact that no advance model is as yet available for test. By reason of its similarity in general design to the Personal, the writer fully expects it to share the same high quality of the two cameras which he has actually used over relatively long periods of time.

Interlocking Images.—Naturally, unless a great deal of film is to be wasted, the stereo pairs cannot be kept separate when taking. In one sequence as used by Realist and Personal cameras, they are intermingled in such a way that the film cannot be cut at any point without dividing a pair. This is of no consequence when the images are to be individually mounted, but for viewers using strip films, such procedure means the loss of one picture at each cut. It is also used in the Vivid.

This interlock can be easily understood when the "lefts" and "rights" are considered separately as shown here:

Left Exposures, 1 — 2 — 3 — 4 — 5 — 6 — 7 — 8 — 9
Right Exposures, 0 — 1 — 2 — 3 — 4 — 5 — 6 — 7
Interlock
Sequence, 1—0—2—1—3—2—4—3—5—4—6—5—7—6—8—7—9

This normal interlock used in the three cameras just described, is based upon the so-called normal sequence in which there are *two* images between each stereo pair. European cameras including the Iloca and the Verascope 40 make wider images and have but *one* image between each pair, so their interlock sequence is: 1–2–1–2* 3–4–3–4* 5–6–5–6* 7–8–7–8* etc. It will be noted that this film may be cut at any point marked * without injuring a pair. This interlock is accomplished by having a film transport which moves the film a longer distance at one winding and a shorter distance at the next.

VERASCOPE F40. This is a French camera made by the firm of Jules Richard of Paris. The name of Richard has long been known as a hallmark of quality in stereo equipment, but this is their first model made in accord with modern miniature camera

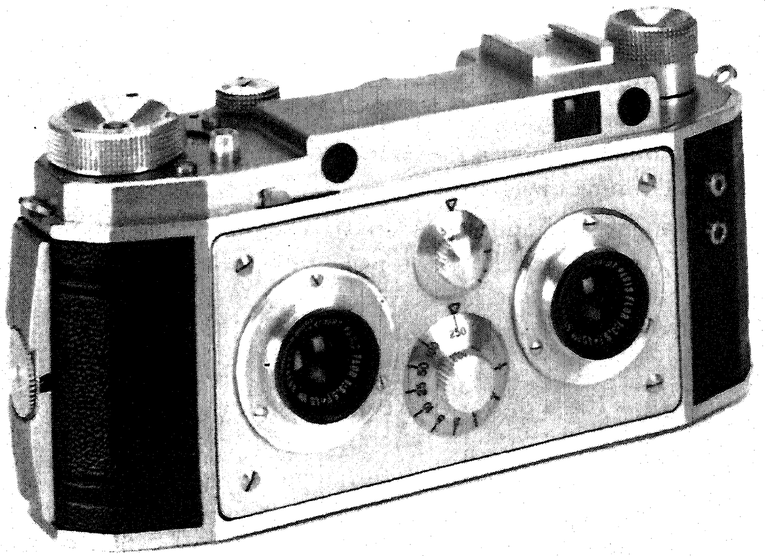

Fig. 2–4. Busch Verascope F-40.

design. It was first imported sporadically, but recently the Busch Camera Corporation started to import them as exclusive U. S. distributors. The camera, while conforming to basic 35mm stereo camera design has several unique features.

The camera is of the usual long shape, covered with black leather with satin chrome top and bottom plates. The Busch models have U. S. standard tripod sockets and are calibrated in feet, while the original imports had the Continental tripod socket and were calibrated according to the metric system. In giving this description we shall deal only with the Busch imports. Any discrepancy regarding Verascopes known to you who read this may be attributed to the changes made for the U. S. market.

The film used is the standard 35mm cartridge as made for all miniature cameras, black and white or color. Loading and operation are similar to other 35mm cameras.

The lenses are 40mm focal length, f/3.5 aperture, coated. In tests made in the Stereo Guild laboratories, definition was found to be excellent yielding a good, crisp image. Focus is controlled by coupled rangefinder. The control is a vertical disc set at the top-rear of the camera. This dial has an engraved depth-of-field scale for all apertures down to f/16.

The shutter is the usual French guillotine type, giving permanent, positive synchronization and with automatic speeds from one second to 1/250 with Time and Bulb. The lenses and shutter are mounted upon a movable lens board of the conventional type which moves with the focusing operation.

The rangefinder and finder are located in the top plate of the camera. The release is at the top-right-front of the body, and the button is threaded for cable release. Just at the left of the lens board are the two contact sockets for the internal flash synchronizer.

So much is more or less conventional, but there are some novel features.

The picture width is 30mm, although the height is the 24mm normal to 35mm film. This format is directly related to two other novel features. This width is considerably greater than the 22.5 and 24 of our domestic cameras. The choice, however, is a matter of personal preference.

This picture width makes it impossible to use the original interlocked sequence, so there is only one odd picture between pairs, so the sequence is: 1-2-1-2*3-4-3-4*5-6-5-6*7-8-7-8* and so on. It will be seen that the film may be cut at any point marked (*) without interrupting a pair. This type of sequence makes necessary a film advance which is long-short-long-short and so on, that is the actual film winding knob is turned about 1/4 revolution to wind the film, and the next film has to be wound 3/4 revolution and so on.

The fundamental reason for the picture width is the fact that this camera serves for both single and stereo exposures. By turning a small knob on top of the camera, one film aperture is obscured and the film transport altered to a single frame advance.

To make the single picture operation comparable to that of standard miniature cameras (36mm width), the frame width was made a compromise between the normal stereo and the normal single frame sizes. If, for any reason, it should be desired to make single pictures, this feature enables one camera to serve both purposes.

This duality is reflected in the counter. The exposure counter indicates single frames exposed. That is, it advances two units for each stereo exposure made. It will be seen that all of the novel features are therefore closely related to one another.

Accessories are being introduced for this camera. Case, filters, sunshades and the like are now available, as well as flash.

Design, appearance and performance are those which might be expected from a factory which has produced de luxe stereo equipment for many years.

ILOCA CAMERA. The Iloca is the current German version of the 35mm stereo. Its general appearance may be visualized by imagining one of the original Leica models lengthened and with a second lens added except that between-lens shutters are used.

The camera takes the standard 35mm film magazine, as do all the cameras described before. Loading is done by removing the bottom plate, just as in the Leica. The lenses are set off from the relatively thin body by lens tubes, and carry the Prontor shutters at the ends of these tubes in a manner familiar in many miniature cameras using this type of shutter.

The camera is 6⅞x2⅝x2⅜ inches in size. It weighs 1½ pounds loaded. The finish is black leather and chrome satin.

The lenses are brown coated, 45mm focal length, f/3.5. Focusing is done by separating the elements, a familiar German design, but as the two lenses are not linked for focus, an error might be made. Iris and speed are linked, with a top speed of 1/300 plus built-in flash synchronization. Focusing is by scale as there is no rangefinder.

As we go to press we are informed that in later models the lenses' focusing is connected. We are also told that this camera is to be brought out in a stereo-reflex model.

The pictures are the usual wide format of the European film and in both size and interlock resemble the Verascope.

Although the camera is of simplified design, lacking some refinements which we usually desire in a de luxe camera, the one we tried out gave very good results, comparable to the work produced by other de luxe stereo cameras.

Although of unfamiliar name, the moderate cost and the Continental size will undoubtedly appeal to many who like the wide frame but who cannot afford to invest the rather considerable amount necessary for the purchase of a Verascope.

These five cameras have been described in detail because this size is relatively new in the stereo field, although rapidly becoming popular. The five represent the American, the French, and the German designs, in the 35mm field.

CONVENTIONAL SMALL CAMERAS.—There have been literally hundreds of models of stereoscopic cameras offered from time to time, starting with the old Daguerrotype cameras and paralleling monocular design since that era. It would be useless to try to describe all of them, so we shall limit our discussion to relatively modern designs; to designs of some degree of originality; and to designs which are still available either new or used. We are informed that the well-known Rolleiflex line is once more available, and there are promises of additional domestic cameras, but as details are not available at this time we must pass over them.

FOLDING CAMERAS.—Many of the well-known makes of folding roll-film cameras were made at one time or another in the stereo type. There was once a Stereo Kodak made in this country, also the Stereo Hawkeye; while among the imported cameras, Ihagee and the Ica Ideal were both made in stereo models. These cameras were typical of the cameras most familiar to us as amateur film and filmpack models.

The press type of camera was also made in stereo. This camera is typically a thin, flat instrument when folded and extends, not by means of a hinged door, but by pulling the lensboard straight out upon lazy-tongs supports. In this group the better known stereo cameras included Ernemann, Zeiss (one model), Makina, and Mentor. These cameras are superior to the conventional folding type because the lensboard is supported top and bottom, but the ideal stereo camera is of rigid construction. A slight displacement of the lens in a monocular camera is of little importance, but in the stereo camera such displacement, because of the movable lensboard, too often results in unequal displacement of the two lenses, and the essential identity of base is destroyed. (Generally obsolete).

REFLEX CAMERAS.—The reflecting principle has been popular because the body is rigid, and the lens extension so short and so sturdily built that there is far less danger of lens displacement than in the folding types. One of the best of this type of camera, although it does not belong to the small camera group, was the Stereo Graflex using a 5x7 plate upon which the two stereo units were recorded in size suitable for direct printing in the American 3x6 inch paper print.

THREE-LENS CAMERA.—These cameras are often said to follow the Rolleiflex model, but that is reverse order. The Heidoscope was originally built as a rigid, all metal, three-lens camera, the center lens being the finder lens co-acting with a reflecting mirror set in the center of the top of the camera. This camera proved so successful that the manufacturers later brought out a twin-lens monocular-type camera which they named the Rolleiflex.

The same design was adopted for the Voigtländer Stereoflecktoscope. Both the Heidoscope and the Stereoflecktoscope were made in both the normal sizes.

ROLLEIDOSCOPE CAMERA.—In this country we may regard the plate cameras as obsolete, but the rollfilm version of the Heidoscope, known as the Rolleidoscope is strictly modern and has all of the quality and attractiveness of the plate model Heidoscope. If you are in the market for a 6x13 camera, you will do well to give the Rolleidoscope very careful consideration. There is no better camera made in this size.

The construction is conventional. Just imagine two Rolleiflex cameras built side by side, with only one finder lens and that situated midway between the two taking lenses instead of above. The reflex focusing-and-finding system is the same as in the Rolleiflex.

The camera makes five stereo pairs upon a standard roll of 120 film, the negatives corresponding to the 6x13 stereo size. The shutter is a Stereo-Compur of the usual set type. Focusing and speed are controlled by knobs at the two ends of the lensboard, and a moderate amount of rising front is provided. The lenses are f/4.5 Tessars, 75mm focal length.

The general construction is the rigid box so desirable in stereo cameras, but the camera is not inconveniently bulky. The carrying case measures only 4x5x7.5 inches over-all while the camera itself measures only 3.5x4x7 inches.

For color work, Ektachrome 120 or Anscocolor provides excellent results. For making stereos for reproduction either by normal side-by-side halftone or anaglyph the camera is unexcelled.

REFLECTORS.—At the present time the domestic market offers the Stereotach, a fixed-adjustment reflector which may be used with appropriate single-lens cameras for the production of satisfactory stereograms. For the amateur interested only in the production of a casual stereogram now and then, and for the beginner who wishes to try out stereo, these reflectors are excellent. The results are perfectly satisfactory within the limitations of the instrument, but of course the serious stereographer will wish to work with the double camera.

The stereo reflector does serve one purpose which cannot be served in any other way at present. This is the production of instantaneous pictures. The Stereotach does very well when used in conjunction with the Polaroid Land camera, and makes possible the production of good stereograms in monochrome within one minute after the exposure.

There are many technical applications particularly in the realm of forensic photography, when this rapid availability is of great value. Because stereo has met with such instant approval in the forensic field, this special technique should not be overlooked.

Many years ago there was an adjustable reflector on the market which was excellent in that it could be adapted instantly to any negative size and any focal-length lens. Such reflectors were very convenient, for while the stereographer will own and use the double camera, there are many times when only the single-lens camera is available, and if the reflector is carried habitually, it will save the day when a good stereo subject presents itself.

It would be a mistake to say that the reflector replaces the stereo camera, but at the same time every stereographer who owns and uses a single-lens camera as well as those interested in making stereo movies, will find it advisable to provide a reflector for emergency use. Although the adjustable models are not available at this writing, it is not difficult to make one, and it is to be hoped that some manufacturer will, in the near future, provide such a device.

SUMMARY OF 35MM STEREO CAMERAS.

	Personal	Stereo Vivid	Realist	Vera-scope	Iloca
Length	6″	6.25″	6.75″	6.50″	6.875″
Height	3.25″	3.125″	2.50″	3.125″	2.625″
Thickness	2″	2.25″	2″	2.125″	2.375″
Weight loaded	25 oz	?	32 oz	34 oz	24 oz
Lens: Aperture	3.5	3.5	3.5	3.5	3.5
Focal length . . .	25mm	35mm	35mm	40mm	45mm
Separation . . .	62mm	?	69.5 mm	63mm	67mm
Coated	Yes	Yes	Yes	Yes	Brown
Between-lens shutter . .			Yes		Yes
Guillotine shutter	Yes	Mod.		Yes	
Focusing	Fixed	RF	RF	RF	Scale
Max. speed	1/100	1/150	1/150	1/250	1/300
Approx. picture size (mm)	12x13	24x24	22x24	30x24	30x24
Exposures (20-exp. mag.)	38	15	16	11	11
Built-in synchronizer	Yes	Yes	Yes	Yes	Yes
Film-shutter interlock	Yes	Yes	No	Yes	No
Shutter coupling	Yes	Yes	Yes	Yes	Except focus
Single picture . . .	No	No	With cap	Yes	No
Integral exposure meter	Yes	Yes	No	No	No
Integral level in finder	Yes	Yes	No	No	No

NOTE: All cameras take the standard 35mm magazines as used in conventional miniature cameras. All have finders, tripod sockets, eveready cases and usual accessories. Picture sizes may be plus or minus a half millimeter. Number of pictures per roll may vary with loading.

CHAPTER 3

THE STEREOSCOPE

MOST STEREOGRAMS MUST BE VIEWED with some device which causes the two eyes to see their respective images optically superimposed. This is true without exception of orthostereograms. There are some types of photographs which incorporate dual images which are seen in relief without any viewing device, but this does not make them orthostereograms, because although they exhibit relief they do not fulfill the fundamental requirement of exhibiting the object in full natural size at full natural distance.

Many stereographers have developed the ability to see a stereogram without a viewer. This is the result of so training the eye muscles that accommodation and convergence are separated, so that the eyes can focus upon the near-by stereogram while retaining the zero convergence of infinity viewing. This type of stereo vision approximates the ideal more closely than the free-view devices, but it is still not orthostereo.

The device used for viewing is generally called a *stereoscope*. There is a widespread but inexcusable error of calling it a stereopticon, which means simply a lantern used for projecting lantern slides; specifically, the double-dissolving type now almost extinct. Do not fall into this error.

The stereoscope may be a simple, folding arrangement of cardboard carrying two simple magnifying lenses, or it may be a beautifully finished piece of furniture containing an elaborate mechanism for displaying the stereograms in any desired order. Between the two extremes there are many different forms.

The first difference is based upon size, of which we have far too many. The sizes are divided into two great groups, those which are spaced to correspond to the average eye spacing of 65mm, and those which are spaced farther apart than the normal interpupillary distance.

NORMAL SPACING.—Normal spacing starts with the 16mm film. These are either printed upon a length of film with the units of various pairs interlaced in sequence, or as in the Sawyer Viewmaster with seven pairs of pictures spaced about the periphery of a cardboard disc and viewed in succession by moving a lever in the device. Despite the absence of adjustments, the Viewmaster is a highly satisfactory stereoscope.

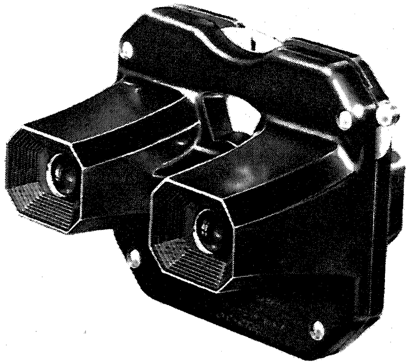

Fig. 3-1. The Sawyer Viewmaster.

THE REALIST VIEWER (Fig. 3-2), companion to the camera of the same name, is of polished black plastic material and contains its own battery and lamp, thus making the unit self-contained and ready for use regardless of external light conditions. This has long been recognized as the desirable method of stereo viewing. For home use a low voltage transformer is available so the light can be maintained at a more uniform level, a most important factor in color viewing.

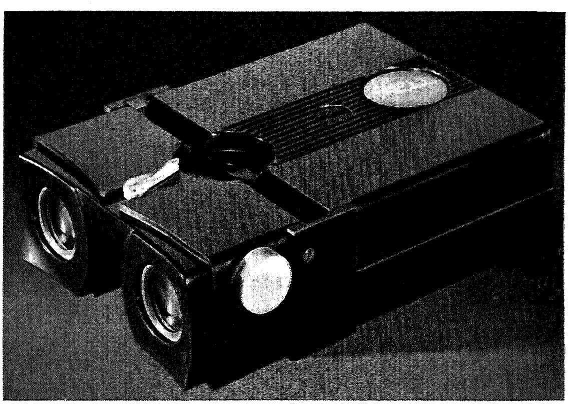

Fig. 3-2. Stereo Realist viewer. Self-illuminated. with focusing and interpupillary adjustments.

The images are viewed through black channels or tunnels, another instance of the most desirable condition. The lenses are of adequate dimensions and are provided with motions for focusing and for interpupillary adjustment. The focusing is by thumb wheel, and the interpupillary by lever. This viewer thus includes all of the features essential for stereo viewing at its best.

T.D.C. VIEWER.—This viewer is also made of polished black plastic, but more nearly resembles a pair of binoculars. The

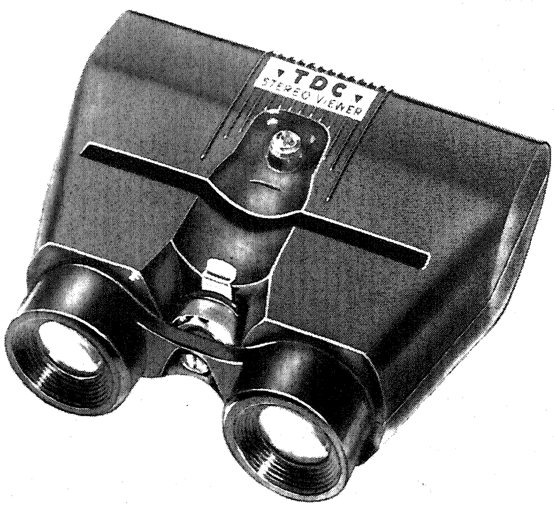

Fig. 3–3. TDC stereo viewer, companion to the Vivid camera and one of the least costly of the quality viewers.

ocular lenses are mounted in the binocular fashion and focusing is done by the central wheel of binocular type.

It is self illuminated with a switch which may be locked in place for continued viewing. The translucent switch button serves as a pilot to show when the lamp is burning.

Access to the interior for servicing is gained by simply raising a hinged cover.

This viewer takes the American standard stereo slide which measures 1⅝x4 inches, in either glass or cardboard mounts.

BUSCH-VERASCOPE VIEWER.—In conformity with American practice, the U. S. distributors for the Verascope have introduced a normal, non-transposing viewer.

Like the two just discussed, this viewer is of black plastic material, with self contained illumination. In general appearance it resembles the two types described, but both focus and interpupillary are provided with scales so that the viewer may be preset for any individual needs once the setting has been determined.

Naturally, although this viewer takes the standard size mount,

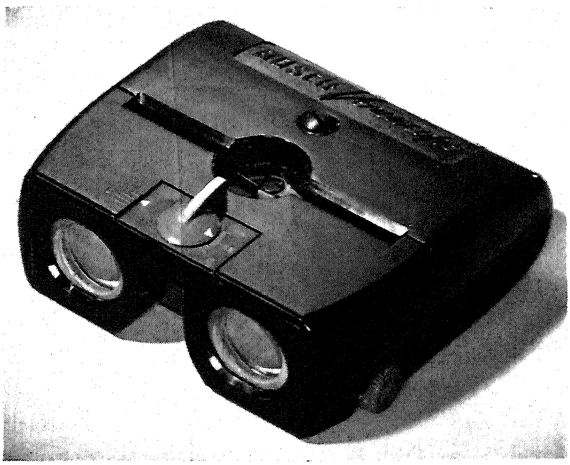

Fig. 3–4. The Verascope viewer, provided with calibrated scales for both focus and interocular. It takes all standard 35mm stereograms including the wide Verascope type.

the apertures are designed to accommodate the wide frame which is characteristic of the Verascope camera.

BRUMBERGER VIEWER.—This viewer is similar in general details to those which have been described, but does not have the interpupillary adjustment. It is of plastic construction with self contained illumination.

ILLUMINATION.—The color characteristics of any slide are greatly affected by the color of the viewing light. Viewers with no self illumination are decidedly unsatisfactory; even the battery powered viewers are not wholly so, as the color changes as the batteries lose power. The most satisfactory illumination is that obtained with the self illuminated viewer adapted for house current illumination.

Conversion cords are available with a tiny transformer built into the plug. These operate the standard bulb of 3 volt rating normally used, so no bulb changes are necessary. Only with this light is it possible to obtain and maintain the best effect from color slides.

OTHER NORMAL SIZES.—These include the 45x107mm and the 6x13cm, both of which are normal dual images spaced by approximately 65mm. Richard makes a 7x13, but its superiority to the universal 6x13 is open to question. For these normal sizes the range of available viewers is greatest.

Folding Types.—The folding stereoscope is, at best, an emergency instrument. It rarely maintains a level base, it has no field mask, it has no interocular adjustment, and the focusing is often of the most crude type. One of the surest ways to lose interest in stereo is to habitually make use of a folding viewer.

Book Viewers.—The one logical use for the folding viewer is to accompany stereo-illustrated books. The German version is to place a separate folding viewer in a pocket formed in the abnormally heavy binding. One American viewer has a folding post attached to the binding to support the viewer in correct position above the page. Neither method is satisfactory to the stereographer, and they are important only in so far as their novelty is concerned.

Box Viewers.—This is the largest group of all. It starts with a simple rectangular box equipped with lenses set in one side, and slide grooves at the other side to accept the stereo diapositive.

The same box may be provided with a hinged lid in the top which may be raised to admit light to the surface of a paper stereogram. This is the basic form upon which the usual box viewers are designed. All of the later forms consist in refinements and elaborations of this form. Therefore, instead of repeating the descriptions of the various models, we shall simply note the refinement and its effect upon the whole instrument, bearing in mind that all of those described may be, and are, applied separately and collectively to the basic box form.

In some box viewers the lenses are set in sliding tubes not unlike opera glasses, and are usually controlled by a button at the side of the box. This permits the lenses to be focused for any individual vision.

Variable Separation.—The generally accepted standard stereo separation is 65mm, but human eyes may be separated by either as little as 55 or as much as 75, with a variation of 5mm in either direction relatively common. Anatomists usually accept 62½ as the average interpupillary separation. Thus we find that while most cameras and viewers conform to the stereo standard of 65mm, the Verascopes of Richard conform to the anatomical standard of 62½mm.

It is desirable, and almost essential, that the viewer lenses and

Fig. 3–5. Telebinocular. One of the most satisfactory of the Brewster type viewers. This is the instrument used in the laboratories of the Stereo Guild for all stereograms of abnormal separation, such as the old "parlor" type of view.

camera lenses be of substantially the same focal length, and used at the same separation. It is an ideal condition when one can look through the centers of the lenses, but this is possible only when the interpupillary exactly corresponds to the separation of the lenses. Although in theory the stereoscope lenses act as collimators, making it unimportant to use the lens centers, it is visually more comfortable to have the lenses movable so that the separation corresponds to the interpupillary rather than to conform to stereo theory and remain exactly opposite the image centers. Normally the eyes converge and accommodate (focus) at the same time. Thus when viewing images of near-by objects the accommodation changes. Many persons, particularly those not accustomed to stereo viewing, adjust the focus for a nearer distance than infinity. Thus the true collimating effect is lost, and interpupillary adjustment becomes more of a necessity.

Stereoscopes of the full lenticular type should have lenses not less than 15mm in diameter to provide free vision for interpupillary distances between 60 and 70mm. When the lenses are not set at infinity focus, the adjustable separation becomes desirable.

Stereoscopes whose lenses are 30mm or more in diameter and of variable separation may be used either as full lenticular or semilenticular (Brewster) instruments. They may be used with stereograms of widely varying image separations.

It is an advantage to have cups for shielding the eyes when the viewer has no self-contained illuminating system. Achromatic lenses are advisable in all types of viewers, and are well worth the slight extra cost. Both full lenticular and Brewster instruments are available so equipped.

Variable Focus.—Some elaborate European viewers are equipped with interchangeable lenses of various focal lengths. Although these are sold for the purpose of obtaining variable magnification, the feature has value *only* when a single viewer is to be used with stereograms made with different cameras having different focal lengths. Other than this, the use of interchangeable lens viewers is to be avoided.

Automatic Hand Viewers.—The automatic viewer is simply a box viewer of the better class, fitted with a simple mechanism into which several views are loaded. Pressure upon a convenient lever, or turning a button, causes the views to be presented in succession. Usually this viewer has an auxiliary table stand, although it may be held freehand. It is intermediate between the box viewer and the cabinet type.

Cabinet Viewers.—These are table instruments, and while all models vary somewhat, it may be stated that as an average they measure about 10 inches square and stand about 15 inches high. They are usually in the form of a rectangular wooden cabinet with the lenses set near the upper end of the front side.

The views are ordinarily loaded in trays of twelve or twenty-five. An indexing mechanism on the outside permits the selection of any desired view. If all the views are to be observed, pressure upon the operating lever will bring the views into position in succession without any manipulation of the index lever.

These cabinets are made for use with transparencies only, as the viewing space is a black tunnel with the view masked to the actual picture area. In the case of cabinets for the smaller 45x107, which have the two picture images separated by a space in which the title is ordinarily written, an auxiliary lever is provided which lifts a shutter and inserts a prism in the optical path to make the title visible.

The cabinet viewers usually have both focusing and interpupillary adjustments, and most of them are provided (as extras) with illuminating boxes for artificial light and with single or double projection systems. Some of them (e.g., Mattey) are interchangeable for both 6x13 and 45x107 sizes. While there are many very good cabinets, or classifiers as they are called, the Richard Taxiphot may be regarded as typical.

The Mattey dual size cabinet instrument just described has been converted, very easily, to take the 35mm slides in both glass and cardboard mounts. This type of stereoscope is often called a "classifier."

Chain Viewers.—The chain viewer resembles the classifier externally, but usually has no interpupillary adjustment. The views are carried upon a pair of endless chains which hang upon sprockets attached to the operating knob. The knob is turned to bring the views into position successively. In the simpler type, the chain is built into the cabinet, and views must be removed from the chain and replaced when a change is desired. The better type has interchangeable chains so that any number of loaded chains may be kept in readiness for use.

VIEWERS FOR THE AMERICAN SIZE.—This is the old parlor size in which the stereogram measuring approximately 3x6 inches is mounted upon a card measuring 3½x7. It is the size most familiar to American and British amateurs and to those who are not stereographers, but the size most rarely used by the European stereo enthusiast. The views are almost universally paper, although a few transparencies are encountered now and then.

Hand Viewer.—The common viewer is the old parlor hand viewer known variously as the *American, Mexican, Holmes,* or *Parlor* viewer. It belongs to the same class as the folding viewer, and is to be regarded with the same suspicion. The wood construction and the inaccurate fitting produce a shaky contraption which is more often out of adjustment than in. Even those made by reputable firms are acknowledged to be designed only for occasional or demonstration use.

Table Viewers.—The table viewer is the Holmes instrument made of metal and carefully fitted. The whole is mounted upon a sturdy base and has in general those physical characteristics expected of an optical instrument of practical quality. These instruments are inexpensive in the simpler models, and should always be used for the American size when no better instrument is available. Inasmuch as these viewers are optically of the Brewster type, focusing is accomplished by moving the view rather than the lenses, an arrangement which is convenient.

Therapeutic Models.—One of the most practical of all Holmes viewers is that made for use in ophthalmic treatment. These instruments are similar to the table models, but they are heavier and more rugged. The infinity homologous distance is greater, the lenses are of better quality, the focusing scale is accurately calibrated, the body is fully adjustable for height and angle to provide the most comfortable viewing, and the eyepieces are grooved to take correction lenses so that even those with defective eyesight may use the instrument without wearing spectacles.

Inasmuch as the therapeutic viewers cost about the same as the automatic box viewer and much less than the cabinet classifiers, they are well within the reach of every serious amateur who works in this size, or those who use a small camera and then make use of enlarging to produce the final American size. The Keystone Ophthalmic Telebinocular is an excellent example of this type of viewer and one which can be recommended without reservation (Fig. 3-5). I use this instrument exclusively for this size of stereogram.

Cabinet-Type Viewers.—The classifier is not available for the American size print (although it is available for transparencies in the same size), but chain viewers with reflectors for illuminating the paper print are made. These are so exactly similar to the transparency chain viewer that nothing further need be said about them.

Pantoscope.—The Pantoscope was once a great favorite but is now rarely found in this country although still available in Europe. It consists of a folding wooden frame, sometimes elaborately carved, made in three sections. The base rests upon a table. The center section rises at the front end to slope from the user down toward the table. The third section rises at right angles to the middle section. At the rear of the middle section two rods rise at right angles to support the view.

The top or front section contains a large single lens from four to seven inches in diameter. Below this lies a pair of stereo lenses. The large single lens is for viewing ordinary photographs to give them a "plastic" appearance (a phenomenon to be discussed later), while the two lower lenses are provided for normal stereo viewing.

MISCELLANEOUS VIEWERS.—Coin-operated viewers are often found in Penny Arcades. Highly elaborate instruments have been designed for mapping, for therapeutic use, and for other special purposes. As these are of little interest to the amateur, we shall mention none of them except for the Wheatstone viewer, which is a basic type widely copied for general purposes.

The Wheatstone viewer (Fig. 3-6) consists of a pair of mirrors set at right angles and placed immediately before the eyes so that the left visual axis is deflected to the left and the right axis to the right. The two views are separate and are placed in suitable supports facing each other. The operator must adjust the positions to produce final stereo fusion. The advantage lies in the fact that the size of the prints used is unlimited. This viewer is largely used in aerial survey work and in X-ray stereography. In the latter

Fig. 3–6. The Ryker, a small version of the Wheatstone stereoscope used for viewing prints up to six inches square, is an aerial photo type of viewer. Courtesy J. P. Medders.

application, the unit pictures may be as large as 16x20 inches.

A small Wheatstone viewer with prismatic reflectors was made by Zeiss under the name of Pulfrich. Improved prismatic viewers have been repeatedly designed for industrial and survey work in which the pictures are laid side by side upon a table, but the fundamental principle is the same.

IMPORTANCE OF VIEWERS.—We have spent a considerable amount of time discussing viewers, for a very good reason, even though most of them are types which seem to be growing obsolete. Success in stereoscopy depends upon the perfection of the image, so in stereography satisfaction is derived only when the presentation of the image is flawless. The fact that cheap viewers can, and do, ruin the work of skilled stereographers using fine cameras, is well known. If the beginner wants to derive the utmost satisfaction from stereography, let him first buy the best viewer he can afford and then obtain the best camera he can for what remains of his funds. A $30 box camera and a $100 viewer will provide far more satisfaction than a $300 camera and a $5 viewer! Practically every disappointed beginner can trace his disappointment to the use of a cheap or faulty viewer.

Optical Characteristics of Viewers.—The function of the stereo viewer is not difficult to understand, but once understood, the necessity for the best possible instrument will be appreciated.

Lenticular Viewers.—The normal viewer, that is, the viewer used with stereograms whose I-H separation (homologous separation for objects at infinity) is 65mm, is usually called a lenticular viewer. The lenses are used as simple magnifiers, *but not for the purpose of making the image appear larger.*

The lenses serve a dual purpose. First they magnify the images to just that degree needed to compensate the diminution or negative magnification of the short focus camera lens, and second to bring the image into sharp focus while leaving the eyes in the condition of rest. (Infinity focus = zero accommodation).

Thus while there exists the magnification incident to viewing anything through a positive lens, this magnification, under orthostereo conditions has no significance because it only brings back to normal dimensions an image which has been made small in the camera.

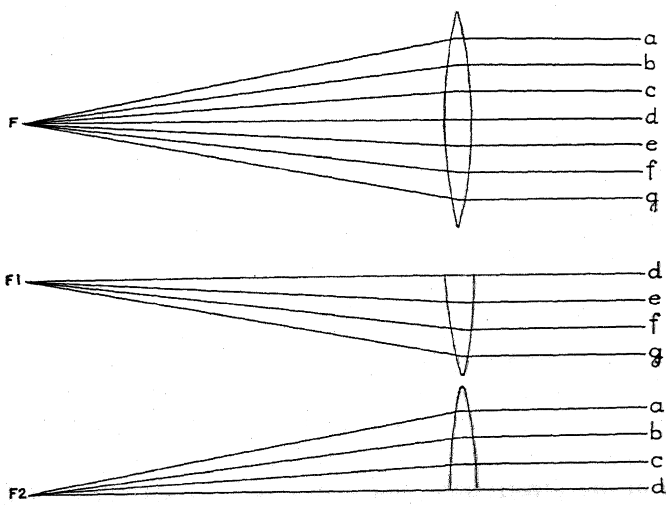

Fig. 3–7. A large lens focuses parallel rays a to g at F. If lens is split and the halves transposed, the upper half focuses rays d-g at F1; lower half focuses rays a-d at F2.

Thus, when a magnifying glass is used, we may assume that we see a very large image at an infinite distance or we see a smaller but still large image at the normal reading distánce of (usually) 16 inches. In the stereoscope we use the lenses to show us a "life size" image at (a maximum of) an infinite distance, and other similarly life size images at their correct, relative positions in space. This orienting of objects in space does not conform, subjectively, to magnification as usually understood.

However, lenses bend rays of light according to known laws. Simple lenses do not exert a uniform influence upon the rays, and if the axis of the lens does not coincide with the original axis of the image, the rays are not bent to the correct position. In short, for results which are fully satisfactory, an achromatic lens should be used and the instrument should provide such mounting that the optical axes are maintained in their correct positions relative to one another and relative to the optical axes of the stereoscope.

The Brewster Stereoscope.—In the Brewster instrument we have another set of conditions. To understand the origin of the lenses used, imagine a large lens whose diameter is twice that of the lenses to be used in the stereoscope (Figs. 3-7 and 3-8). From this large lens two smaller lenses are cut, one from each half as

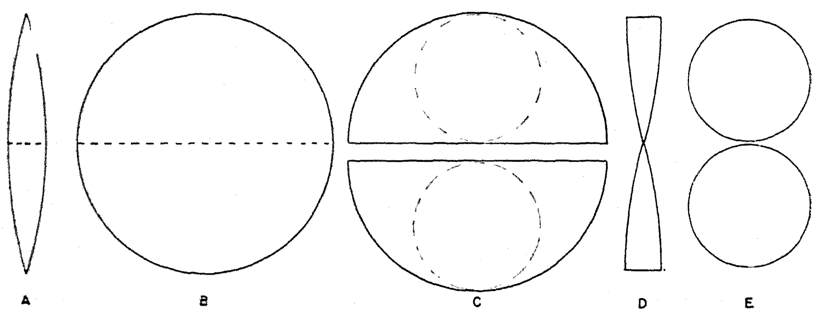

Fig. 3–8. A, B and C show how lens is divided to cut out two smaller lenses which are transposed and shown at D in edge view, and at E in plane view.

shown in the illustration. These two derived lenses each have the optical center of the original lens at their extreme periphery. These two lenses are then mounted with their positions reversed, that is with their thin edges adjacent. Thus for ideal results the

I-H separation of the stereogram should be equal to the distance between the optical centers, or the extreme outer edges of the two small lenses.

When adjusted for normal vision, the stereogram is supported in a plane whose distance from the lens is equal to the focal length of the original lens. Now we shall see why this viewer requires no interpupillary adjustment.

If the instrument is set up and a plain card placed in the support and a parallel beam of light is then projected into the lenses, they will bring the beam to two foci which are separated by a distance equal to the distance between the optical centers of the lenses and equal to the normal I-H distance. All parallel rays falling upon any part of the lens are brought to the focus. This is a characteristic example of the use of a collimating lens, or using a lens to produce a parallel beam from a point source, or vice versa.

As the human eye at rest is in a condition of zero convergence and accommodation, the visual axes are parallel. Thus no matter what the interpupillary, these parallel visual axes will coincide with a pair of rays in the parallel beams, and the visual axes will be projected to the optic foci by the collimating action already described. Thus, regardless of interpupillary, all eyes will react in a similar manner.

The choice between the full lenticular and the Brewster (or semilenticular) instruments has led to bitter argument, both schools having adherents, but a little thought will show that they are optically very similar, and that when the interpupillary is less than normal, the viewing conditions of both types are identical. The real choice lies in stereogram size, or rather homologous separation. If the separation is greater than the normal 65mm, the Brewster is used. The whole point is that the optical centers of the lenses should be separated by the distance equal to the homologous separation of the images. The Brewster type would work just the same if full lenses were substituted for the half lenses, but as the external halves could never be used, why waste glass?

Thus, any full lenticular viewer may be used as a Brewster by separating lenses and stereogram images to any distance greater than the normal interpupillary of the observer. Likewise, in a

Brewster instrument of 85mm separation, anyone so abnormal as to have this as their interpupillary would look through the outer edges of the Brewster lenses, that is, through the optical centers just as through a full lenticular. The Brewster is a full lenticular stereoscope in which the optical axes are separated by more than the interpupillary and in which the unused half lens is not physically present.

CHOICE OF A STEREOSCOPE.—The choice lies primarily in the size of the stereogram. For all sizes with normal interpupillaries, the full lenticular type of viewer is used, including those for 35 and 16mm film stereograms. This refers to all stereograms, regardless of the dimensions of the print, as long as the homologous separation is substantially 65mm.

For perfect results, the stereoscope should theoretically remain with fixed separation and fixed focus. Any compensations made for focus should be made by the use of supplementary ophthalmic lenses rather than by altering the distance between lens and stereogram. However, as this is not often practical, focusing by the conventional method is acceptable, and supplemented by variable separation does not produce obvious distortion. For the most comfortable use, experience has shown variable focus to be essential in all but the smallest sizes, and variable separation often convenient.

The stereoscope should have a rigid mechanical structure, should be equipped with achromatic lenses, and if possible, it should be equipped with some kind of illuminator to provide uniform illumination to both images of the stereogram.

THE STEREOSCOPE IN USE.—The stereoscope is too often regarded as simply a peephole device for looking at stereograms, no thought being given to the optical and neuro-optical phenomena involved. Because the stereographer can do much better work by understanding the fundamental principles of stereoscopic vision, we shall devote some space to this consideration, even though every attempt has been made in this book to eliminate theoretical discussion.

Cyclopean Vision and Stereo-projection.—Stereoscopic vision is based upon the perception of an image which has no physical existence. It is synthesized within the brain from two dissimilar sphero-planar images, and then projected into space. This involves a process which seems at first glance to go back to the early days of black magic and superstition, until we differentiate between the projection of a real beam, such as of light, and psychological projection which deals purely with the subjective. All of the clearly visible space in a stereogram is projected psychologically from the stereo images. Psychological projection can be a very real thing!

In Fig. 3-9 there is a hexagonal object, the subject of vision. The two retinas receive images which are dissimilar. These unit

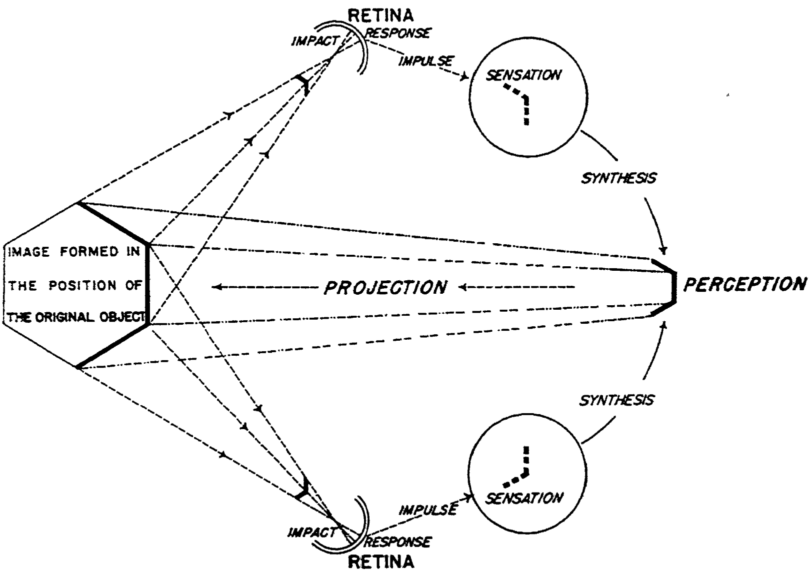

Fig. 3-9. Schematic illustration of stereoscopic perception. Retinal rivalry slide. Courtesy of Marel Laboratory.

images consist of an image of the front surface of the hexagon combined with one side, but in the two unit images, different sides are perceived. These images are formed upon the retina according to conventional optical laws, but from this point onward optics cease to be the controlling factor, and we enter the realm of subjective perception.

The retina responds to the impact of the image, and the two dissimilar images are perceived in the brain centers, as a result of normal sensation. At this point the less tangible reactions take place. The two sensations are synthesized by a process which we do not fully understand, to produce in the Cyclopean center a perception of the three-dimensional image corresponding to the *visible surface* of the solid hexagonal object. However, this image is created and exists only in the brain, hence the necessity for the final step, the projection. The image which is synthesized is then psychologically projected out into space until it occupies the same identical position in space occupied by the original solid body, and we have the sensation of seeing into space for a definite distance. A more detailed discussion of this "projection" of the image from the Cyclopean center into space may be found in any authoritative reference book of physiological optics.

The stereoscope is the physical means which we use to make possible a projection into space identical with that which would have existed had we viewed the original object. It is well known that "free-vision" stereograms, such as Vectographs, anaglyphs, bar-screen stereograms, and the like, do not even approximate the original distances of depth, as does the true orthostereogram, and in that respect they are inferior to the viewer type of stereogram. The projection of the free vision image is strictly limited.

The stereoscope provides a set of physical conditions which make possible exactly the same projection which would exist in directly viewing the original object. Thus it is possible for us to sit in a room, facing a wall only a few feet away yet truly see hundreds of yards out into space directly through the wall. However this may suggest fantasy, every competent stereographer knows it to be a very real fact. That is the basis, not only of the charm of stereo, but for some very genuine beneficial effects which result from the consistent use of the stereoscope.

Stereoscopic Idiosyncrasy.—Stereoscopic perception is a characteristic of marked variability. Like those who are color blind, there are those who have perfect binocular vision (that is, they have two eyes which are synchronized and which produce perfect visual images) yet who have little or no stereoscopic perception. The condition itself is somewhat analogous to color blindness, but unlike that defect of vision, in many instances stereoscopic perception can be developed by consistent exercise.

Some people have such a marked stereoscopic sense that they are always painfully aware of the flatness of the ordinary photograph; there are others who have so little stereo perception that the perception of depth depends upon such extrinsic factors as the diminution of size due to perspective, and similar effects. In fact, this has led in the past to the use of the word "perspective" when stereo depth is meant. The words, far from being synonymous, are complementary. These people see depth in a good planar photograph or when viewing a motion-picture screen.

Such people see nothing unusual when viewing their first stereogram. They see just what they do when looking at a transparency in an illuminated viewer for example. This not uncommon lack of stereopsis is one reason that stereo has not become even more widely popular.

Several optometrists and ophthalmologists, who specialize in stereoscopic treatment, were asked about the average conditions. These men are located in the East, Southeast, Southwest, and West, fairly representative of the nation. The consensus was that about one-third of all adults have low stereoscopic perception, and of the remaining two-thirds, from 12 to 15 percent have fully developed stereopsis. How much of this is due to physical or organic defects in the visual apparatus is open to question, but all are agreed that thorough training will show a marked increase in stereopsis in the case of anyone who has the slightest degree of it with which to start; that those who practice stereoscopic photography are usually in the high bracket; and most significant of all, that the use of stereograms in the home and office results in a marked improvement in vision. Incidentally, this answers those who refuse to work with stereo for fear of injuring their eyesight.

Stereoscopic Exercise.—It is well known that exercise, either physical or mental, is of value in sustaining health and in developing ability. Visual exercises are often regarded as purely subjective, but the visual organs, the eyes, operate through the agency of a complete system of delicate and highly co-ordinated muscles. That these muscles will respond to exercise just as will any other muscle is not only logical, but also a proven fact.

With each succeeding generation more of our major effort is expended within doors, and the maximum range of vision is perhaps 50 feet, with 10 to 15 a more common average. With the eyes adjusted for such distances, the position of rest (the position of the eyes when we are looking at a far distant object) becomes really an abnormal condition. Vision at close distances also necessitates convergence of the eyes, and as a consequence we are tending toward national nearsightedness and convergent squint or "crossed eyes." Optometrists find a surprisingly great number of people who have a tendency to squint which is not manifest in their ordinary vision, or in their appearance.

It has been found that even a quarter of an hour each day spent in looking at stereograms will do much to offset this tendency and give everyone a chance to look into the far distance. The use of the stereoscope not only provides for the complete relaxation of the ocular muscles into the condition of rest or infinity vision, but it also provides for a period of complete relaxation of convergence. While any good stereogram will approximate these conditions, a standard therapeutic stereoscope and a set of special exercise slides prepared for use with it, will provide exactly the relaxation desirable and will also, through the use of other slides, provide for flexing the muscles or alternating from convergence to relaxation through specific angles and through specific series. Thus the therapeutic stereoscope provides a visual gymnasium which can become one of the most valuable possessions of the consistent user. The reward for consistent exercise is better vision, freedom from eyestrain and its attendant headaches, greater acuity of vision, and retardation of the effects of presbyopia or "old age" vision.*

Non-stereoscopic Stereograms.—While discussing the subject of stereograms for visual training, the type of slide which is binocular but not stereoscopic should be considered. These are of several types.

The simplest is a picture slide such as is shown here (Fig. 3-10). The dog is seen by one eye and the pig by the other. The dog will appear to be jumping over the pig, but it may be just starting the jump, it may be midway over the pig, or it may be past the pig and ready to land. The relative positions reveal any tendency toward abnormal convergence or divergence. Similar slides containing an arrow pointing toward a series of numerals, serve a like purpose but provide a more exact result.

* Such stereograms are made by Bausch & Lomb, American Optical Co., and Keystone View Co.

Fig. 3-10. Courtesy Keystone View Co.

Another type is the split slide which is actually two separate slides, each having a portion of a picture upon it. Thus there may be a star upon one slide and a circle upon the other. In this instance the star is supposed to be seen within the circle, and to achieve this result the two cards are moved farther apart or nearer together in a calibrated holder.

In still another type, a special desk form of stereoscope is used and the cards have a simple outline picture such as a flower, vase, boat, or the like, printed upon one end only. The subject places this in the stereoscope and then proceeds to draw the second image upon the blank end of the card. When this can be done successfully the eyes are exceptionally well co-ordinated. The use of this stereoscope develops both co-ordination and stereopsis to a marked degree.

Although these slides are known generally as therapeutic ones, they are of interest and of value to every stereographer. Unfortunately space does not permit a detailed account of the experiments and exercises which anyone may use at home, but the information is readily available to those interested.

Similar therapeutic slides are made which do not use the stereoscope but which make use of Vectograph slides, such as the Bausch & Lomb Orthofusor.

Characteristics of the Stereogram.—As we shall see in the next chapter, the use of the stereoscope is essential for reproducing the orthostereoscopic (true stereo) effect, and to produce this effect the PePax principle is fundamental. This principle states that true stereo is possible only when the ratios of perspective and parallax are kept constant. The principle is considerably more complex than this simple statement indicates, but as it is largely a matter of theory I shall not go further into it here.

It is necessary, though, to remember that perspective and parallax are complementary, and in one sense they are opposed terms. Parallax pertains to distance in depth, away from the point of observation. Perspective pertains to dimensions in planes which are perpendicular to the visual axis.

We ordinarily consider perspective to be essentially the appearance of depth or relief, but those familiar with its principles will recall that perspective is primarily the art of reproducing a series

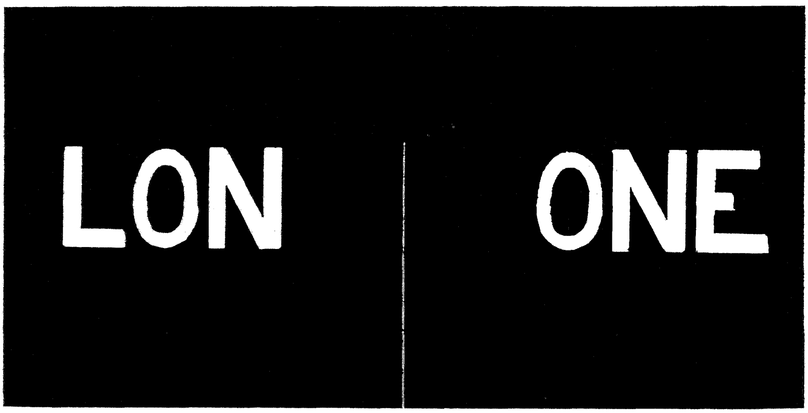

Fig. 3–11. Divided word. In the stereoscope, normal vision will show the complete word, "LONE."

of objects at various distances, *as they appear in a single plane.* The ordinary planar photograph, for example, exhibits a perfect example of perspective, yet it is the antithesis of the stereogram in which depth is directly and unmistakably apparent.

Parallax Controlling Factor.—The parallax, that is, the amount of difference between the two unit images, is the sole controlling factor in presenting the appearance of definite depth or distance.

If an object, for example a man six feet tall, is photographed at a distance of, let us say, 20 feet, he will appear to be 20 feet distant in the resulting stereogram and will appear to be about six feet tall. However, if between two successive parallactic exposures the man be moved (without changing his posture) so that the parallax is diminished by 50 percent, he will appear to be 40 feet away and to be about 12 feet tall. If the motion is in a direction to increase the parallax by 50 percent he will appear to be 15 feet distant and to have a height of approximately four and a half feet. This principle was once widely used in making fantastic stereograms such as a dancing girl inside a wine bottle, and the like; and is again becoming popular among those who like to experiment with this so-called *Space Control.*

Size Indefinite.—Our perception of absolute size is most unreliable. The reason the controlled parallax just described is operable is that the parallax definitely places the image at a fixed distance, and we estimate the size by comparison with that of known objects at the same distance. Thus when the image plane is artificially moved nearer, by increased parallax we still have the image size as originally diminished by perspective, so the object

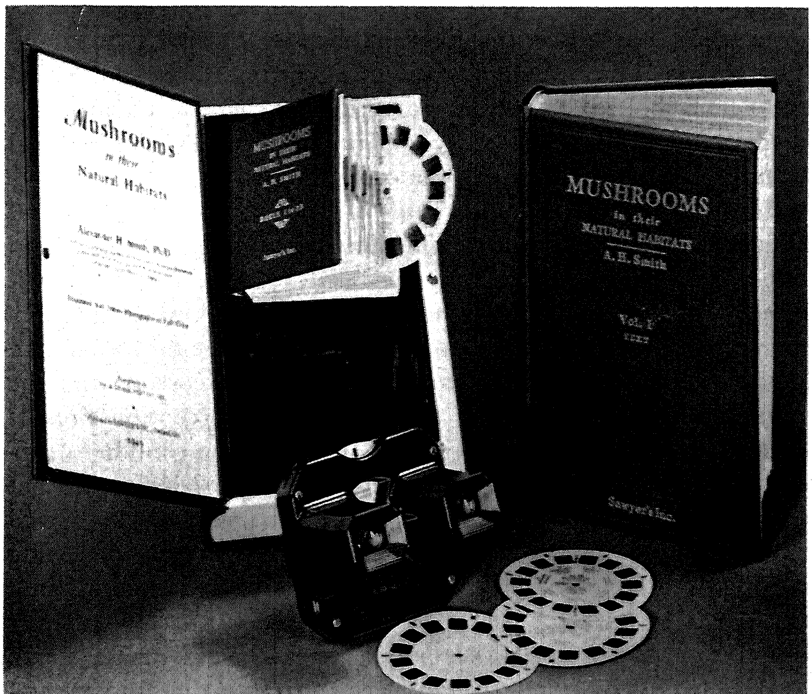

Fig. 3–12. One of the most notable of stereo illustrated books, with 231 three-dimensional pictures in full color.

appears to be smaller by comparison with other objects at the same apparent distance.

The same thing applies to the use of hyperstereo. If we have a vast expanse in a mountainous country, the distances are so great that the major portion of the scene lies beyond stereo infinity and we might as well use a planar camera. However, we can introduce true stereo relief by making use of an increased base. In short, we increase the degree of parallax beyond the natural. Thus by every applicable law of stereo, we should have a small sized image at an apparently near distance. In fact this is the argument ordinarily chosen to combat the use of the technique. Unfortunately the argument is not tenable because of the fact that size perception is always relative, and if we have no other objects in the same stereogram which exhibit a basically different degree of parallax for a fixed degree of perspective, there is nothing to show that the subject is a "miniature view."

Pseudo-Stereograms.—The pseudo-stereogram, or false stereogram, must not be confused with the pseudoscopic stereogram. The latter is simply a stereogram which has not been transposed and which shows the relationships of depth reversed. This is often used in the study of small, complex solid bodies, the reversal bringing out points which in the ordinary view are overlooked.

The pseudo-stereogram is simply a slide made of two identical images. That is, two prints from the same negative are mounted side-by-side. It is obvious that the result will be flat because it lacks parallax. However, it is also known that looking at any photograph through a lens system gives to it a vague appearance of solidity. This appearance is enhanced in the stereoscope and the result is that we have every factor of depth perception present except parallax. Usually the result is the indefinite roundness supplemented by the specific characteristics of perspective, so that many who are not experienced in stereo are deceived by a well made pseudo-stereogram. At the same time there is something lacking, and usually the comment is that the stereogram "isn't very good."

Stereoscopic Diplopia.—We may well ask what makes stereo work. There is no conclusive answer to this, but the fundamental mechanism of stereoscopic vision may be glimpsed when we consider a factor or two which are ordinarily ignored.

The activating stimulus of stereo vision is undoubtedly that of dynamic stereo diplopia. Diplopia means seeing two images of one object, and the diplopia normal to stereoscopic vision is known as stereo diplopia to differentiate it from the pathological form. Hold one finger vertically about a foot in front of the bridge of the nose and in line with a window. Look at the window. You will see two ghost images of the finger, one at each side of the window. Look at the finger and you will see two windows, one at each side of the finger. These are examples of stereo diplopia. Look from the finger to the window. During the act, the images of the finger separate into two and the two images of the window merge to form one. In the midway period you see two images of both objects. This motion of the dilopic images toward or away from one another is dynamic stereo diplopia. It will also be seen that the nearer any secondary object is to that which is the center of visual attention, the smaller is the separation between the ghosts. This diplopia is a function of dynamic parallax.

When we view an open scene, not only does the visual attention shift constantly from object to object, but with each shift there is a complementary alteration of the distances separating each pair of ghosts, so that stereo vision embraces an intricate, interweaving dance of ghostly pairs. It is this contraction and expansion of the degree of stereo diplopia which provides the stimulus to depth perception. The amount of distance between two ghost images which must be overcome to fuse the images is the subjective key to its position in space. This must not be confused with the physical, muscular tension involved in converging the eyeballs. The latter is of extremely minor importance in producing stereoscopic vision.

This fact is subject to the most striking proof. Take up a comfortable position which can be maintained for several minutes without discomfort. Select such a position that two objects, such as two trees, are aligned in such a manner that both may be seen simultaneously without shifting the eyes. It is better if the distance separating the two objects in the line of vision be not more than half the distance separating the nearest from the eyes of the observer, although this is not an essential condition.

Select some fairly prominent spot in the nearer object, perhaps a broken twig, a dead leaf, or the like. Keep the eyes fixed upon this one spot. Do not allow the vision to shift for a second. This will be extremely difficult, for the eyes normally shift all the time from object to object. While maintaining the visual focus upon the one spot, remain conscious of the images of both objects. At first they will appear in normal relationship, but after an interval, perhaps 15 seconds, perhaps a minute, they will be seen to be apparently in one plane, just as in an ordinary photograph. The specific stereo differentiation has been lost. This occurs very quickly, but at first it takes a few seconds for us to fully realize the change. Once the loss of depth has been recognized, shift the eyes, even as little as to the next bough of the tree, and instantly the images jump apart into their original stereo separation. This second change from the non-stereo to the stereo phase is marked and unmistakable. Thus it seems to be the continual shifting of the degree of stereo diplopia which is directly responsible for stereo perception.

To support the Wheatstone theory that static parallax is the sole stimulus of stereoscopic vision, an experiment is cited in which a subject is permitted to view a scene "for a very short period of time" with the (claimed) result that full stereo depth is perceived. In the laboratories of the Stereo Guild several subjects were used in a similar experiment. The slides were artificial stereograms of graded depth but containing no familiar figures, no extrinsic factors of depth. Illuminated with an electric flash whose duration was extremely short (so that the period of vision should be limited to the normal visual persistence), it was found that not one subject could identify the relative spatial positions in any slide, although all subjects could correctly classify all slides when permitted a period of vision of only a few seconds. This seems to support the theory of dynamic parallax rather than of static.

Parallax in the Stereoscope.—As we have seen, the lateral distance separating the two images of the same object in the stereogram is known as the homologous distance. In a stereogram the homologous distance decreases as the object occupies planes nearer the eye. Thus it is obvious that when the visual attention is focused upon any one object in the stereogram, the images of all other objects will fail to superimpose, but will produce stereo diplopia or ghost images.

The angular separation of these images is, in the orthostereoscopic reproduction, exactly the same as that which separated the similar images when the scene was viewed directly. Not only is this true, but as the attention of the eye changes from object to object, there is exactly the same continuous variation of diplopia which would have been present in the real scene.

Thus we find that although the individual pictures of the stereogram are sharply defined throughout, when viewed in the stereoscope there is the same "out-of-focus" effect in objects in remote planes that is observed in real life. The diffuse definition observed in direct vision in all objects not the center of attention, is not actually a matter of the focus of the crystalline lens, but is due to the doubling of the stereo images, an effect which is exactly reproduced in the stereogram. Hence, it follows that those who suggest using wide apertures when making stereograms to differentiate planes as in planar photography, fail utterly to understand the extent to which the stereogram duplicates conditions of direct stereoscopic vision.

Accommodation and Convergence.—Accommodation refers to the actual alteration of focus of the crystalline lens of the eye. The

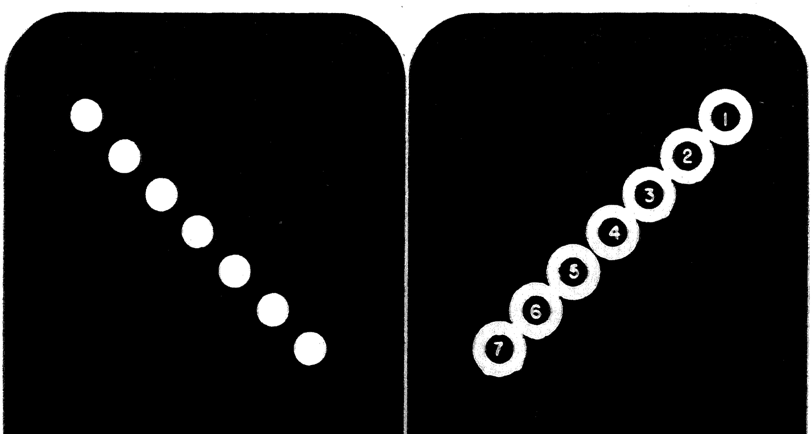

Fig. 3–13. Individual vergence. In the stereoscope, one numbered circle will have a dot over its center. This shows the individual tendency to convergence or divergence.

ability of the individual to adjust his vision for both near and distant objects is known as his "accommodation range." At the same time, when nearby objects are viewed, the axes of the eyeballs converge toward each other. It is obvious that both actions are definite, and that for any specific accommodation there must be an exactly corresponding convergence. There are many people who believe the two actions are inseparably combined by functional apparatus. This is not at all true. The two actions are wholly independent and only because long habit has caused them to synchronize, are they apparently inseparable.

The normal stereoscope, lenticular or Brewster, used with the correctly made normal stereogram, is so adjusted that the viewing lenses act as collimators. That is, the eye itself is in the condition for infinity viewing or zero accommodation. The lens is completely relaxed. At the same time convergence is also at zero for those objects lying beyond stereo infinity, but for all nearer objects convergence is normal. Thus in any stereoscope, convergence is divorced from accommodation.

Naturally it is not easy to overcome a lifelong habit, and those unaccustomed to the instrument will unconsciously accommodate as they converge. As a result they find it impossible to hold sharp focus, and as a compromise will almost always select a point midway between far-point and near-point focus. As a result they see nothing sharply outside the one plane of compromise focus. This is literally true. In viewing a stereogram which is needle sharp throughout, these people will see both distance and near foreground as out of focus if the compromise convergence focus point lies in the mid distance. This is because their eyes constantly change focus to keep up with the actual convergence changes induced by the variable separation of the stereo images. The condition does not, as a rule, last very long however. It is often overcome within 15 or 20 minutes, and rarely lasts through as much as two hours of actual viewing. Such a person finds the use of the stereoscope uncomfortable, and not until by continued use the two functions are separated, does he really enjoy stereoscopy.

In some instances, the coupling works the other way, and focus is maintained but convergence insists upon remaining with focus, and the two images cannot be fused. No matter what is done, the subject sees two distinct images. This, too, will readily yield to practice. Just as soon as the two functions are separated there is usually experienced a sense of increased visual comfort, not only in viewing the stereogram but in normal, direct vision as well.

The writer has never experienced either of these types of coupling, and for many years the failure of tyros to see the stereo image was a puzzle. There was always the possibility of the absence of stereopsis, but this was not really a satisfactory explanation. Only after some period of time spent in study did the facts reveal themselves. Unfortunately for our pet slogan, the stereo-

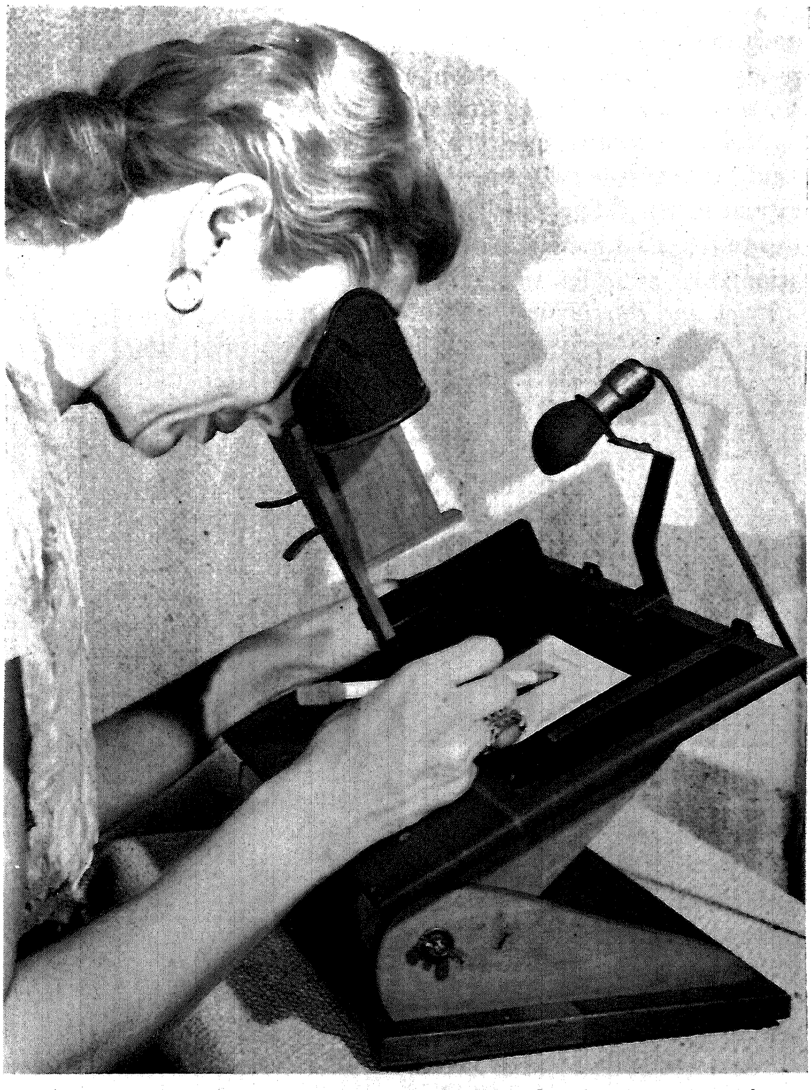

Fig. 3–14. Drawing stereoscope used to develop better stereopsis.

gram does not in this one respect duplicate direct vision; but this fact is fortunate as far as the stereographer is concerned inasmuch as it provides him with increased visual skill after a little practice.

It will be noticed that the foregoing remarks assume the existence of correctly made and correlated stereoscope and view. It is of interest to know that the therapeutic stereoscope is so accurately calibrated that the operator can introduce any desired accommodation and any desired convergence, both independently adjustable. Note however, that *parallax* is not adjustable. It is a characteristic of the stereogram. This makes it possible to measure the degree of both functions, to study the results of the habitual bond between the two, and to treat certain tendencies toward abnormal vision. "The Telebinocular Manual," Keystone View Co., Meadville, Pa., provides detailed instructions for this manipulation.

Trick and Puzzle Stereograms.—The stereoscope is also a source of enjoyment for a group. Those present need not have any knowledge of stereo. In fact, when they do not, the results are even more baffling. For example through the control of parallax (space control) see Chapter 16, a stereogram can be made of someone well known to those present, but the figure is obviously only six or eight inches tall and standing upon a table at which another familiar person is seated. The method has already been described.

The pseudoscopic stereogram may also be made a source of pleasure when well done. Suitable subjects are rarely found in

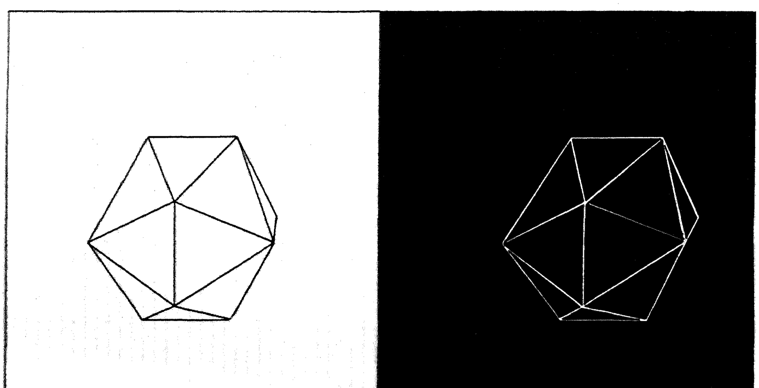

Fig. 3–15. Iridescent drawing.

landscapes, owing to the confused overlapping contours, but a rounded, solid object makes an attractive slide. (See Pictorial Stereography.)

Iridescent slides are ordinarily hand drawn, one of black lines upon white and the other of white lines upon black. The binocular mingling of the black and white produces a scintillating, iridescent effect.

Similarly, a pseudo-stereogram of some subject such as a fountain or a waterfall, one image made in dull light, the other in direct sunlight, will have no real stereo relief. However, due to retinal rivalry the sparkling image will conflict with the dull one and often the effect is that of moving water.

Retinal Rivalry.—It is impossible for two widely different images, transmitted by the two retinas independently, to be simultaneously perceived. This fact should not be confused with stereo

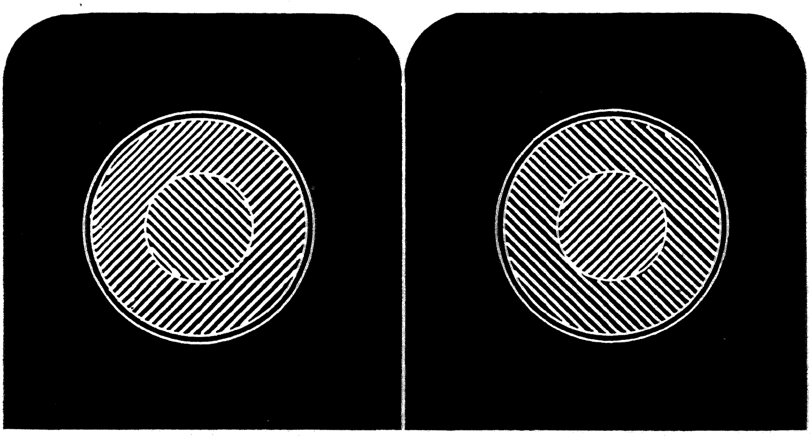

Fig. 3–16. Retinal rivalry. The eye does not see a true crosshatch, but alternating vision in small patches of first one set of lines, then the other.

diplopia, for there the dual images are seen by oblique vision. But when two different objects are the subject of direct macular vision, first one image will be seen, then the other. The successive phases may last for several seconds, or for only a fraction of a second. This is best illustrated by a dual slide in which there are oblique lines at right angles in the two units (Fig. 3-16). Instead of a perfect crosshatch pattern, the area will show small patches of left lines mingled with patches of right lines, and the patches will continually shift.

The old color anaglyph was based upon the assumption that a red perception in one eye and a simultaneous green perception in the other would produce white by the addition of color. As is well known this method of stereoscopy proved a failure because of the visually painful "bombardment." This effect is nothing more than retinal rivalry which transmits first the green, then the red. Many people however see only the color which results from the additive mixing of the two colors, i.e., red and green (of correct hues) produce white.

Stereo-Cryptograms.—The stereo-cryptogram is another source of amusement. In this, a series of letters are shown in solid block

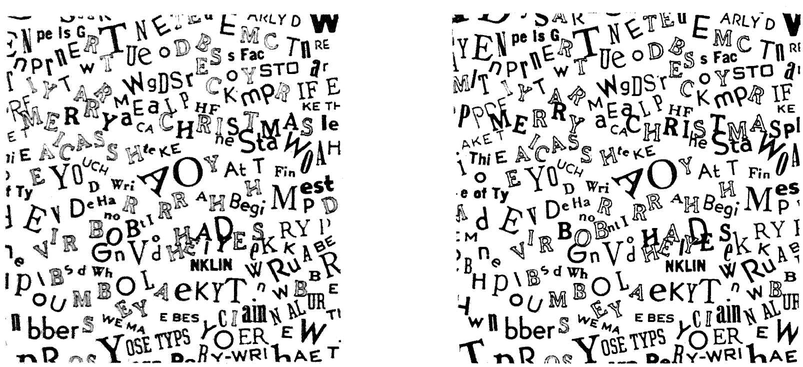

Fig. 3–17. Cryptogram Christmas card. The stereo cryptogram adapted to a Christmas card. Courtesy Robert Hayes.

form in each unit (Fig. 3-17). Examined in the stereoscope certain letters stand out before the mass or lie behind it, and so form a message. Another form consists of an innocent message, certain words or syllables of which are stereoscopically displaced to produce a hidden message.

Such cryptograms are made through parallax control. The significant letters or words are written with different homologous separation from the rest of the message. When the messages are typewritten, the first message, the left for example, is written straightforwardly. Then in the correct position, the second message is written with the significant letters or words omitted. When this draft is complete, the paper is shifted carefully in the carriage.

The slightest possible motion is enough. One fourth a millimeter displacement will produce well defined stereo relief. The use of the typewriter maintains both type alignment and degree of stereo relief, so there is no sign of the irregular relief seen in hand-lettered messages.

When such cryptograms are printed in type, the characters are separated by "thin spaces," and for the second impression the appropriate spaces are withdrawn, thus shifting the position of the

```
WHATEVER   WORDS          WHATEVER   WORDS
YOU  WRITE   YOU          YOU  WRITE   YOU
 MUST  STAND  BY           MUST  STAND  BY
 YOUR    STATE-            YOUR    STATE-
 MENTS  WITHOUT            MENTS  WITHOUT
 CEASING  THERE-           CEASING  THERE-
 IN   YOU   WILL           IN   YOU   WILL
 CONFRONT  YOUR            CONFRONT  YOUR
 OPPONENTS  WHO            OPPONENTS  WHO
 OFFER    THEIR            OFFER    THEIR
 OBJECTIONS  TO            OBJECTIONS  TO
 EACH  SENTENCE            EACH  SENTENCE
 YOU  COMMIT  TO           YOU  COMMIT  TO
      PAPER                     PAPER
```

Fig. 3–18. Regular spaced cryptogram.

character. If ordinary 24 pound paper is used for spacing, the difference in the two imprints will not be obvious to the unaided eye, but the stereoscope will reveal a decided relief.

These are but a few suggestions as to the ways in which the stereoscope may be used by the interested stereographer. But in any experimental work, one thing must be kept in mind; in fact it must be kept in mind at all times. The stereoscope and the stereogram must, independently and jointly, be in perfect adjustment. This means a rigid, accurate stereoscope, preferably of metal construction with lenses correctly aligned, and if it is of the lenticular type the interpupillary must be correctly adjusted. The stereogram must be exactly aligned along the base, the homologous separation must be that correct for the stereoscope used and preferably matched to the interpupillary of the spectator, although this is hardly practical when more than one person is to view it. The stereogram should be set at the infinity focus of the instrument, and the viewer should have lenses accurately matched in focal length to those of the camera. When such conditions are observed, even the experienced stereographer will find new pleasure in the complete realism of the subject revealed.

CHAPTER 4

CORRELATION OF CAMERA AND VIEWER

ORTHOSTEREO.—Orthostereoscopy (true stereoscopy) is that stereoscopy in which the objects when viewed appear in their full life size and at their full natural distance. Direct vision is automatically orthostereoscopic. It is also a result of a specific method of stereogram making and viewing combined; and cannot exist other than as a subjective phenomenon. There is no such thing as an "orthostereogram," simply because a stereogram which will provide ortho results with one viewer will not necessarily do so with another.

In speaking of "life size," the term is used literally, but it should be understood. Suppose you look at two men, each six feet tall, one twice as far away as the other. You know that by the rules of perspective, the actual retinal image of the nearer is twice as tall as that of the farther. You can prove this by holding a ruler at arm's length and measuring the image height of each man against it, but in actual experience both men appear to us to be equally tall, to have "life size," in other words. By experience we see the distance, and from that unconsciously compensate for the size discrepancy. Thus life-size means a size appearance which is identical to that which the original object would have presented had we been enabled to see it by direct vision.

To attain this objective it is essential that the camera and the viewer have identical bases (lens separation); that this base equal the interpupillary of the user; and that both camera and viewer be equipped with lenses of identical focal lengths. In actual practice the deviation from ortho is not obvious until the viewer lenses differ from the focal length of the camera lenses by some 30 percent. The use of the standard base of 65mm does not introduce any visible distortion even though the actual interpupillary is not 65mm. However, these are practical tolerances whose existences have no bearing upon the validity of the theory. Similarly, in practice the camera base is often greater than that of the viewer, but no visible distortion results.

It is obvious that to maintain orthostereo conditions renders any attempt at conventional telestereography impossible, for the gain resulting from using long-focus camera lenses is exactly neutralized by the loss resulting from the long-focus viewer lenses. Thus no matter what the focal length used, the results are identical, with the sole exception that the shorter the focal length the greater the area embraced within the field. Otherwise every object has that size-distance character possessed by the original as viewed from the camera position.

Inasmuch as both stereomicrography and telestereography are of importance, it is highly desirable that some such techniques may be used. Various methods have been suggested in the past, but only parastereoscopy fully meets the demand for telestereography. Parastereoscopy is substantially the same as orthostereoscopy with the exception of one condition whose importance is far greater as a matter of theory than as a matter of practical application. In fact, parastereograms have no distortion which is discernible to vision. Measurement alone will reveal the difference. Parastereoscopy is made by strictly observing the PePax relationship, which is done by altering the stereo base and focal length in exact ratio.

If the camera and viewer are normally equipped with three-inch lenses, then that is the normal for that particular pair of instruments. If it is desired to use six-inch lenses, then the base is doubled by moving the lenses to 130mm separation. The resulting stereogram will be viewed without perceptible distortion in the normal viewer.

The use of long bases is difficult with the ordinary camera, particularly when simultaneous exposures are desired. My first PePax reflector was made upon the sliding tube principle, and later I substituted one designed along the lines of the periscopic stereobinocular, with barrels rotating in an arc to provide the desired separation. This, however, was a purely experimental device and has not been commercially manufactured. These reflectors are in every way similar to the conventional stereo reflector with the single exception that the internal reflectors instead of being positioned immediately adjacent, are separated by the normal stereo base. This construction makes the reflector applicable to the normal stereo camera and provides any desired base up to the maximum, which may reasonably be ten times normal, or 65 centimeters.

Because so many inquiries have been received about this reflector it should be repeated that it is *not* available commercially. It can be made by altering a war surplus instrument, but it is subject to the very real disadvantage that the field is extremely narrow. It is more suitable for experimental purposes than for the production of satisfactory pictures.

Keeping in mind the fact that the orthostereogram reproduces the original in full life size and at full natural distance, we shall now consider those variations in manipulation which result in the stereoscopic distortion of either size or distance, or both. This will serve to indicate those errors of technique of which the stereographer should not be guilty, and even more to the point, it will indicate some violations of traditional stereo rules which may be made to great advantage.

In practice, orthostereoscopy is rare because the average viewer lenses exceed camera lenses in focal length by amounts varying between 25 and 50 percent. A 25 percent degree of discrepancy yields an image in which the distortion is not readily apparent, but a 50 percent difference will produce a distortion of spatial dimension, perceptible to the expert stereographer.

Fixed and Variable Factors.—Although there is an infinite variation in the interpupillary distance of human beings, these variations are within such close limits that we may establish an arbitrary standard such as 65mm and henceforth regard that as a fixed factor.

Once the exposure has been made, the parallax of that stereo image is fixed.

The perspective dimension of the image (dimensions in the picture plane) is subject to alteration in making the negative by changing the focal length of the lens. It is subject to further alteration in the process of projection printing by either enlargement or reduction, and it is subject to final variation by the focal length of the viewer lenses.

To sum up, we may say that, generally speaking, parallax is fixed while perspective dimensions are variable. Hence it shall be our goal to control the perspective so that it will always match the parallax correctly—or otherwise—as we desire. It is true that in parastereoscopy we do this indirectly by deliberately introducing an abnormal base in making the negative, but as this has already been discussed we shall confine ourselves largely at this time to the effects of abnormalities of perspective and parallax without giving undue regard to balancing such abnormalities.

One important phase of this discussion is that of pointing out the serious errors which arise, for example when a club or society holds an exhibition or sends out a postal portfolio composed of slides made to conform to a variety of standards. This inevitably means that many stereograms will be examined in stereoscopes wholly unsuited to the view. As a result, the stereograms are subjected to criticism which is manifestly unfair. These criticisms should have been leveled at the lack of stereo technique displayed by the critic who failed to observe one of the great fundamental laws of stereoscopy. 35mm viewers have different focal lengths but the differences are slight, hence the modern amateurs can exchange slides freely. This is far different from the time when the camera might have had 3-inch lenses and the stereogram be viewed with 8-inch ones.

Variations of Focal Length.—Figure 4-1 shows the visual rays

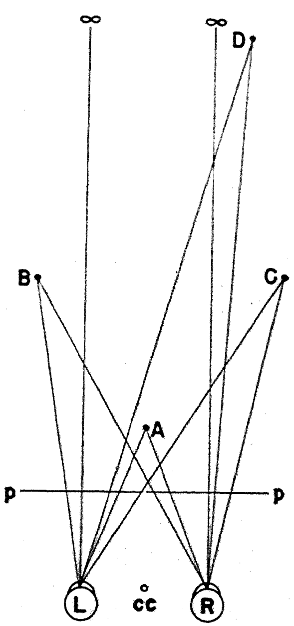

Fig. 4–1.

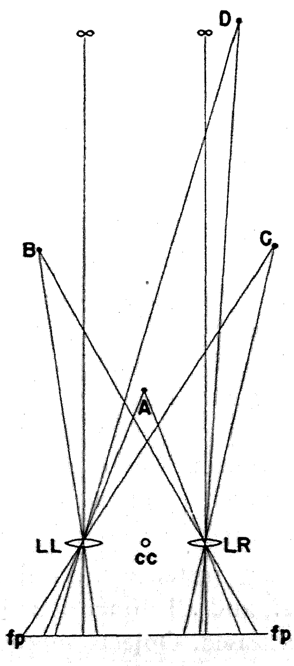

Fig. 4–2.

when the two eyes view the objects *A, B, C* and *D,* as well as an object at infinity. It is well to note that although we speak of an "object," we actually refer to some prominent point in the visible surface of that body. Thus the significant ray path is, in each instance, truly represented by a single straight line from the eye (or lens) to that point in the object. As we have already seen, orthostereoscopic results will not be achieved unless these significant ray paths are duplicated when viewing the positive stereogram.

Figure 4-2 shows the same field as it is photographed by two lenses *LL* and *LR*. In both figures *CC* marks the position of the Cyclopean Center, or the position of synthesized stereoscopic vision.

If the negatives *fp–fp* are rotated vertically and horizontally about the common center of the lenses, *fp–fp* will coincide with *p–p* of Fig. 4-1. The focal plane of the camera becomes the picture plane of the positive, with an inversion of image.

Figure 4-3 is the same as Fig. 4-2 except that the lenses have a focal length which is one-third less than normal (considering the conditions of Fig. 4-2 as normal). The direction of all ray paths remains the same but *fp–fp* is now necessarily nearer the lenses, making the images smaller throughout. If viewed with lenses of similarly short focal length, it is obvious that the relationship between Fig. 4-1 and Fig. 4-2 would also exist between Fig. 4-3 and any such condition. Therefore we pass directly to the viewing of this smaller image in the normal stereoscope, as illustrated in Fig. 4-4. The points of intersection remain fixed because they are a part of the physical silver image. When this pair of images is placed in the normal picture plane the results are as shown. The points at which the rays terminate indicate the images as actually seen; the points with no connecting rays show the true positions of the objects where they should be seen orthostereoscopically. The difference indicates the degree and kind of distortion (object *D* is omitted on account of space limitations).

In each instance the object is seen at a greater distance than normal, and all dimensions in the line of the visual axis (depth) are increased. Objects appear elongated in depth and far distant.

To make these distortions clearer, we shall supplement the

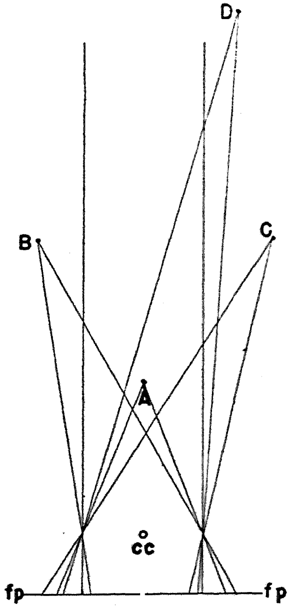

Fig. 4–3. Camera focus less than normal.

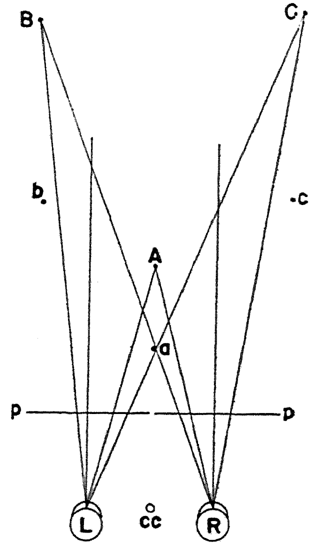

Fig. 4–4. Viewing stereogram made with camera focus less than normal.

basic diagrams with others showing the actual structure of the image.

Fig. 4-5 is a key diagram to the series. The triangular object *A″B″C″* is seen by two eyes or, photographed by two lenses, at *EE′*. *Pn* is the normal picture plane for the normal image *A″B″C″*. *Pd* is the picture plane for the distorted image *D″F″G″*.

Rays *A, B* and *C* connect the eyepoint *E* with the three significant points *A″, B″* and *C″* of the original object and also of the orthostereoscopic image *A″B″C″*. The small circles indicate the intersection of these rays with the plane *Pn*. Points *D, F* and *G* are disposed in the same plane symmetrically to *A–B–C*.

If we assume the stereoscope to have lenses which are half the focal length of those in the camera, we place the plane *Pd* halfway between the plane *Pn* and the eye plane as shown. Then from *A, B, C, D, F* and *G* perpendiculars are drawn from the original *Pn* plane to the *Pd* plane, thus locating *A′, B′, C′, D′, F′* and *G′* in the latter. Because *D, F* and *G* exactly correspond to *A,*

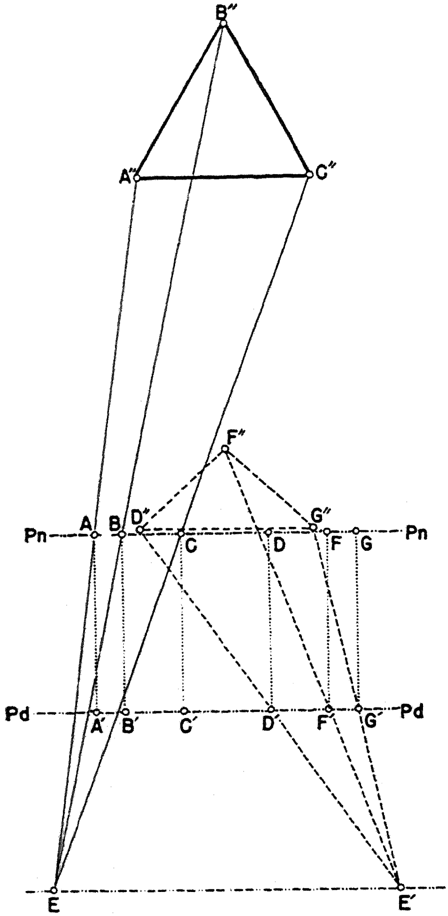

Fig. 4–5.

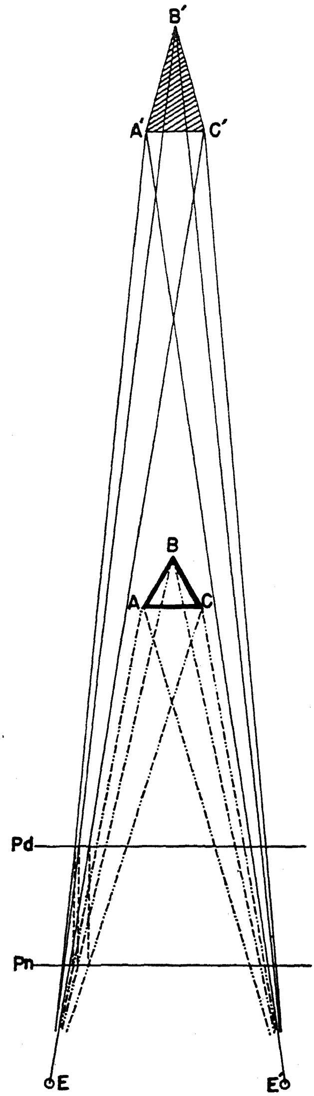

Fig. 4–6.

B and *C,* we may use the right side of the diagram for the new condition to prevent too great confusion in the drawing.

The points *D, F* and *G* are fixed in the image, so when the image (print) is moved nearer the lenses as it must be when these have shorter focal length, we find that the outer rays *D* and *G* intercept the original *Pn* plane at D'' and G'' instead of at D and G. As $D''G''$ must equal $A''C''$ and occupy a corresponding lateral position, we find side $D''G''$ located just halfway between the eyes and side $A''C''$. Thus we locate the viewed image $D''F''G''$ which is seen to be nearer the observer than normal. Because the lateral width is truly the same as the original but the distance only half, the *apparent* size of the object is increased. As might be expected with the general condensation of depth, the altitude of the triangle is lessened and the degree of loss is one-half. Thus the degree of distortion keeps step with the original differences throughout.

In the following diagrams of the triangle series, the various measuring points are not numbered, only the triangle and the planes being indicated. The measuring lines are shown but not indexed.

Figure 4-6 shows in the graphic triangle form the error which was illustrated by Figs. 4-3 and 4-4. As it is just the reverse of the

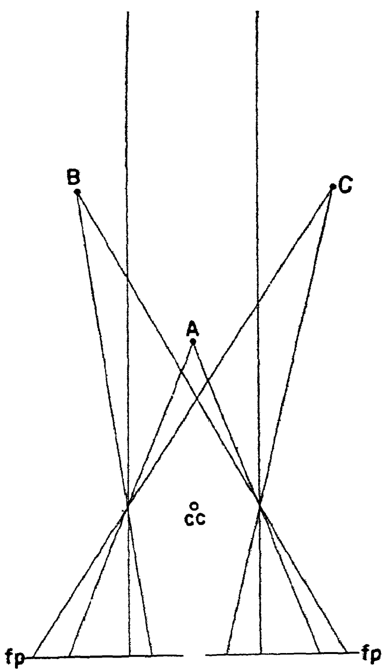

Fig. 4–7. Camera focus greater than normal.

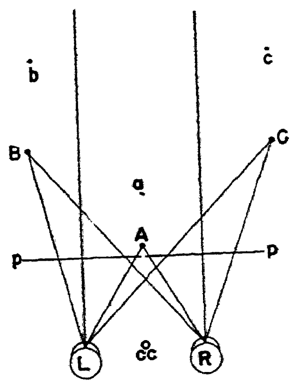

Fig. 4–8. Viewing stereogram made with camera focus greater than normal.

key plate, it may be easily followed. Here we see the elongation in depth and the increased apparent distance caused by having the camera lens of shorter focal length than the viewer lenses or having viewer lenses of longer focal length than the camera lenses. It is all the same, but at times we overlook this obvious interchange of terms.

When the focal length of the camera lens is greater than that of the stereoscope lenses, the reverse is true. Having gone through both types of diagrams in detail, we do not believe it essential to

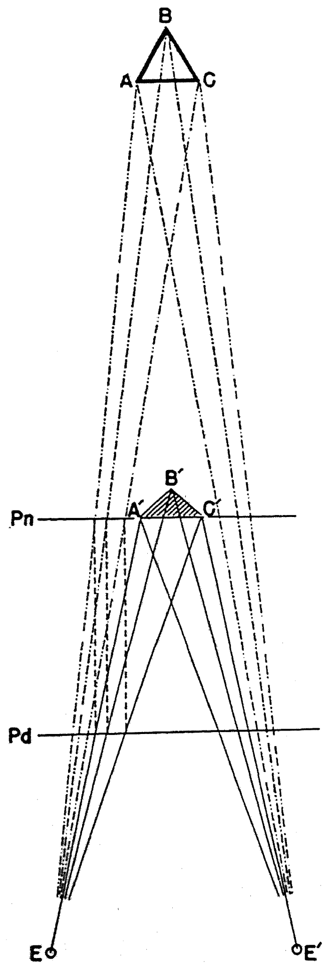

Fig. 4–9.

repeat the details in each instance. Figures 4-7 and 4-8 show the significant ray paths for this condition, while the graphic diagram is shown in Fig. 4-9. Incidentally, Fig. 4-9 is the complete drawing for the condition used in the key plate, Fig. 4-5. Longitudinal distances appear to be lessened and solid objects are thinner in depth, tending toward the "silhouette" form.

Variations in Base.—When variations in base are considered, the matter becomes more puzzling because we have complications arising from subjective interpretation to confuse the stereoscopic reproduction.

Naturally, unless we use some kind of special reflector eyepiece, the viewer interocular must conform more or less closely to the anatomical interocular, so these variations of base will be assumed to apply to the camera, being either greater or less than the normal.

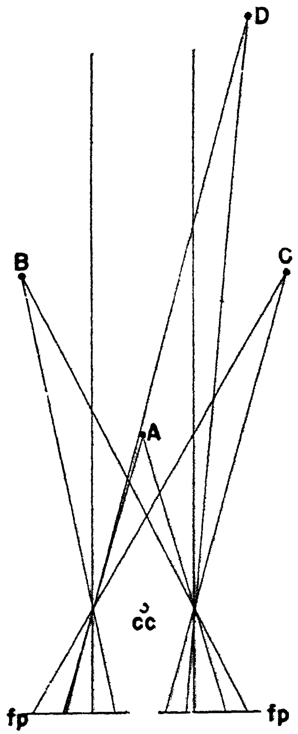

Fig. 4–10. Camera base less than normal.

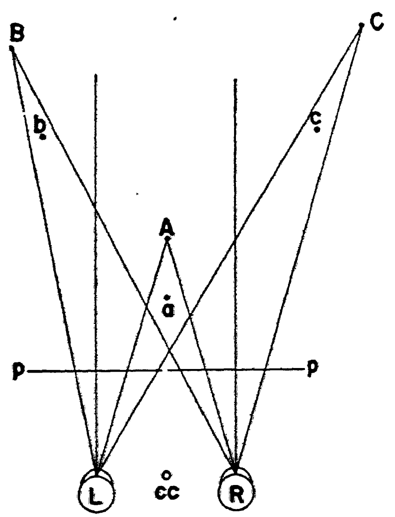

Fig. 4–11. Viewing stereogram made with camera base less than normal.

Figure 4-10 illustrates the significant rays for the condition wherein the camera base is less than normal. The broken line in *fp–fp* indicates that portion where the two bases of the camera overlap. In Fig. 4-11 note that the original position of the object lies along the line which bisects the two visual axes. In short, the direction of the image is identical with that of the original object, but it seems to have been moved farther away. The net result is that of a larger object removed into the distance. As *D* is beyond the limit of the diagram it is not shown.

The greater the stereo base, the greater will be the parallax. Also, the nearer any object is to the eye, the greater is its parallax, and conversely. In Fig. 4-11 the decreased parallax has given the appearance of an object farther away, while the undiminished perspective gives to that apparent distance an apparently greater object size.

Figure 4-12 shows a base which has been increased by 50 per-

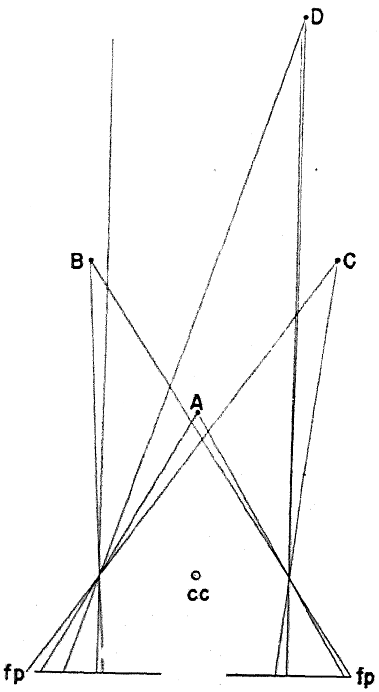

Fig. 4–12. Camera base greater than normal.

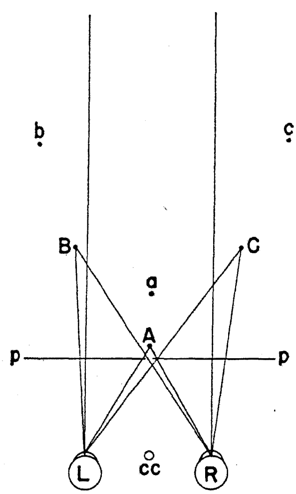

Fig. 4–13. Viewing stereogram made with camera base greater than normal.

cent over normal. Figure 4-13 shows the result of viewing such a stereogram. The object displays greater parallax and it appears to be nearer the spectator than the original, but having the original perspective it appears to be smaller than normal.

Figure 4-14 adapted from Lüscher, illustrates graphically both these base conditions. Assuming the use of the greater than normal base, *L–L′* represent the two lenses, while *E–E′* are the two eyes. Note that for simplicity *L′* and *E′* are given the same position. It would be equally correct to place *E* and *E′* equidistant from *L* and *L′*, but would involve a far more complex construction in the diagram.

In taking, the lenses form the image of triangle *ABC* from the

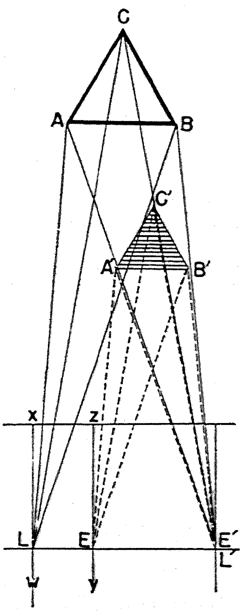

Fig. 4–14.

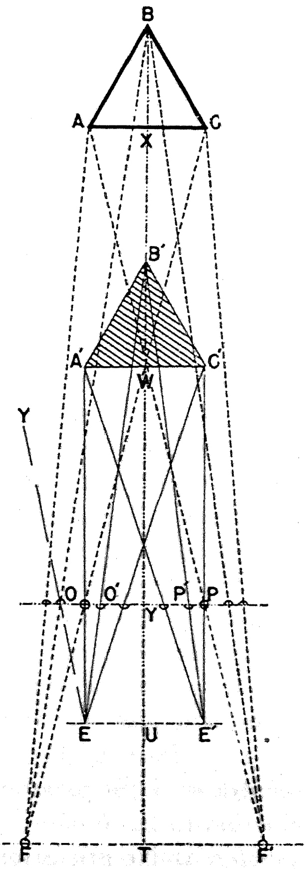

Fig. 4–15.

two points *L–L′*. The line *wx* passes through *L* and intersects the picture plane *xz*. Draw *yz* parallel to *wx*, through *E* to the picture plane. The intersection of the rays *LA, LC,* and *LB* with *xz* are repeated upon *xz* starting at point *z*. The significant ray paths are then drawn from *E* through these repeated intersections, to form the triangle *A′B′C′*.

It will be seen that this corresponds to the former description of an object without perspective or parallax distortion, but which appears to be nearer and smaller than the real object.

It is obvious that if *E* and *E′* are assumed to be the lens positions, and *L–L′* the eye positions, the same diagram will illustrate the use of a less than normal base.

It should be said that the expression "appears to be smaller" should be regarded as highly theoretical inasmuch as we have no absolute size perception, size being always estimated by a system of comparison. Therefore, as a matter of fact the abnormal size factor is rarely observed unless the subject is so familiar that we know its approximate size, or unless there is some external object (as in trick stereograms) by which comparison may be made. On the contrary, the differential distance perception by parallax is surprisingly accurate.

Finally we have in Fig. 4-15 the explanation of the PePax principle of maintained perspective-parallactic ratio. The lenses *F–F′* have twice normal focal length and are used at twice normal separation. The viewer lenses *E–E′* are normal. By the same reasoning used heretofore it will be seen that the original triangle *ABC* will be seen in the apparent position *A′, B′, C′*. Here the object appears to be at only half the distance, it appears to be undistorted, and it appears to have natural size. This is the parastereoscopic image, and differs from the orthostereoscopic only in the fact that a given space contains a greater amount of solids than is physically possible, but because of the sequence system of human vision which prevents us from looking at the whole of a scene simultaneously, we are unable to grasp the physical impossibility in the form of any perceptible visible distortion. Therefore the distortion of parastereoscopy is only that of *knowing* the reproduction to be unnatural, not one of *seeing* that it is.

Hyperstereo.—No discussion of variable base would be complete without the mention of hyperstereo. This is the making of stereograms with a greater than normal base. It is a practice which has been almost universally condemned, simply because it is a violation of the principles of orthostereoscopy. However, as the image is not proportionately distorted, the subject has a natural appearance, thus making the technique one of the most potent available to the stereographer.

Because of the arguments involved and the importance of the subject, it will be fully discussed in a later chapter, instead of trying to deal with the subject in the limited space available in the present chapter.

Convergent Axes.—The argument is often offered that the best stereogram results when two cameras are used, converging in the manner of the human eyes. This argument, although quite valid in special fields such as photomicrography of objects in a single plane, is a result of faulty reasoning. The stereoscopic camera is not a substitute for our eyes. It is a tool, an instrument which produces an imitation of the original scene toward which our eyes function just as they would with the real scene. Our eyes still converge normally when the stereogram is made in a parallel axes camera.

The objection to the convergent axes system is that a very definite spatial distortion is produced, and the greater the degree of convergence the greater the distortion. When the camera axes are parallel, the homologous distances of all images are directly related to their real distances, but when convergent axes are used this essential relationship is lost, and apparent distances vary widely from the original ones. Any degree of convergence introduces distortions of distance, and hence is not satisfactory unless the subject matter is confined substantially to one plane.

The convergent stereogram (and the divergent as well) can be made and can be viewed up to a limit, but they are never truly realistic.

Figure 4-16 shows two cameras converged upon object *A*. When viewed, as shown in Fig. 4-17, we find *A* is satisfactory, but *B* and *C* are apparently farther away than their true positions, *b* and *c*.

It should be noted that the farther the object from the center of convergence, the greater the distortion. Thus convergent axes result in a variable degree of spatial distortion.

Only parallel axes will produce uniformly satisfactory stereo-

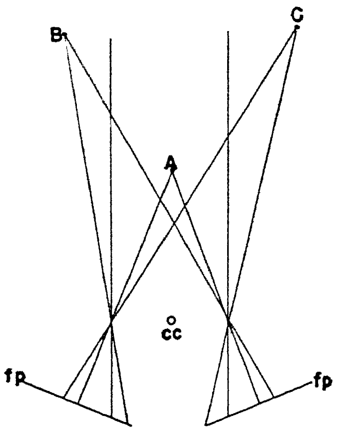

Fig. 4–16. Cameras with convergent axes.

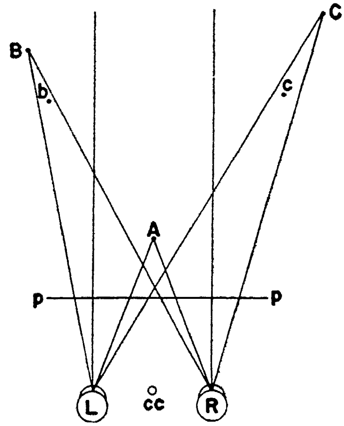

Fig. 4–17. Viewing stereogram made with cameras with convergent axes.

grams under all conditions and of all types of subject.

STEREO RE-CREATION.—It is now possible to understand why the stereogram viewed orthostereoscopically does actually so re-create the original scene that all of the major visual phenomena experienced in viewing the original are also experienced in viewing the stereogram.

Referring again to Fig. 4-1, as the eyes converge upon *A* both eyes are equally converged to a marked degree. Shifting vision to *B,* the convergence is less, and both axes incline to the left. Passing to *C* the convergence is still less, and the dual inclination is to the right. In looking at *D* while the inclination is still to the right, both the inclination and convergence are less than for *C.* Viewing a distant object, the axes are parallel, that is, there is zero convergence and zero inclination.

If the stereogram is mounted so that the centers of the unit images are not spaced to the correct degree of separation, then when looking at some object in the far distance the eyes will either converge and assume the position of looking at a relatively nearby object, or they will diverge, a condition wholly foreign to normal eyesight and usually painful, if not impossible.

Thus the stereographer has the responsibility of seeing that his stereograms are mounted with the correct separation, as determined for the stereoscope he uses.

CHAPTER 5

MOUNTING, TRANSPOSITION AND SPACING

SO FAR WE HAVE CONSIDERED only the essential factors involved in making the stereogram, but there are some factors involving the relationships of the two images which must be considered.

TRANSPOSITION.—One of the most important things the stereo beginner must learn is correct transposition. To do this it is necessary to know why the operation is required, what the operation actually consists of, and what happens if it is ignored.

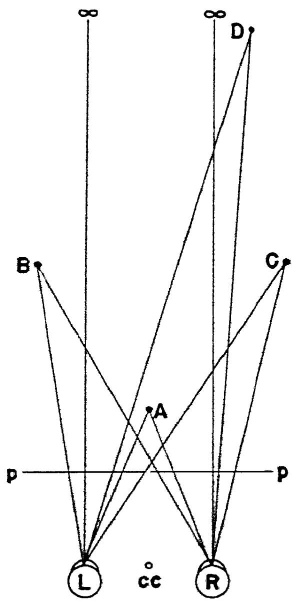

Fig. 5–1.

Figure 5-1 is a plan view of a stereo field as seen by the two eyes *L* and *R*. The field contains the objects *A, B, C* and *D* as well as an object at an infinite distance. In front of the eyes lies the picture plane *p–p*. The intercept of the ray path in this plane from any point in the field determines the *perspective* of the field, and, when viewing the stereogram, the stereo images actually occupy this field whence they are visually projected to their correct position in space. If this plane is physically fixed by placing in it a sheet of glass, for example, and the apparent positions of the objects marked upon it, the result will be similar to that shown in Fig. 5-2. *CC* is the Cyclopean center or the synthetic, stereoscopic point of view.

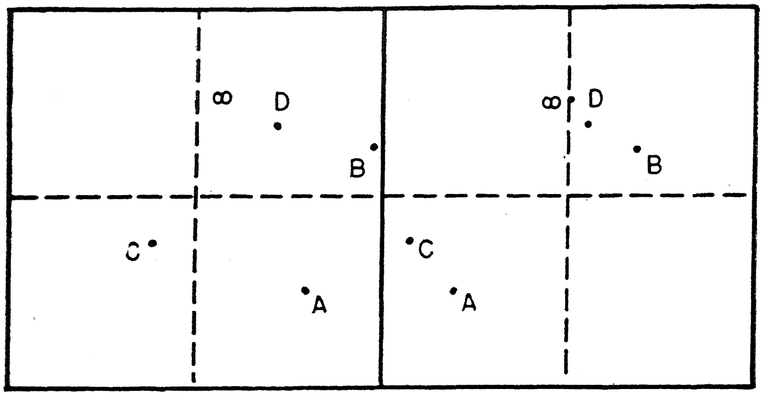

Fig. 5–2.

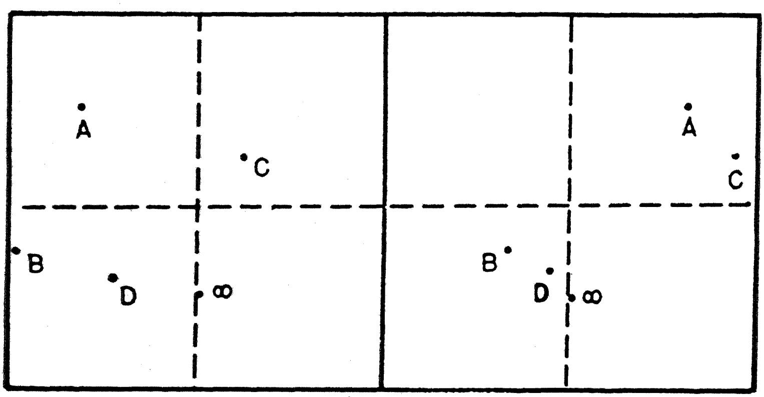

Fig. 5–3.

However, if we examine the ground glass of a stereo camera, or if we make a stereo negative, we find that it has the appearance shown in Fig. 5-3. There seems to be some similarity between Figs. 5-2 and 5-3, but they are noticeably different.

Reference to Fig. 5-4 shows the reason for the similarity and the difference. The field of Fig. 5-4 is the same as that of Fig. 5-1 with objects *A, B, C* and *D* included in the same positions. However, instead of two eyes, we have two camera lenses *LL* and *LR*. The rays from the objects pass through these lenses and form a duplicate of the picture plane *behind* the lenses at *fp–fp*. It will be noticed however that, due to the crossing of the rays in the camera lens, these images are reversed in relation to the images in the picture plane. Right and left and top and bottom are reversed. This is familiar in ordinary camera work, and the two cameras

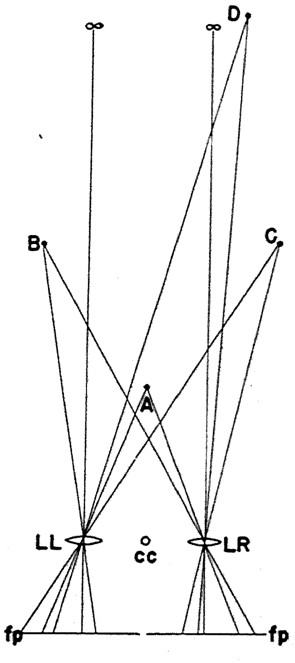

Fig. 5–4.

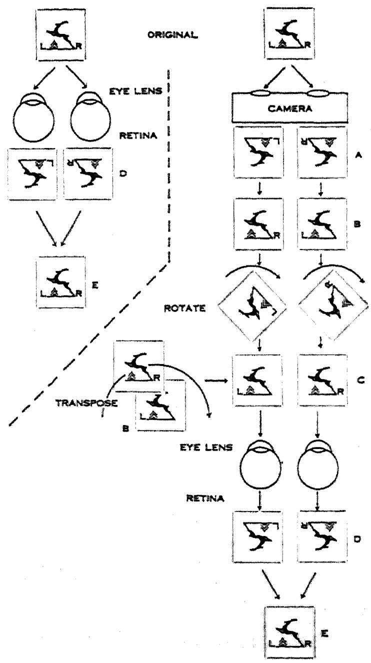

Fig. 5–5.

which make up the stereo instrument act individually just like any ordinary camera.

In Fig. 5-5 we have the deer as an object. In the original we have arbitrarily designated the left and right aspects with the letters *"L"* and *"R."* The original is duplicated at the top of the figure. At the left we see the visual sequence. The two eyes see the two stereo aspects *L* and *R*, and each of these is independently inverted upon the retina. The neuro-psychological mechanism of stereo vision then synthesizes these aspects to form the final reproduction of the original.

At the right the camera makes two negatives (even color film is developed as a negative before being converted into a positive) as shown at *A*. From this a print is made and turned right side up (*B*). However when this is done the left image is at the right and the right image is at the left. Therefore, for the time being we move step *B* to the left of the main column as shown. Restoring the print to the upside down position of *A*, we cut the two pictures apart and rotate each one upon its own axis, through 180° and then we have the correct relationship as shown at *C*. As a matter of fact, we do not do this. Instead we return to *B* at the left of the column, cut the two pictures apart and simply lift the right image over the left until it lies at the right as shown at *C*. Thus the rotation and the position interchange both accomplish the end result. Rotation is what is done theoretically, the position change or transposition is what is usually done in practice.

The two images in correct relationship *C* are now viewed by the two eyes, which instead of being fixed upon a single, common original, have an original image for each eye. Thence the process duplicates the steps *D* and *E* as first described for direct vision.

Referring again to Figs. 5-2 and 5-3, note that the infinity image is above center in the visual picture plane, but below center in the negative. Images *A* and *C* in the right picture plane occupy the lower left quadrant, while *B* and *D* are in the upper right. In the negative these positions are just reversed. Thus we find that the right negative is simply the right picture plane reversed top and bottom, right and left. The same is true of the left negative and left picture plane.

Thus although the relative positions of all objects within the field are inverted, the field at the left is the true left field and that at the right is the true right field.

This brings us to a basic factor in stereoscopy. If the photograph is identical with the image of the picture plane, the photographic images of each object will occupy the position in the photograph which the visual image occupied in the picture plane.

The two eyes do not converge upon a single image to look *at* it. On the contrary, the stereogram provides a separate image for each eye, and we look *through* the image, in a sense. The two images of any given object are so spaced in the stereogram that the visual paths from each eye to its respective image, will, if continued, cross at a distance equal to the true distance of the original object.

Thus the stereogram is not a physical object to be visually examined. Rather it is simply a guide or stencil which when visually projected causes the two separate images to fuse at some point out in space equal to the original distance of the object. This visual projection, as can be seen from the diagram, is a very real thing and not at all fanciful theory.

As we have seen, direct stereoscopic vision is possible only by virtue of a psychological visual projection, so this geometric visual projection is quite simple, yet it is the keystone of all stereoscopy.

Thus it will be seen that the photographic image must be inverted to cause it to correspond to the original picture plane image. However, in actual practice it is not usual to revolve the images after they are cut apart.

METHODS OF TRANSPOSITION.—*Glass-based images.* When glass plates are used in the camera, and when the positives are printed upon glass, the transposing printing frame is used. This is a frame which is longer than the negative, sometimes half as long again, sometimes twice as long. The frame which is as long as three single images is the most common. The negative is placed at the left side and the positive at the right. The two overlap in the center where the printing opening of the frame is located. The exposure is made. The frame is opened and the negative is pushed to the right while the positive is pushed to the left, and again the exposure is made. Thus the left negative image is printed at the right of the positive and vice versa.

It can be seen that this principle presupposes the use of rigid materials which will conform to the limits of the frame used, but glass is not the only material that can be used. If the positives are made upon stiff sheet film, the transposing frame may be used, and even when both negative and positive are of roll film it may still be used if care is observed.

Film negatives. It is customary when the negatives are made upon film, to cut the two images apart, reverse the positions and re-attach the two images with a strip of adhesive tape. Quarter-inch cellulose tape is excellent for the purpose, although if the negatives are not kept in individual envelopes, they will stick together in time.

Many stereographers use a diamond point and cut glass negatives in a similar way. Obviously when this is done the printing requires only a single exposure as when printing an ordinary negative. This is a distinct advantage when printing upon paper, as paper has not sufficient rigidity to make its use in the transposing frame practical.

Print transposition. Some stereographers make their dual prints from the untransposed negatives at a single exposure, then cut the prints apart and mount them singly after transposing. This is the most difficult method as it means that every print must be individually transposed and that print alignment must be preserved during the process of mounting. Both rubber cement and thermoplastic mountants are difficult, because the prints are inclined to

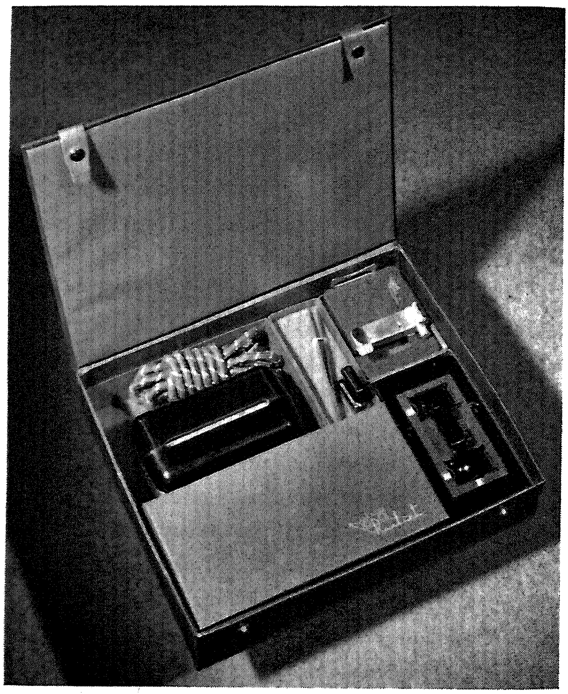

Fig. 5–6. Stereo Realist mounting kit. The case includes at upper left, the heater; center, film forceps and sealing iron; right, film cutter. Lower left, the sorting box for films and lower right, the mounting jig.

shift slightly during the mounting, and an error of half a millimeter is sufficient to produce a poor print.

35mm Stereograms. Modern stereograms made on 35mm film are the most easily mounted of all. The pictures are simply cut apart, the film edge providing a positive horizontal alignment base, or in the case of the Personal, a dual punch makes it possible to punch out both frames at once thus providing positive separation and alignment.

Realist films may be jig mounted. A mounting guide or jig is provided for use with heat-adhesive masks. The mask is placed in the jig, the cut films are placed in corresponding wells which align the film, and the films are sealed into the adhesive mask with a heated sealing iron. The mask is then mounted between glass slips and sealed with tape. A special cutter is provided to insure cutting the film perpendicular to the edges.

An alternative is a cardboard mount which is almost as rigid as the glass slide. It has accurately diecut pre-formed pockets into which the film is slipped. As the pockets are already spaced, it is only necessary to keep the left and right films in correct order, slip each into its own pocket and the slide is ready for use. This method of mounting is proving popular for both hand viewing and projection.

Another type of mount is the Permamount. This is a plastic base into which three channels are molded in the form of a very squat "H." A glass slip is dropped into the cross channel, then the films are laid in the two end channels and another glass on top. The whole is sealed and label provided by a die-cut, self adhesive panel which seals the assembly into a permanent unit.

These are provided with three separations which compensate for projection base and permit all types of subject from close-up to distance to be projected in any sequence without adjusting the projector control.

The Personal films are mounted in a similar way. Blank "reels" familiar to those who have used the Viewmaster are provided. These have accurately formed pockets into which the film is slipped from the edge inward. Because of the blank tab at the end of the film this may be done without touching the film. The accuracy of alignment is extremely satisfactory, and the system so easy that a child can learn to do it in a few minutes. These reels are stamped with the consecutive number of the films as well as the semi-circular and square notch symbols so that there is no danger of confusing the right and left images. They are marked in the camera and cannot be confused.

Because so many 35mm stereograms are destined for projection, and because projection slides should be more precisely aligned than others, what are the limits?

This all depends upon the individual spectator, so all that can be said is to give a low average for the limits which apply to the alignments discussed below.

The two images should not have more than one-half prism diopter vertical deviation, that is a deviation which a one-half diopter prism would compensate. This is equal to one unit departure from identical positions for each 200 units of screen distance. So, if the screen is located four meters *from the spectator,* the greatest advisable vertical difference would be two centimeters, or not quite one inch. Most stereographers prefer half that as a working limit. And remember the angular displacement of the visual axis; the amount of movement demanded of the eyes depends upon the distance from screen to *spectator,* not screen to projector.

Laterally the deviation should be less than three prism diopters or about 12cm, say five inches, for the most comfortable viewing, but usually the spectators can tolerate four and sometimes five prism diopters provided the relative positions are such that this means *convergence,* never divergence. Most people find a half prism diopter divergence uncomfortable, while one prism diopter divergence is impossible for many people. Exact limits of all vergences depend, as has been repeated so often, upon the individual. (Distances given assume 400 cm screen distance.)

Figure 5-7 shows the most frequent mounting errors in exaggerated and diagrammatic style. *A* is the normal mount with the two images correctly aligned.

B shows the result of having the camera tipped endways. Such a pair must be mounted as shown by the dotted lines in the right figure so as to preserve the original horizontal alignment, but if it is more than a degree or so off vertical, no correction should be attempted because painful eye "twisting" will result.

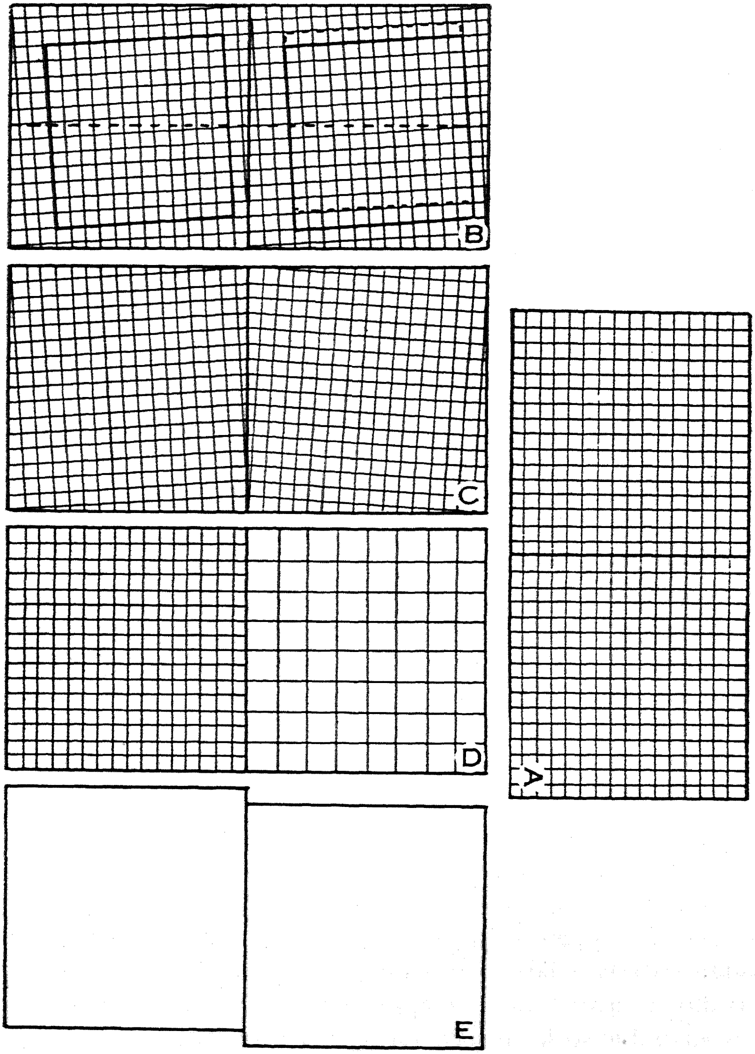

Fig. 5–7. Mounting errors.

C shows the result of cutting the films obliquely along the sides. Only one image may thus be trimmed and the direction may be either right or left, but in any event misalignment results.

D is found when one lens has a greater focal length than the other resulting in one image larger than the other. This may not be anticipated when using stereo cameras of reputable make.

E is the result of perpendicular alignment but with one image lower than the other causing a misalignment of horizontal homologues.

ALIGNMENT.—*Lateral spacing.* The lateral spacing is not critical as far as relief alone is concerned, but if the stereogram is to exhibit the same amount of relief as was seen in the original scene, it is necessary that the prints be carefully spaced. This is done by measuring the distance between the images of the same object at infinity, such as the tip of a tree or a distant steeple. This distance should be equal to the distance between the centers of the lenses of the stereoscope. However, the error resulting from a slight change in this measurement is not obvious and in many cases does not injure the stereogram in any way.

Often 35mm stereograms intended for projection have their separations varied deliberately so that the separation control of the projector need not be used during an exhibition. As will be explained this prevents serious physical discomfort for many of the spectators.

The separation of the unit images is then, not at all a critical factor, its importance being largely theoretical.

Convergence range. Lateral spacing affects the two images as units, but in each stereogram, if there is relief, there is also a variable convergence. If infinity and distant objects are alone in the picture, the convergence from one to the other is slight. If all objects in the stereogram are closely grouped, the change in convergence is small, even if the group lies near the camera, but if the stereogram includes both very near objects and distant ones, then the convergence range or change in looking from near to distant objects is large. This range is fixed at the time of taking and the "remedy" must be applied before the exposure is made. It is advisable to keep such range less than three prism diopters when practicable.

Vertical alignment. While the eyes have a wide latitude in fusing images of various degrees of lateral spacing, a small difference in vertical position causes an appreciable eye strain, and if the discrepancy is more than 1mm, many people cannot fuse the images at all. In good stereo this alignment should be kept within an error of .25mm or less, and in the 35mm stereogram, the limit is about 1/6mm $(0.175\text{mm} = \frac{1}{2}\Delta)$

Rotary alignment. The worst fault of all is to have the true perpendiculars leaning at one side or the other, If the true perpendiculars in the two images are parallel and both slightly inclined, the only immediate effect is a sense of visual discomfort. If the true perpendiculars to the camera base line of the two images incline in different directions the effect is at once noticeable. If the inclination is slight, a definitely painful sensation is experienced when viewing, but if the difference is great the eyes see two different images (diplopia). The term "perpendicular" always refers to those lines perpendicular to the camera base, common to both images. If the negative was made with a laterally tipped camera, the images must be mounted with this degree of tilt. Thus in stereo mounting, camera side tilt should never be rectified by trimming as is the case wth the planar print.

The negatives, whether made in a stereo camera or in a single camera with sliding base or stereo reflector, have a common base line. This is a good guide for correct alignment. If the print bases are also kept uniform, there is little danger of rotary misalignment. However, if the two images have been made by a single-lens camera held freehand, then it is necessary to determine the perpendiculars by visual proof. The two prints are placed in the stereoscope and turned about their centers until the comfortable matching position is found. This is marked and the prints trimmed to that perpendicular. This operation requires some experience, and for that reason freehand exposures are best left until some facility in stereo technique has been acquired.

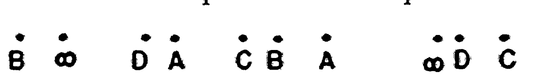

Fig. 5–8a.

Fig. 5–8b.

When the distance between infinity images is correct, and both horizontals and verticals are in correct alignment, there remain only those factors of mounting which are more or less a matter of taste.

Window Trimming.—Figure 5-8*a* and *b* show the relative horizontal distances separating the two images of the various objects of Fig. 5-4 (homologous distances). Figure 5-8*b* shows the disposition of these homologous points in the untransposed stereogram, while Fig. 5-8*a* shows the homologous distances of the transposed image. Notice that the distance between points *A–A* is the least of all and that as the original distances of the objects increase, the separation also increases.

In the finished stereogram the distance between homologous points is directly related to the distances of the original objects

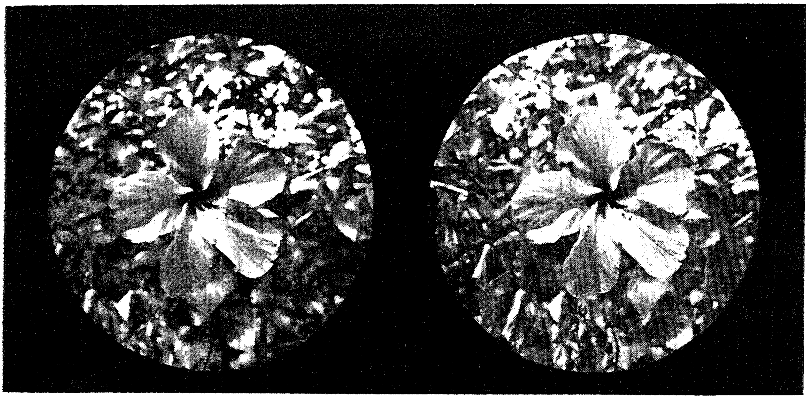

Fig. 5–9. The Window (A). This is the conventional window, placed nearer the eyes than the flower. The flower spacing is constant in all examples, so the spacing of the mask shows the variation which places the window at different distances.

Fig. 5–10. The Window (B). Here the window is in the plane of the tip of the stamen of the flower.

from the camera. The less the homologous separation, the nearer the object.

If a mask be prepared with two openings whose corresponding sides (that is, the two left sides, or the two right sides) are separated by a distance of, let us say, 1mm less than the homologous distance of the nearest object in the foreground, and if this mask is laid over the stereogram, the stereoscopic appearance of the mask will be that of an opening or "window" nearer the observer than the nearest object. In short, the appearance will be that of looking out through a window at the scene.

Obviously if the prints are trimmed exactly to match this mask and are mounted upon a black or dark card, the general effect will be the same. The mount will form a window nearer the eyes than the scene itself. This is known as "window trimming." Many stereographers consider it essential. However, the mere fact that

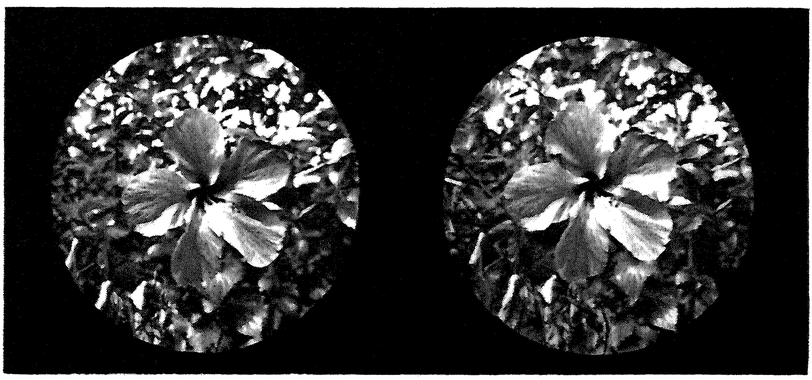

Fig. 5–11. The Window (C). The window is in the plane of the petals of the flower.

striking effects are often obtained by deliberately throwing the window back into the mid-distance is sufficient proof that conventional window trimming is nothing more nor less than a personal preference of the individual. (Figs. 5-9, 5-10, 5-11, 5-12, 5-13, 5-14, and 5-15.) (Note that the separations of the flower images are the same in all seven slides.)

To produce the window effect it is necessary that the images be so trimmed that they appear to be farther away than the frame produced by the edges of the prints. The "frame" must conform to stereoscopic principles, both must be the same size, the horizontal edges must exactly coincide, and the corresponding edges must be regarded as homologous points in the stereogram. It will be found that when the trimming has been completed, the left unit picture contains more of the right side of the subject than does the right unit picture.

It must also be remembered that good stereoscopes are so made made that the field is fully masked, so the effect of trimming for the window effect is lost anyway. The same thing applies to the dictum that only black card mounts shall be used. In a good

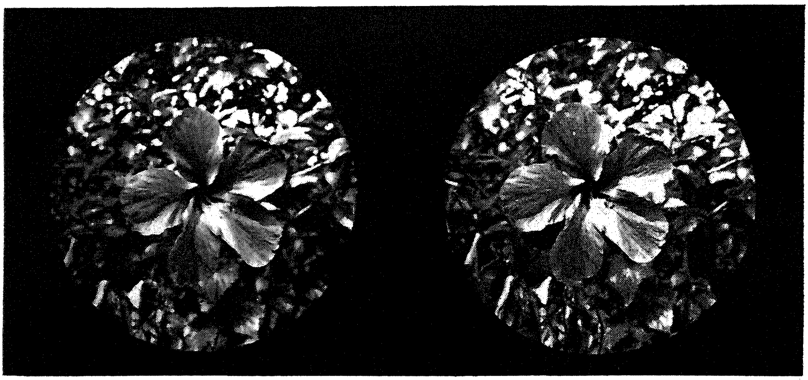

Fig. 5–12. The Window (D). The window is just back of the flower, but in front of the background. This is perhaps the most effective position for this particular subject.

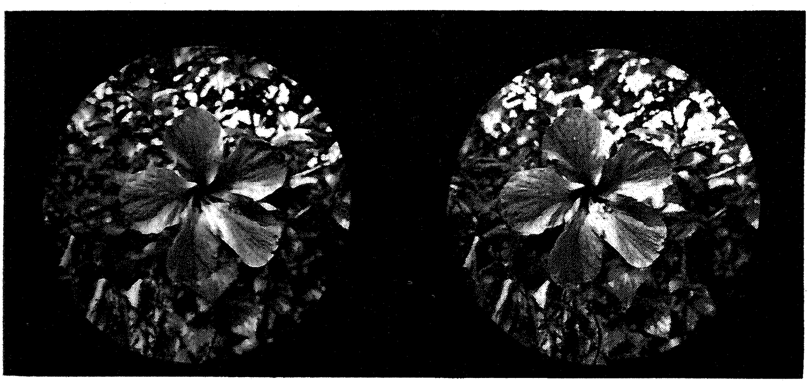

Fig. 5–13. The Window (E). The window is in the foreplane of the background. This is also very effective and might be preferred to D by some technicians.

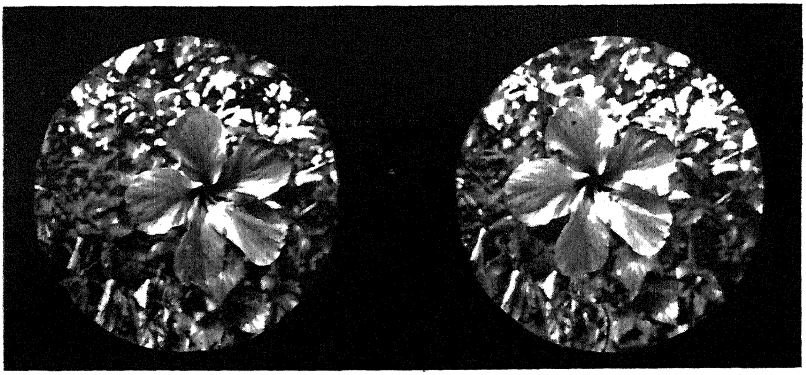

Fig. 5–14. The Window (F). The window is in the most distant plane of background, but it obscures details in the near background, thus causing confusion. This is the least desirable of the group, with A the next least desirable, although A is the position which is supposed to be essential. (Hibiscus used as subject.)

Fig. 5–15. Angular window. The plane of the window is not necessarily perpendicular to the visual axis. It may lie at an angle as shown here, although the position is not recommended for any but demonstration purposes.

stereoscope the mount is not visible, so what difference can it make? Many stereographers use various colors of mounts to distinguish among various classes of subject matter. This applies to paper prints and viewers intended for them.

In modern stereography, the films are mounted in ready prepared mounts. These are occasionally supplied with a special window for close-ups, but this is obtained only by the sacrifice of portions of the film area, making the picture field considerably narrower than normal. The value of such "special window" mounts is open to serious question. Most 35mm workers use the "standard" mount for all types of subjects.

It is essential that the two images be vertically aligned with great care, and that their true perpendiculars be both perpendicular and parallel. It is advisable to have the spacing of homologous objects at infinity equal to the spacing of the stereoscope, but further than that the arrangement is purely a matter of personal preference with no valid arguments for or against any particular style.

Chapter 6

STEREOGRAPHIC TECHNIQUE

One hundred years ago the photographer, professional or amateur, was assumed to be a stereographer as a matter of course. All photographic shops carried full lines of stereo equipment and stereograms by a number of nationally known stereographers were readily available.

Later, specialization set in and stereo become a special field and one in which the amateur took the lead. In that fact we have the key to the loss of stereo popularity. At the end of the last century it seems that in any activity human free will was abhorred as positively obscene. Everything from dawn to midnight was regulated. In short the period was precious in the extreme. Stereo seemed to fall into the hands of a group which was unusually rule-minded. The result was to surround stereo with a wall of rules and regulations which left only the bare possibility of making an occasional exposure. It seems unlikely that any stereographer could observe all of the rules and make more than a half-dozen stereograms in a year!

Today stereo is popular, and fortunately our mentality is such that when we hear of a rule we immediately want to see if it can be successfully broken—in stereo it usually can. Today the stereographer considers an afternoon a loss if he fails to expose a half magazine, that is, some 15 stereo exposures; and 50 or 100 is a normal week-end production. Obviously these are not masterpieces of art, nor are they intended to be such. The modern amateur has learned that stereo reproduces what he originally saw, and the stereo camera preserves the highlights of pleasant weekends or vacations. Many of the stereograms are beautiful, some of them exquisitely so. But the point is that the stereogram of today is made, not because the stereographer believes himself to be a great artist, not to impress a group of friends or club members, not as an excuse to strut pompously before a group, but purely because of the pleasure it affords the maker and his friends. This fortunate and wholesome attitude has revived stereo and will keep it alive.

Therefore, in this discussion of stereo technique, we shall deliberately cast off the old burden of ridiculous rules and discuss those common elements of techniques which affect the result. You will not find a prohibition in the chapter, only a few suggestions with an explanation of probable results if you do so-and-so.

The camera is yours. You bought the film. If you wish to lay the camera on its back and shoot the whole roll making empty pictures of the room ceiling, that is your privilege. In fact if you do the same thing outdoors you might get some interesting cloud effects! You do whatever you wish with your camera. If you find some of the disappointments foretold in this chapter, you will not have wasted time and film because to the hearsay of this discussion you will have added direct personal experience for which nothing else can adequately be substituted.

By all means make experiments. Most useful additions to human knowledge have been made by skeptics who wished to prove (or disprove) some current belief. There have been some highly successful stereograms (and photographs as well) made by a deliberate violation of some widely recognized rule.

In any such discussion as this it is necessary to make decisions as to what subjects are to be included, what to be ignored. Stereography overlaps planar photography, and most of the purely technical aspects of both fields are identical. There is no room to include all conventional photographic technique, and no reason for so doing as it is a subject which has been repeatedly discussed by a number of writers. At the same time there are some aspects of conventional photography which are of such particular interest to the stereographer that they must be discussed at length, as in the two chapters which follow this. Therefore the points discussed will, in many instances, be familiar ones; some will be new.

This discussion will, generally, assume that color film is being used because color is one of the important elements of stereo. It may be said, however, for the benefit of those who use monochrome processes, that the negatives made should be rather soft, that is fully exposed and not overdeveloped.

Color exposure, of course, permits little control through exposure variation, but the effects of under and overexposure affect stereo more adversely than in the case of planar photography.

Filters are quite as important as in planar-monochrome work, but this subject is discussed in detail in a later chapter.

Choice and arrangement of the subject is a matter of pictorial treatment and will be discussed later.

The stereo camera differs from the conventional in being two cameras joined side-by-side, and the actual manipulation of the camera must take this into consideration. Because the camera lenses have the relationship which characterizes the two eyes, it is desirable that this relationship be maintained. Thus if you stand upon a hillside, your feet, ankles and legs are so positioned that the body is maintained in a vertical position, and your eyes are maintained in a common, horizontal axis. When you use the stereo camera, you should take great care to see that the camera is not tipped up at either end.

It is often said that the stereo camera must be kept perfectly level. This is far from the truth. You can tip it up or point it down with far greater freedom than the planar camera because the stereo camera realistically retains the vertical perspective of nature. In the field of drawing, we have only that perspective which applies to the horizontal. Our world is relatively flat, so the need of vertical perspective has not been felt until recently. As a result, a picture of a tall building, made with a conventional camera, violates our training (although it is perfectly normal, because perspective does act vertically as well as horizontally). We say the building appears to be "falling over backward." In the stereogram the building has a normal appearance, and if the head is tipped upward in viewing such a stereogram, the realism becomes astonishing.

It would be well, perhaps, to digress a moment and explain that the cooperation of the spectator can add tremendously to the effectiveness of stereo. If the spectator does not wish to co-operate, he is not interested and the loss is his own. This is true of many phases of stereo, and forms a significant part of technique. Do not waste time trying to convince anyone who is not interested or who wishes to argue the question. Stereo is for enjoyment, and if anyone prefers to indulge in other forms of pleasure, surely the choice is his. But those who really do enjoy stereo find they can increase viewing pleasure by just such "orientation" aids as bending forward to view stereograms made with the downward pointing camera and vice versa. The reason is that the sense of balance changes as the head is moved, and when the balance of looking upward is present, the appearance is rendered even more realistic.

But to get back to the level camera. As a rule the camera should be level from side-to-side, that is, one lens should not be higher than another. The reason is perfectly simple. The stereo picture cannot be twisted and corrected as could a similar planar photograph, because the common central axis must be retained if uncomfortable vision is not to be encountered. If the camera is tilted, the pictures are mounted with the scene at a slant. If this is done, the stereogram is visually acceptable, but hardly satisfactory esthetically.

As far as the rule is concerned it might be stated thus, "If you want your pictures to be straight, keep the camera level from side-to-side." As a matter of fact, the camera can be side tilted to produce some highly fantastic effects, provided the conditions are right.

Another factor is that of the tripod. Color film is still relatively slow, and there are very few people who can make a needle sharp film with a hand held camera operated at a longer exposure than 1/50. Most of you will ignore the advice, of course, but those of you readers who do make use of a tripod will be more than repaid by the great improvement in the quality of most of your shots, and you will be far less handicapped in losing those subjects which require 1/10 second or more exposure.

The stereogram should be sharp throughout if the full realism is to be retained. However this "rule" should not be given too much consideration when the loss of a picture is involved. If you can obtain a satisfactory stereogram which includes some blur, and cannot make an exposure at all with the aperture necessary for all-over sharpness, by all means do the best you can. A stereogram of an interesting subject, even if subject to some technical criticism, is far better than no stereogram at all.

The "rule" actually originated in the days when extreme soft focus was a fashion and every photograph had a series of abruptly changing planes. This was said to imitate the effect of human vision, although why such an absurd statement should have been made by men and women whose own eyes constantly wander from point to point, cannot be understood. Many stereographers went heavily into soft-focus stereogram making, with results which are better imagined than seen.

But, all in all, the greater the sharpness of the stereogram in all planes, the more satisfactory it will be.

Of course to produce this effect, inasmuch as the best stereograms have some relatively nearby object and many of them include backgrounds at infinity, a small lens aperture must be used. When possible, apertures of f/11 and f/16 are advisable, but except under the most intense light, this means exposures of such length that the tripod is necessary.

There are many times when it is necessary to use larger apertures, even to the extreme of f/3.5. Then, too, the shorter the focal length, the greater the aperture which can be used without loss of too much depth of field. In short, the matter is one which you should decide for yourself, but make a practice of referring to depth of field tables (or to the depth scale on your camera if it has one). Then use the smallest aperture which includes the desired field. If you can cover the field at f/8, there is little point in stopping down to f/16, and the quadruple exposure gained aids a lot in balancing exposure against necessary shutter speed.

That matter of having an object relatively near is not a rule at all, it is simply a reflection of normal conditions. It is not often that you find yourself in a position where there is nothing before your eyes for a distance of 100 feet or so. Upon a cliff edge or at a window in a tall building perhaps, but such conditions are not common.

When you take a walk in the country, or in a large park, you can see quite easily that details in the distance, say at 100 yards or less, are not so sharply differentiated in spacing and relief as are objects nearer at hand. Of course the size of the object enters into this, but for ordinary objects, people for example, a distance of 15 or 20 feet reveals more contour than can be seen at a distance of 100 feet. It is just this fact that makes the 15 foot stereogram more definite in relief than the one made at 100 feet.

This of course leads straight into the question of the distance limits, but this has been discussed elsewhere in this book. It is enough to say here that thousands of amateurs who never heard of the limits have made stereograms at 30 inches and have been satisfied with the results. Nothing more than that need be said here.

The subject of close-ups, however, does bring up a most important question of stereomatics. Those who are disappointed with their stereo souvenirs of a vacation are usually so because the stereograms fail to reveal certain things which are affectionately remembered.

Let us borrow from the motion picture. The successful motion picture has two elements of the utmost importance. First it has continuity. The amateur film should be so made that it tells its story so well that most of it could be grasped without the use of titles. (We refer of course to the usual silent amateur film.) The second element is that of visual transport. The audience sees a scene as a whole. A distance change gives a more detailed aspect. Another change and the semi-close-up concentrates attention upon a relatively small area and picks up details and finally the close-up pins attention to one particular object or character, and detail is paramount.

Let us take a simple example. You take a walk in the park and see a tree in bloom. You want to preserve this scene, so you make a shot of the tree. When the stereogram is done, you show it to your friends and find that to tell the story you have to talk on and on. You tell of the day, where you found the tree and the exact appearance of one of the flowers. The slide may be beautiful but the narrative easily becomes boring. Now let us see how this story can be told stereomatically.

1. Entrance to the park, groups of people visible within the park.

2. A portion of the park. The tree in question not particularly noticeable among many other trees.

3. The selected tree fills the frame (with due allowance for spacing of course).

4. Semi-close-up shows one or two branches. The individual flowers are visible, but structure may not be.

5. Close-up. The structure of the individual flowers can be seen easily.

Certainly it takes five exposures instead of one. But when it is all done you have a complete narrative of your experience. Instead of depending upon your (probably inadequate) power of description, the spectator can enjoy the same sequence of emotion which you felt when making the slides. You do not have to embark upon a long and boring dissertation. The slides tell more than you could relate in a half hour. Try it and you will be convinced.

A vacation, for example, could start out with the preliminary preparations. It would include: (a) start, (b) the road back home as you leave town, (c) a few sequence shots along the road, including road signs to provide location, (d) camp entrance, (e) unpacking, (f) the first night, and then start the actual record of camp or hotel or any other vacation spot.

Many make a good start and then let the sequence lag, with the result that the story is spoiled. Do not forget the departure, the trip home, the arrival and the first evening at home.

In short, if you want to make the most of your stereo record without it becoming burdensome, prepare a tentative scenario which of course is always subject to alteration and addition at any time.

In closing it is well to point out that the slide does not show what you actually saw at the time of making the exposure, it shows what you should have seen at that time had you used your eyes! In short, do not become so preoccupied with your principal subject that you overlook undesirable elements in the background and surroundings.

These are the principal points of technique other than those discussed in specific chapters in other parts of this book. You should feel as free with the stereo camera as with the planar type, and as long as you maintain the side-to-side level position, try to get sharp definition and observe the normal technique for conventional cameras, you can do about as you please and obtain good results. Yes, you can even use unconventional angle shots if you watch the background.

NON-WINDOW MASKING.—There are masks used occasionally in stereo which are not used for the purpose of producing a specific window effect; or perhaps, because the window is produced by them, it might be more truthful to say that the window is not the primary object of such masking.

Of course there is the fundamental mask which is used to eliminate portions of the camera field which contain distracting objects; to limit the field to the object of primary interest. This is usually more of a commercial or record type of masking than pictorial. But this leads into the general field of masking.

Planar pictures are usually masked to a rectangle, less often to round or oval and at times "fancy" masks are used such as a star, diamond, leaf, fish or the like. We are not concerned with any question of taste or advisability; only with the fact that these various masks can be used with stereo if desired. As a matter of interest it may be added that the keyhole mask often used in planar photography is more effective in stereo because the window placement plus the shape gives the effect of really looking through a keyhole.

The actual masking is done just like the window masking. The two openings must be of the same size and shape, and the two must be carefully aligned. This is usually accomplished by carefully drawing the outline upon a piece of tracing paper which is then used as a printing mask.

Masks are positive or negative. The negative mask is the most popular because without further mounting it provides a black frame for the stereogram.

The negative mask is made by cutting out from opaque paper two shapes corresponding to the mask openings. These are aligned and attached to a piece of tracing paper. Guide lines are marked upon the paper.

This negative mask is placed in the printer and a sheet of paper exposed behind it. On the back of the sensitive paper, the outline of the mask is traced. This paper is then exposed to the transposed stereo negative, the pencilled lines serving as a guide to locate the centers of the object symmetrically within the mask openings.

The choice of mask is largely determined by the characteristics of the negative. If the negative is thin and open, so that it gives a dark to black background, a positive mask is used (Fig. 6-1), one with the mask openings cut from opaque paper. If the background is medium to dark in the negative (medium to light printer), the negative mask is used. Thus through tonal contrast the shape of the mask is visible.

It is not advisable to carry the use of these masks to the extreme. A set of four or five negative window masks may be used normally, but the fancy shapes should be reserved as a kind of spice

Fig. 6–1. Masks (A). There is little value in a mask when the background of the picture and the mask have similar tonal values. The shape of the mask is lost. (The flower is a night-blooming cereus.)

Fig. 6–2. Masks (B). Fancy shapes may be used, but they are rarely successful unless given a conspicuous position. This one places the window in the plane of the stamen.

to the collection, and used sparingly to preserve the novelty appeal (Figs. 6-2, 6-3 and 6-4).

Filing and Storage.—Any collection of stereograms rapidly grows to such an extent that no hit-or-miss filing system (or lack of such system) will serve. Therefore the stereographer should start some kind of filing system with his first roll of pictures.

There are special cabinets of various types on the market, and

Fig. 6–3. Masks (C). The diamond shape is acceptable if novelty masking is essential, but plain masks, either circular or rectangular, are best.

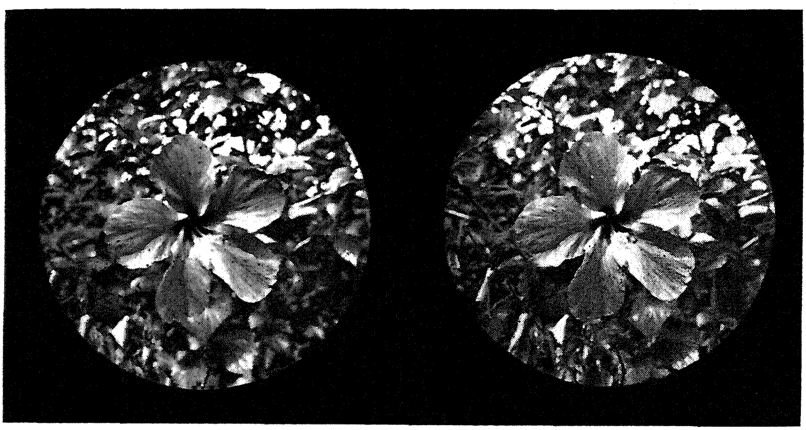

Fig. 6–4. Masks (D). Of all the non-rectangular shapes, the circular (and oval) is perhaps the most generally acceptable.

the choice will depend largely upon the type of mounting you use.

Glass and other thick slides are best filed in a drawer cabinet equipped with guide slots to keep the slides separated. These slots are usually indexed and blank cards supplied. When cardboard mounts are used, two slides may be filed in each division thus doubling the capacity of the drawer.

However, when rigid card mounts are used, the individual divisions may be omitted, but it is advisable to have the drawer divided by a partition about every two inches more or less to prevent a small number of slides from becoming mixed in a long drawer.

It is not necessary to buy a commercial cabinet. In fact, if the collection promises to grow to any great extent it would be advisable to make or have made a cabinet with a capacity of not less than 5000 slides. You should allow about 18 inches of drawer space for each 100 glass slides or about eight inches for each 100 rigid card slides.

INDEXING.—The collection does not have to be very large before indexing is necessary and this necessitates adding a number to

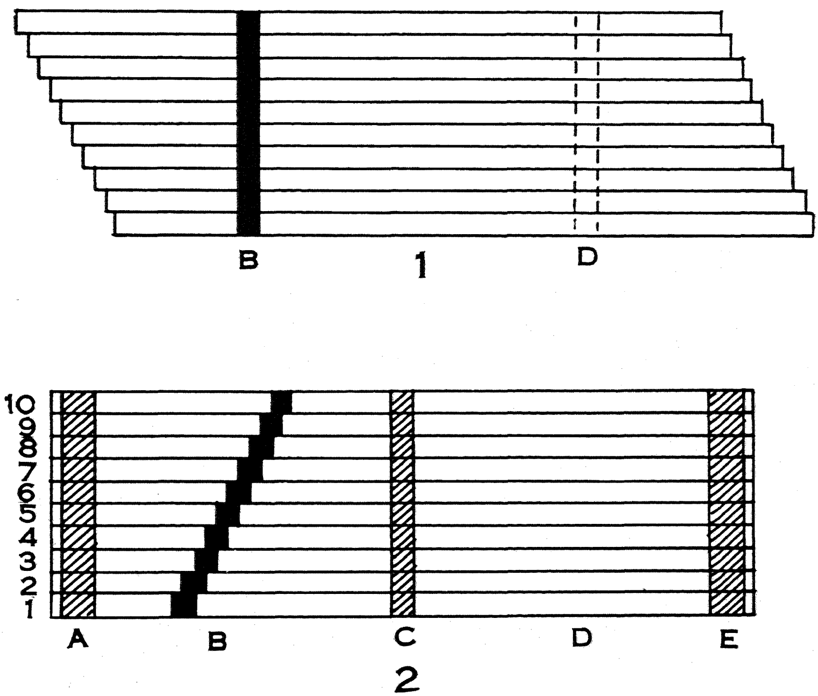

Fig. 6–5. Slide Indexing.

each slide. To make the collection readily accessible, this number should be placed upon the edge of the slide so that it may be read without removing the slide from the drawer.

The glass (or plastic) slide may have a small number, written upon paper and sealed over the edge by a strip of transparent, cellophane tape.

It is easy to work out a complete indexing system for rigid cardboard mounts. These mounts are stacked so that each slide overhangs the one below it by 1/8 inch as shown in Fig. 6-5 (1). In this position a color stripe is painted over the whole pile of ten in one straight line as shown (B). When the pile is straightened up as in (2) of the same figure, the colored portions assume a staggered sequence. If any slide is removed its position is easily ascertained by the break in the regular sequence. This provides the basic group indexing for ten slides.

The second ten (11 to 20) are indexed by painting the stripe at D of Fig. 6-5 (1). This will place the staggered indicia at the right of center.

The actual numbers are color coded in spectral sequence, i.e., 1-20 = violet; 21-40 = blue; 41-60 = green; 61-80 = orange; 81-100 = red. This provides for a sequence of numbers up to 100.

For multiples of 100 the center stripe (C) is color coded.

1-100 = plain	501-600 = yellow
101-200 = gray	601-700 = orange
201-300 = violet	701-800 = scarlet
301-400 = blue	801-900 = brown
401-500 = green	901-1000 = black

For the second thousand a second stripe is added to (C) so there are TWO narrow stripes down the center. The marking is carried on to any desired extent.

Classification is also desirable, and for this purpose the ends (A) and (B) are color coded according to any color code you may wish to use. For example you might have for (A) the following:

violet = scenic	yellow = water
blue = flashlight	orange = action
green = figure	red = animal

For (B) you will have a code for each of the "A" classes. For example under Green A (figure) you might have:

violet = portrait
blue = draped
green = nude
yellow = group
orange = genre
red = action

If you wish to carry this classification to the extreme you might consider such a subject as a nude dancer photographed with strobe light, then at "A" there would be a combined blue and green tab

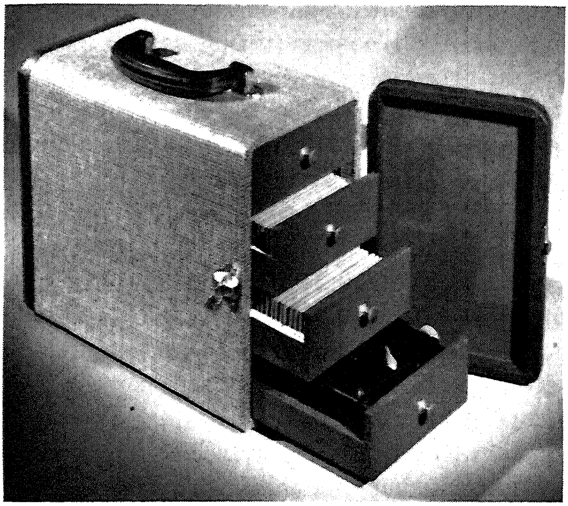

Fig. 6–6. Realist filing cabinet. The three drawers hold 48 glass or 96 cardboard mounts. The lower drawer takes the viewer. This compact cabinet affords protection for slides and viewer in easily portable form.

while at "B" there would be a combined red-green tab. Thus you can provide visual indica for a whole collection which will enable you to select any individual slide by reference to an index or to select any type or group without referring to the index.

Some such classification is essential if the collection is not to lose its value, because hunting through even two or three hundred slides is such a tedious task that too often the effort will not be made.

It is difficult to overemphasize the importance of not allowing your collection to become unwieldy through absence of adequate indexing.

CHAPTER 7

FLASH IN STEREO

MOST MODERN STEREO CAMERAS are equipped with internal synchronization for flash, but too many stereographers neglect this technique and so lose a great deal of pleasure which would otherwise be theirs.

For some reason the idea persists that flash is restricted to making photographs at night, and a great number of stereographers still lower or extinguish the room lights when preparing to make a flash exposure. This is all wrong. Flash is intended for use under normal conditions of artificial lighting or in full daylight. That is the reason for the synchronized flash instead of the "free" or "wild" type.

Flash is a technique whereby the photographer can produce a light of sufficient intensity for making the exposure in such a short time that the great intensity is not painful and has no significant heating effect. To produce this light at just the right instant, synchronization is used.

For older types of shutters, there are various types of mechanical synchronizers which ignite the bulb and open the shutter at the same instant. The whole action may be mechanical, or the motion of the shutter may close a contact to ignite the bulb, or pressure upon a button may ignite the bulb and activate a solenoid which operates the shutter. But in modern cameras, the contacts are usually built into the shutter itself so all that is necessary is to provide a socket for the bulb with associated reflector and the battery case.

Synchronization may be either for a 5-millisecond delay or for a 20-millisecond delay type of bulb.

The F (SF or SM) bulb has a duration of about 1/100 second so it may be used with slow shutters in inexpensive cameras for relatively high speed shots. The M (5 or 25) bulbs are wire-filled and have a broader peak, so they are best used with a shutter which can be set for the desired speed. Synchronization set for one of these types will not necessarily serve for the other, so be sure which type your camera or gun is set for. The midget M bulb (5 or 25) is wire-filled, the F bulb (SF or SM) has no filling. The

M has about 50 percent greater brilliance, but on short exposures some of this is lost by clipping out the peak brilliance with short exposure.

Although these designations were received from an authoritative source, there seems to be some confusion about terms. As used here "F" simply means the "empty" bulb and the "M" a wire-filled bulb.

For general use with Kodachrome, the F bulb is probably the best. Choice often depends upon various circumstances of course, but without good reason for using another type, we recommend the F bulb, unless your camera shutter is synchronized for other bulbs. These bulbs provide an excellent color match for artificial light film without a filter.

We shall not give details of the equipment and its attachment to the camera as this information is given with each flashgun as it applies specifically. With the Realist, for example, the flash reflector slides into the "shoe" on top of the camera, the shutter set at 1/25 or 1/50, a bulb inserted in the socket and the exposure made as usual. The Personal and Stereo Vivid have synchronizing contacts of somewhat different design. More elaborate externally synchronized guns are attached according to the manufacturer's instructions. The Verascope uses a Busch gun of condenser type.

EXPOSURE.—The question constantly arises, "What exposure shall I give with flash?"

Although the flash has high intensity, it is used so close to the subject that its effect varies sharply with distance. According to the inverse square law, the exposure at eight feet must be four times that at four feet. For this reason, the flash exposure is based upon "guide numbers." These guide numbers take into consideration the brilliance of the light, the sensitivity of the film, and the distance of the subject. Thus the guide numbers change as the film sensitivity changes.

Let us take the F bulb, used with film of 10-16 ASA sensitivity. Reference to the exposure guide shows that up to 1/100 second the guide number is 44. We now turn our attention to the subject. The focusing scale tells us that it is eight feet distant. We therefore divide 44 by 8, which gives us 5½. We therefore set the diaphragm at f/5.6 which is close enough to the 5.5 as determined by computation.

You may avoid complex mental computation by using a guide number close to that given. Thus, for a nine foot distance, you may use 45 instead of 44, and the error will not be at all serious. In fact surroundings often alter the effective light intensity to a considerable degree, yet there is enough tolerance to give, usually, good results from an approximate guide number.

There are conditions which call for some departure from the computed exposure. For objects which are very dark, use one-half stop larger aperture, for those which are light, one-half stop smaller. Note that this also applies to rooms. In a small room with white walls a reduction is required, but in a large room particularly with dark walls, use the increase in exposure. For outdoor work, use a full stop increase. To do this compute the exposure first and then add one stop, do *not* use one-half the original guide number.

It may be that you will find it necessary to alter the guide numbers after some experience. Different types of reflector make a difference in the intensity of light reflected from the subject, and that is the factor of importance. If the light is concentrated it will be brighter, but if a wide beam reflector is used, it will be less brilliant.

FLASH POSITION.—There is a distinct relationship between the effect produced and the position of the flash bulb in relation to the lens. If the light is close to and directly above the lenses, the lighting will be very flat, and projections along the camera axis, or in the direction of the camera, will be minimized. For example if a model is facing the camera directly, the nose will be shortened, the facial expression altered, the eyes set flush in the face instead of being in their sockets. In short the face is flattened and robbed of expression.

If the flash is supported at the side of the camera, and lies at the same side of both lenses, there will be enough cast shadow to remedy, to some extent the fault just noted. This is the position used in most press photography, and for purely record work it is acceptable, but it is still far from good.

The best position for the flash is above and at one side of the camera, the distance from the lens at least 30 inches, and more if the subject is more than four feet from the camera.

The illustrations which illustrate these points were made with a display mannikin as the model so that any difference must necessarily be a result of the technique, not of any change in the model.

Fig. 7-1.

Figure 7-1. Note that there is a slight halo of shadow all around the head. You will also see that this halo at the right is just a bit more broad in the right image than in the left one. Examine the nose with a stereoscope, and you will see that its projection is somewhat vague. In fact you are inclined to overlook the fact that there is a nose there.

Fig. 7-2.

Figure 7-2. This is made with the flash mounted at the side of the camera upon the conventional press-camera bracket. Note that the shadow at the left is somewhat wider than it is in the first illustration, but of much more importance, note that the nose now has a far more definite modelling than in the first. However, the pointed shadow beneath the chin is about the same as in the first and is not at all satisfactory. In short this is better than the first, but not much.

Fig. 7–3.

Figure 7-3. The light was held, freehand, about 30 inches from the camera, above and at the right. It was fired by an extension cord and is typical of "extension flash." Note that while the left ear and cheek are in deep shadow, the face modelling is far better than in either of the others, and that even in the flat, the face appears to have more roundness than in the first two. Compare the lips with those of the other two. The modelling is far better. In short, although the total relief of the head is not greatly altered, the modelling of detail grows as the lighting becomes more angular. This is in direct accord with the visual effect, as all portrait photographers and all artists know. Light affects stereo quality simply because it affects visual quality.

These exposures were made under average amateur conditions by an amateur stereoscopist of average experience to avoid any influence which might result from professional technique. They were made with the Rolleidoscope with the Kalart Master gun and extension, using F bulbs and Plus X film.

Pink Eye.—When the flash is almost in line with the camera lens a peculiar effect results, one in which the pupils of the eyes have an unusual pink coloration. Two explanations have been offered, both similar. One is that the light reflects at the retina and fills the eye with a reddish glow, the other is that a fluorescence is excited similar to that observed in animals' eyes when illuminated by a light almost in line with the eyes of the observer. One thing is certain, the effect does come as a result of too close alignment of flash and lens and it may be cured by moving the flash to one side. Occasionally there is a pink eye found in color shots made with the side mounted flash, if the bracket is close to the camera, but you will not discover it in extension flash shots.

As the effect amounts to a grave distortion of color value, it naturally spoils the picture. For that reason alone the use of extension flash is to be recommended.

Kalart has introduced a gun which is a compromise between the "anti-pink-eye" and the bulky extension. It is a gun of conventional appearance, but the bottom of the battery case is fitted with a shoe which slides into the Realist stirrup. All you do is to slip the shoe into the stirrup and the gun is ready for use. The bulb is raised several inches above the usual position and cuts down the number of pink-eyes.

Staring Eyes.—You have all seen the flash shots in which everyone seems to have his eyes popping out of his head. You are also no doubt aware of the explanation that the bright flare of the flash causes it. However you might stop to consider that the flash is over and a thing of the past before any muscular reaction can take place in the human body. No, this pop-eyed expression is one normal to everyone when in the dark! The flash is so quick that it only catches the expressions which are normal to darkness. Moral: Do *not* turn out the room lights before making a flash shot.

THE COLOR FACTOR.—Now we come to one of the most hotly discussed factors in all flash work. This has to do with the color effect of the flash. Some use daylight film with no filter, some use daylight film with the incandescent filter, some use A film with the daylight compensator, some use A film without filter. What is correct?

The correct procedure depends upon circumstances. First of all there is the color temperature of the flash. This varies with different types of bulbs, and of course electronic flash is still different. The F bulb is about 3300K (Photoflood = 3400; HP tungsten = 3200). The M bulbs run about 3800K. On the contrary, the electronic flash is more blue than "normal" daylight and from our tests seems to run close to 6800 to 7000K.

Then too, room walls affect the color, and as these are usually a warm tint such as cream, ivory or tan, they tend to lower the over-all color temperature. As this is so variable, we shall limit the discussion to the actual flash color.

Standard Balance.—Daylight film is usually balanced for 5900K, the tungsten films are corrected for projection bulbs at about 3200 and photoflood are corrected for 3400. But in actual use both the projection and flood bulbs tend to fall below this color, photoflood bulbs particularly fall off rapidly with use.

Thus, if we assume the color temperatures of flashbulbs to be accurate (and they are more accurate than the average tungsten or photoflood), the corrections may be ascertained.

When using the F type bulb, use no filter with either type A or tungsten films. The light is very slightly warm for A and cool for tungsten, but the variation is not more than other variations to be expected in commercial products, so with the F type, rapid bulb, *use no correcting filter* when using either of the artificial light film types.

For use with daylight film, use the usual filter which would be used with this film for artificial light use.

The M type bulb, at 3800K, is the standard flash color for other bulbs except the blue series. For use with photoflood film (type A), the H&H C 1/4 is used and with tungsten film the C 1/2 is indicated. With daylight film a B2 filter would be indicated rather than the B4 for F bulbs. Corresponding filters of other series will provide similar corrections.

If the electronic flash is used, the color temperature may be assumed to be 7000K more or less or one correction step more blue than the light for which daylight film is corrected. Daylight film would therefore call for a C 1/4 filter, photoflood would need the C5 and tungsten film the C6 for correction. However, it is advisable to use an artificial light film type for flash work, rather than the daylight type, unless electronic flash is used, when daylight film is preferable.

Blue Bulbs.—There are times when it is necessary to use daylight film, such as when balancing flash and daylight. In this case it is better to filter the light at its source than to use a filter over the camera lens.

The easiest way to do this is to use blue bulbs, but they are more costly than the clear type and have a decidedly lower output. For example the Sylvania SF (F) has a peak lumen output of 800,000, the Press 25 (M) has 1,250,000 while the 25B (M-blue) has only 500,000; this is actually less than the output of the F type of clear bulb.

It is economical to dye your own bulbs. This may be done by dipping them into a solution such as Jen-Dip provided you dye two or three dozen bulbs at once. It is not economical otherwise as the dye is highly volatile and often when you return to dye another small lot you find the bottle empty!

Dipping is also advantageous in that the dye strength depends upon the time of immersion and by care you may make up your own correction to give just the effect you want.

Another method is to use a filter over the reflector. This is least costly, and it works all right. The filter used is ordinarily incorporated with a protective shield which prevents particles from flying if a bulb should burst, as occasionally does happen. We have found the combination entirely satisfactory. However it must be remembered that the low efficiency of the blue bulb is due to the absorption of the more plentiful red component, and any filter will have a similar effect, so whether you use blue bulbs, dipped bulbs or filter, use the guide number for the blue bulb which corresponds in size to the bulb you use.

Multiple Flash.—The usual flashgun will ordinarily handle two bulbs, in extension work, without difficulty. If more than two bulbs are to be ignited at once, it is advisable to use some ignition system designed for this heavier load to insure prompt and sure fire. For elaborate layouts a special power pack is used, but for intermediate use, such as from three to six or eight bulbs, the simplest solution is the use of a gun which incorporates a condenser. This stores up a charge and when released hits the bulbs with a heavy "kick."

As a rule it is advisable, when using extension flash, to have no bulb in the main gun, as this would tend toward the flattening effect typical of any gun attached to the camera. It is necessary to have a shorting plug in the main gun when bulb filaments are in series. Usually one is above the camera, at one side and nearer the subject than the lens; the other is at the opposite side, lower than the lens and about twice as far from the subject as the first one.

Daylight Flash.—To most amateurs flash means night, but there are many times when the value of flash in full daylight far outweighs its value as a night illuminant.

First of all let us catalog some of the ways in which flash may be used in daylight.

Shooting against the sun; shooting where the light is spotty; where there is a big differential between foreground and background illumination; exposures on the beach and other locations of intense light; making shots in mist or fog; making shots in the rain; stopping rapidly moving objects; groups under overhead shade; modelling groups in cast shadow; adding intensity for morning and evening shots; adding accents to otherwise flat illumination . . . and more may be added.

In short, the daylight flash adds to the picture in intense sun, in bright sun, in hazy light, under overcast skies, in very low light and in mist, fog or haze. Which may all be summed up by saying that flash can add to the picture quality in any kind of daylight. It would be going a bit far to say that any outdoor picture can be improved by flash, but for any type of subject in which the center of interest is confined to the foreground, the flash will add to the picture in about 75 percent to 80 percent of all exposures.

At first it seems foolish to make use of such an insignificant light source as a flash when we have full sunlight, but after all let us consider that even with a midget 25 bulb ten feet from the subject the exposure is 1/50 at f/9. This is just about the exposure for intense sunlight, assuming an index of 8 for both. Thus we may consider that at about ten feet, more or less, the intensity of the flash and of the sun are about equal.

But note this difference, at 20 feet the sunlight has not altered, but the flash is 1/4 sun intensity. While the sunlight remains unchanged, the flash dies at this rate: 30 feet = 1/9; 50 feet = 1/25 and so on. For all practical purposes, and under the conditions stated, the flash effect will die out at not more than 30 feet. If the sunlight drops to half normal, it will balance at between 14 and 15 feet and so on. So, in the flash we do have a light source which is comparable in intensity to sunlight, provided the subject is located at a relatively close distance.

Flash is and can be combined with daylight to very good advantage, and while some experience is necessary to obtain the the best results, the beginner with daylight flash will obtain better shots with flash than he would without it.

FLASH COLOR.—One problem which may or may not give you trouble is that of the color of the light. Flash usually has a color which is definitely red compared to daylight. If this color is used as an auxiliary to daylight the effect is not unlike that of using a red or pink spot for accent in a white flood light. This point has been the subject of much bitter argument, but it is a fact that the warm flash can be mixed with the cold daylight in many instances, but for this discussion we shall assume a match is to be made.

If type A film is used without a filter, the effect will be very blue, contrary to the red of the flash, the latter being almost normal for the film. Therefore it is possible to use a "red" filter to balance the two. Inasmuch as a red C3 is required to balance the film to daylight and a C1/4 can be used with the flash, the midpoint would be about a C1.

This is a false balance! The balance which does occur is that which depends upon simultaneous color contrast rather than an orthochromatic reproduction. That is, where the daylight is predominant, the colors will be too blue. Where the flash is stronger, red will be strongest, and true color will occur only in those places where the lights fall upon a surface in equal intensity. Thus this balance is one which can be used to the best advantage only after a considerable experience, but then it can often be used for some very spectacular effects.

The true balance lies in working under daylight conditions, that is either with daylight film or type A with the full strength compensator. The flash used is blue, either a blue flash filter or blue bulbs. Here again the reflector filter forms the most satisfactory practical compromise.

It may be added that if an electronic flash of sufficient power (300 to 500 w/s) is available, it may be used with the daylight combination but it is advisable to use the type A film with a corrector one degree lighter than usual, because the electronic flash is as blue as daylight and usually somewhat more, ranging often over 7000 Kelvin.

FLASH TECHNIQUE.—Under the usual conditions, the flash is the specific illuminator of the principal subject. The exposure is determined by using the usual guide number for distances of ten feet and more. For nearer distances the aperture is a half stop smaller than that called for. It has often been asked why you can double the amount of light without overexposing; that is, when you have daylight and then add the flash and give an exposure which either one would require, why does not overexposure result? There are several reasons. First, you are working outdoors, where at night you would use a stop larger than the guide calls for, so you are using the flash at what is really half strength. Second, you use a flash because the subject or some part of it is shaded and you wish to subdue the heavy contrast. Third, this light intensity is present only near the camera and the greater portion of the film area is lighted by daylight alone. Fourth, the presence of a 100 percent increase in exposure is visible, but it does not injure the film unless a base exposure much greater than normal is used. In short, film latitude takes care of a lot of it. With all of those factors involved, it is easy to see why the use of "normal" flash aperture and time is not excessive.

The flash should, when possible, be extension flash, because the centered flash can and will produce all of the undesirable results which characterize it in night work; flat relief, pink eyes and all. In outdoor flash, you are making a flash exposure with the daylight acting as a base level of illumination.

SPECIFIC SUBJECTS.—Now let us consider some of the types of subject which were first mentioned.

Against the sun.—Flash is not used for *contre jour* effects, as that requires a low level in the main figure to be contrasted with the brilliant background. However, there are many occasions when the desired angle is not such that the normal light is good; often this angle is more or less against the sun, as when shooting generally south at any hour. Flash will permit a fully exposed subject under such conditions.

Spotty light.—If your model is posed in the shade of a tree, it is probable that the light passing through the leaves will fall upon the model as a spotty pattern of light and shade. This effectively kills modelling and gives an appearance of exaggerated freckles.

Unless desired as a form of bizarre pattern, such a light pattern is highly irritating.

Flash should be used at a level slightly higher than the sunlight. This will effectively wash out the spots.

Local color.—This too is encountered among many other conditions, beneath trees especially in the spring when the leaves are light in color and less dense than later in the season. The leaves cast a very unpleasant green tint over the flesh tones, which effectively spoils the picture. Here it is often possible to make use of the mixed balance, that is a clear bulb, and with type A a compromise filter. Another common source of local color is a wall or other large reflecting surface.

Massed contrast.—This situation often occurs in parks. The model is placed beneath a group of trees, but the open background is fully illuminated. Under this light, modelling tends to become flat, and if an adequate exposure is used the background is washed out by overexposure.

Flash will illuminate and accent the model, but it will die away so that a group of trees of any size will retain their shaded appearance. At the same time the background will receive only normal exposure. Thus the best features are preserved, with full, modelled exposure of the figure.

Detail contrast.—A model on a beach or in some other exposed location will ordinarily wear a hat or have some other protection from the sun. If this is discarded a squint results. If it is not discarded, the cast shadow appears in the picture as heavy, often blank shadow.

Flash used at balanced intensity will illuminate the face in the shadow, but will not entirely erase the shadow so that normal appearance is preserved. The shadow is so light and delicate that it appears quite normal to the subject and not as a defect.

Mist and fog.—Pictures made in the midst of fog are rarely satisfactory because the fog seems to be more solid and opaque than it really is. The use of flash illuminates the fog itself as well as the subject, and this luminous fog has the tenuous appearance of the real thing. Such technique is almost essential to such subjects.

Rain.—Usually when a shot is made in the rain, it is better to have the rain unmistakable, otherwise it may look like a poor exposure. If flash is used, not only will it overcome the flat lighting incident to the cloudy light, but it will highlight the rain itself and by the sparkling reflections, add much to the brilliance of an otherwise dull lighting.

Stopping motion.—Often in dull or hazy light, the problem of stopping motion becomes an almost impossible one with which to cope. Here the flash again saves the day, but naturally the flash intensity is gaged for the shutter time demanded, which means that it will far override the normal light with the consequence that the portion of the scene outside the flash area will be very dark. In short, the daylight is dull and of low intensity, so outside the flash area, this appearance will persist.

OTHER SUBJECTS.—It would be impossible to catalog all of the possible uses of daylight flash, because almost every subject can be improved by flash, but each presents its own problem as to just how the flash is to be used. There are no hard and fast rules, and each subject must be treated according to its own characteristics. This is difficult for the beginner. That is why we have listed the foregoing common types of subject. Using them as a rough guide, it is easy to make experiments, so that experience may be gained. Once you have experience you will find not only that you have confidence in the use of the flash, but you will find it hard to work without it.

The technique of daylight flash depends largely upon two factors, position and intensity.

Position.—As stated in the first part of this chapter, the position of the flash will give you any type of modelling from flat to full relief, depending upon the distance between the flash and the camera lenses. It may be added that even the "pink eye" condition can be used to advantage. If you ever wish to have direct reflections recorded, then the nearer the flash to the lens the better. This is of value at times for special effects.

On the contrary, the extension flash will prove just as effective in modelling in daylight as it is in night work.

Intensity.—In daylight flash, you have two lights which can be balanced in various ways. You have the normal daylight, which establishes a basic level of illumination over most of the scene.

You also have the flash whose intensity is within your control.

Thus you can have the flash intensity, at the principal object, below daylight, equal to it or greater than it is.

You always have a certain daylight level upon the principal subject, so the flash is never the sole illumination. The subject illumination, therefore, is the daylight plus the flash. Because the subject is often lighted at a lower level than the general scene, that is when there are cast shadows, the flash usually (but not always) is designed to raise the level to that point where it will equal or fall slightly short of the general daylight level.

The principal object will have an appearance which is determined by flash plus daylight, while the general scene will have the appearance due to daylight alone. The two lights are self-blending as to intensity, and no sharp line of demarcation will be seen, regardless of the flash intensity.

(A) Flash below daylight level. This is the normal procedure when the normal guide number is used to select the flash exposure. (B) Flash equal to daylight. This tends to eliminate cast shadows completely, and to substitute flash modelling for natural modelling. (C) Flash brighter than daylight. This is used for stopping motion and also for pictorial effects because it causes the general scene to be darkened to a degree depending upon the relative intensities of the two lights, providing the principal subject is correctly exposed.

In all of these conditions it is assumed that there is some principal object, a figure or a group of comparatively limited size. Flash will not ordinarily be satisfactory if the distance of such object from the camera varies through a distance equal to more than one-third the distance of the nearest part of the subject from the camera. For example, if a group of people is so placed that the farthest member is three feet away from the nearest, then the flash should be at least nine feet from the nearest member.

The relative intensity of light upon the nearest member will be 9×9 or 81 units, that of the member three feet farther will be 12×12 or 144. Taken in inverse order the light intensities are on the order of 1/81 to 1/144, so the farthest object receives a little more than half the illumination of the nearest.

As we have seen, the number 25 bulb will approximately average daylight intensity at ten feet. This of necessity is a very vague statement, as "average" daylight may be twice as bright as the flash or even more, or it may be one-half or one-third. There is no definite intensity level for daylight which may accurately be called "normal".

A number 3 bulb has twice that guide number at 1/25, which means four times the intensity. A number 2 has about twice the intensity. This simply means that a number 3 bulb at 1/25 has the effect at 20 feet which the 25 has at 10! Not much gain is there? The inverse square law places a most stringent limitation upon the effectiveness of artificial light.

To make matters worse, if you wish to extend the range to 40 feet, you will need four number 3 bulbs at 1/25! So, the practical limit must be taken as something less than 25 feet, and for the small bulbs which we ordinarily use, that limit is about ten feet. Of course when we make use of a blue filter or blue bulbs we draw the limit even nearer the camera.

This does not mean that the flash is ineffective. Far from it. Once you use dayflash you will always use it, but you will soon learn that it is primarily used for nearby objects and not for the illumination of large areas. You will learn that it is used for light *correction* rather than for primary illumination.

Once you learn the true usefulness of flash, its great advantages and its limitations, you will be able to make use of it intelligently. When you can do that, you will find that its value is hard to overestimate.

Yes, it does add to the initial cost, but consider it this way. You expose 16 pictures at a film cost of a bit less than $4. You pay the costs of a day's outing, perhaps $10. You encounter some subjects which cannot be duplicated, with the value of $*.**. You find that the effectiveness of the shots is gone, ruined by poor lighting. $14 in cash and a day full of imponderable values gone! You add about $2 or say 15 percent and you get 16 superb shots . . . does that make flash an extravagance or an investment? Better four *good* shots than 16 poor to mediocre ones. It is not a *picture* which has value to you, but a *good* picture.

CHAPTER 8

COLOR IN STEREO

MODERN STEREO IS COLOR STEREO. Not only is color predominant but it adds specifically to the realism which is the great characteristic of stereo. No black-and-white stereo can approach the realism of the color stereogram, and this is true of a white statue as of any other subject. There is no monochrome in nature and those objects and scenes which we call monochromatic are in reality colored. We have, in another portion of this volume, discussed the importance of color perspective in regard to stereo, and have mentioned the fact that color accuracy is of far greater importance in stereo than in planar work. In the planar, color does no more than add to the attractiveness of the subject, in stereo it is a definite factor in the establishment of spatial relationship, the very core of stereo.

COLOR ERROR.—We may as well face the fact, we all know it. Average results with color film are not satisfactory to those who have a discriminating color appreciation. More than that, many such color shots are not satisfactory to anyone at all. This condition is an intolerable one as far as stereo is concerned, but what can be done about it? Where does the fault lie? Can it be overcome?

Quite naturally, you think the fault lies in the film; and in so thinking you are making a grave error. The film is not perfect, of course, but it is quite good enough to satisfy a competent colorist when given a chance to do its work. No, dear reader, the trouble lies with *you,* or possibly with the dealer who did not store the film properly, but in all likelihood the fault is yours and yours alone.

It is all very well to sit back and let modern technology carry your burdens, but there is a limit. You must do a few things for yourself. Consider the days before color film. What was done then? The color photographer laboriously made three exposures, and without really satisfactory red-sensitive plates. He developed them giving each one just the development it needed. He probably resorted to intensification and reduction. He petted and babied those negatives through processing. When they were done he made three positives, maybe dye masters for imbibition, maybe carbons for carbro, perhaps in some other medium, but he made them. Then he superimposed them and if anything had gone wrong the whole thing was ruined.

Can you, without being ashamed, refuse to spend five short minutes, perhaps less, to improve that color film you are making? Think of it! There was a time when you would work, work hard for two or three days or more to make just one color print. Now, by adding four minutes to the time spent, you can bring your color films up to a quality level you never dreamed of. Isn't it worth it? Particularly when you think of the great influence of color upon the stereogram, isn't it worth it?

Color films are balanced for a certain kind of light, a light which has a certain color balance. Daylight films are balanced for "normal daylight," but that is a kind of daylight which we rarely if ever see. It is just another non-existent average condition, or almost non-existent, Fortunately color film or our color perception or both have such great latitude that the actual light used may be considerably off-standard and still give color results which are satisfactory. But there is a limit, and much of our daylight—I should say offhand about 50 percent of it—is beyond the limit. So, a lot of amateur color exposures are not satisfactory.

The truth is that daylight film does reproduce the color which existed at the time, but we find it unacceptable because we did not see it that way. In other words, with the exception of lights which are deeply and brilliantly colored, our color perception rapidly adapts itself to any color and when the adaptation is complete, that predominating color is "white" to us.

The purpose in having two types of film is based upon this fact. Daylight film reproduces color naturally under normal or average daylight, but if we use that film for artificial light, even the brilliantly "white" photoflood, the film comes out definitely red. The actual appearance of the scene, *to eyes adjusted to daylight,* is that shown by the film; but because, as soon as the lights are turned on our color standard shifts to make the red-yellow artificial light "white," the daylight standard is not acceptable.

You are familiar with the deep yellow color of any light bulb which burns in daylight. It does not change color at night, only our color perception changes to transform this golden yellow into "white."

"White" might be defined as the color of the predominating illumination.

Now with such a change as that, is it any wonder that the color value of daylight can change without our being aware of it? In fact even training cannot teach us to perceive such changes by our unaided visual sense, unless the change is relatively great. But any change perceptible to the most delicate color perception, is many times as great as the amount of change necessary to throw the color film off balance.

So, if you want to make good color films, the best way is to do what you can to assist the film in its job.

COLOR TEMPERATURE.—Under certain laboratory conditions, there is a very close relationship between the temperature of an object and the exact color of the light which it emits. This relationship has been studied and the color-temperature scale worked out. The color is designated in degrees of the Kelvin scale and is usually written "K." We are not going into such factors as a "black body" nor "absolute temperature." It is enough to know there is a scale of color temperature which we can use, and which is reliable.

In this scale we have a constant change characteristic of a hot body growing steadily hotter. The first appearance is red, as the temperature rises, so does the predominant hue, and with green added to red we have the yellow of incandescence. Later the growth of blue produces a true "white" and as this is raised, the red decreases and the color becomes definitely blue-white, then blue. Note that in all of these changes, we do not have a haphazard scramble of colors, but simply a changing balance of red and blue, the colors which represent the lowest and the highest heat of incandescence.

Because this is true, all we need is a set of filters divided into two categories; one set to absorb blue the other to absorb red. If these are graduated in strength, you can convert the photographic color balance of any common light to that of any other. You can run the scale with Kelvin degrees. You can use *any* type or make of color film with *any* ordinary kind or color of light (of sufficient photographic intensity), and obtain a color picture of better than average color balance. It is as easy as that.

You can do this simply by placing a filter over each camera lens, but to select the correct filter you must know the color composition of the existing light and how far it is out of normal balance. In short you just know the color temperature of the existing light and the color temperature for which the film is balanced. By filter compensation you can then easily coordinate film and light balance.

Practically, this is easy and pays excellent dividends in increased color quality. There is just one thing against it. It is just too much trouble to carry around the necessary filters and to make a CT reading of the light. Too—much—trouble! The same old thing which is responsible for such a tremendous amount of photographic inferiority among the work of our amateurs.

So much for "Why," now for the "What" and "How."

Consider these color temperatures:

Dull red-hot iron	800K
Candle	1850K
Ordinary electric bulb	2900K
Projection lamp, special	3200K
TUNGSTEN COLOR FILM	3200K
SF/SM flashbulbs	3300K
Photoflood lamp	3400K
TYPE A FILM	3400K
Wire filled flashbulb	3800K
Blue photoflood	5000K
Noon sunlight	5400K
Sun in blue sky	5900K
Electronic flash about	7000K
Blue sky	9000 to 30,000K

Suppose you have Type A film in your camera, and you wish to make a sunlight exposure. What should you do? The film is balanced for light of 3400K, the light you will use has a CT of 5400K, a difference of 2000K. The sunlight is higher in temperature than the film balance which means it is more blue. You must use a filter which will absorb a sufficient amount of the blue of sunlight to reduce its effective CT to 3400K. This is exactly what the familiar conversion filter does.

If you use daylight film, balanced for 5900K and you are using photoflood light at 3400K, you have a film balanced for blue and a light which has too little blue. How can you make up the deficiency of blue in the photoflood? You cannot *build up* the blue content of the light, but you can remove enough of the red to leave the blue in proper balance. So you use a red-absorbing filter (bluish) of the correct density.

But what if you are using daylight film and an SF flashbulb, 5900K film and 3300K light?

The light is 3300K, Type A film is balanced for 3400K. The difference is insignificant, so you can safely use the same filter you use for balancing daylight film to photoflood light, and by the same reasoning you need *no filter* to balance Type A film to SF or SM flashbulbs.

Thus adequate color control depends upon just two things, knowing how to determine the color of the light used and how to determine the filter necessary to balance this light to the film you are using.

Fortunately artificial light sources may be assumed to conform to published ratings which means the difference between actual and nominal rating is not enough to spoil the color effect. In fact most light sources conform to average ratings. Therefore your light measuring problem is limited largely to daylight conditions. The measurement is done by a color temperature meter. This may either be a visual meter, an electric CT meter or an attachment for the G.E. exposure meter.

If you can distinguish between purple and blue, that is, whether a blue color has any tinge of red in it or not, you can use the visual meter successfully. You simply find three visual filters one of which is purple, one of which is pure blue and one of which is neutral or in-between.

If you doubt your color sensitivity, then use the attachment for the exposure meter which gives you a definite reading unaffected by personal visual error, or an electric CT meter.

As to the filters necessary, you can obtain filters from Eastman and from Ansco for certain corrections of their films, but the writer prefers the Harrison & Harrison correction set which has 11 blues, 11 reds or a total of 22 filters for each lens, a grand total of 44 filters for the stereo camera. These filters make it possible to correct the balance of *any* light from 2800K to 9500K for use with *any* film, and when using daylight film this is extended to 30,000K.

These filters are arranged in graded steps, the temperatures corresponding to the steps are: 2800, 2900, 3000, 3200, 3400, 3600, 3800, 4300, 4800, 5400, 5900, 6500, 7100, 8000, 9500, 11,000, 13,000, 16,000, 20,000, 25,000, 30,000. The blue filters (red absorbing) are indicated by B, the blue absorbing (pink) filters are "C." The depths of color range by numerical values, 1/8, 1/4, 1/2, 1, 2, 3, 4, 5, 6, 7 and 8.

Thus to correct daylight film for wire filled flash, you find that the film is balanced for 5900K, the flash has a color of 3800K and to compensate it is necessary to use a B2 filter.

Let us assume that, like many others, you make a practice of using only Type A film with the corrective filter. This is your scheme of conversion for several different lights:

Ordinary house lighting electric bulbs	B1 to B1/2
Projection bulbs	B1/8
White fluorescent	None
Type SF or SM flash	None
Wire filled flash	C1/4
Morning or evening light	C1/2 to C1
Noon sun	C2
Bright sunlighted day	C3
Average daylight	C4
Daylight fluorescent	C4
Open bright sky, no direct sun	C5 to C8 (Max. 11,000K)

(The "B" filters are blue in color, the "C" type is pink.)

But this is not all. When you gain experience in the use of correction filters you can use them to correct "local" color such as a reflection from a red brick wall. The color meter will give you the analysis if you use it to measure the actual light which falls upon the subject.

You can also make a color reading, and then deliberately over or under correct, to produce an effect which is warmer or cooler than normal, and for certain experimental and "effect" purposes you can swing very wide of standard and produce deliberately falsified effects.

In short, color is a most flexible medium, and once you gain control of it, you will find that instead of being one of the unpredictable factors, it is of very great service. For example, one photographer produced beautiful, blue-haze effects when making stereograms of mountain scenery. Others obtained a suggestion of the effect, but the blue was dull and inclined to be leaden while this man's work was practically of Maxfield Parrish quality in the blues. How? After considerable experimentation he had found that exact strength of blue correction filter which would clear up the blues without too greatly falsifying other colors. His greens were slightly blue-green, the edge taken from pure red but these effects were not at all obvious and passed unnoticed unless they were sought deliberately.

This did not constitute a correction to normal, but an over-correction designed for one specific purpose.

To return to the more commonplace, you will usually find that the average, normal light in your part of the country results in color which is consistently red or consistently blue. True, many people do not recognize these effects, but merely think of the picture as being "a little dull" or "a little muddy." Look at the whites and at the strong colors. Study them. You will almost always find that a flaming red, for example, has a deadened appearance, just a hint of maroon which is really a hint of wine, the tinge of blue. Or it may be that your blues are just a little dull and lifeless and all of them carry a suggestion of purple or magenta, hardly perceptible. You are overrunning in red. Often the slide will be distinctly brown-purple-dun-muddy which indicates a heavy overrun of red. But color correction can give you color shots in which 80 percent at least will be above criticism other than the most searching.

Certainly color correction filters are far more necessary in color photography than ordinary filters are in black and white work. For years, amateur photographers did without filters, and when they were introduced they were simply "cloud filters" one degree of yellow. It took more years for the amateur to become "filter conscious."

We first took our color film as it came and made the best of it. Then we adopted the conversion filters and the flash filters, and were happier. Finally the control filters were introduced, but they failed to win popularity because of the high cost of color meters and the difficulty of using them. Now that we have color meters which are reasonably priced and not difficult to use, we are entering the color filter stage comparable to the third stage of black-and-white. In short we are slowly becoming filter conscious in color work.

Yes, it does involve trouble. You must carry a certain number of filters, you must make the color reading, you must apply the correct filter. All that takes time, as much as two or three minutes, but when the stereogram is complete, it will be with you for years. Is your time so valuable that you cannot devote two or three minutes to producing a good slide when otherwise you would only have a poor one?

Or look at it this way. You will spend a whole day, and use a magazine of film in making 20 exposures. Careless color technique means you will probably get not more than five good slides. But *one hour* divided among the 20 exposures, at the most, will insure at least 15 good color slides. If you can devote eight hours to five slides or more than 1.5 hours each, you can surely devote nine hours to 15 slides, which is considerably less than a half hour each! And we do not even mention the money invested in the lost film.

If color is worth doing, it is worth doing well. Take your time. It is better to make a half dozen good slides in one day than to produce a hundred mediocre ones which you will not value.

Most stereographers prefer to use one type of color film for all purposes, thus avoiding the necessity for two cameras or for wasting film. Therefore it will not be necessary to have the full stereo set of 44 filters. The table below indicates the Harrison and Harrison color correcting filters to adjust any film to any ordinary light.

	Film		
Light	*Daylight*	*Type A*	*Mazda*
"3200" tungsten	B5	B1/8	None
Photoflood	B4	None	C1/8
Wire filled flash	B2	C1/4	C1/2
Late daylight	B1/2*	C1*	C2*
Noon sunlight	B1/4	C2	C3
Sun and sky	Haze	C3	C4
Average daylight	C1/8	C4	C5
Shade—Strobe-light	C1/4	C5	C6
Sky light	C1/2**	C6**	C7**

*May vary to call for B1, C1/2 and C1.

**May vary to call for as much as C2, C7 and C8 respectively, or even enough to necessitate up to C7 with daylight film.

Thus 7, 9 or 11 pairs will meet most requirements, while the addition of B8, B1 and B1½, respectively, adapts the three films to ordinary home lighting. I would suggest the extra pair for late daylight and an extra one for blue sky light, plus the mazda home light, making a total of ten pairs of filters, or less than half the full set. Such a series of ten pairs should meet 98 percent of the requirements as long as you stick to one film type.

Incidentally never expose any film out of doors without a filter because of the ultra-violet exposure which will result. When daylight film calls for "O" filter, use a haze filter.

Color Temperature (CT) Meter.—There have been a number of CT meters offered from time to time. One of the earliest was the Eastman which we are told is no longer available. Of the more recent models, the first was the visual meter of H&H. This is a disc-shaped black plastic case with a graded series of visual filters around the edges. The filters range in color from definite blue to an equally pronounced purple. A shield over the side of the meter obscures all but three of these filters, although by rotating the body of the meter, the full sequence passes behind this triple mask.

A white reflecting sheet of controlled color is used as a standard. It seems strange to speak of the color of white, but there are a great many colors ranging from pale cream to very pale blue which pass ordinarily as "white." This reflecting sheet is of a white color which reflects red and blue equally.

The reflector is held so it is illuminated by the light which falls upon the object. The disc is then rotated while looking through the filters at the reflector. There will be one set of three adjacent filters; one appears blue, one seems to be a blue-gray and the third shows a distinct tinge of purple. This is the end point, and the reading of the scale at that point indicates the color temperature of the light.

This meter is good, as far as the instrument is concerned, but most people do not have the sensitivity to color which makes it possible to arrive at a positive end point, and even those who do have sensitive color perception, are often unsure and so may be off one full point of the scale.

To overcome this difficulty H&H brought out their color attachment. This is a square case which contains a slit diaphragm, adjustable in width, and a pair of filters, one red and one blue. A plunger in the bottom serves to change the filters in the aperture.

The attachment has a rectangular window which fits the G.E. exposure meter when the hood is removed. To use it, the attachment is placed upon the meter and the incident light allowed to fall upon the filter. The diaphragm is closed until the meter reads either "10" or "20". Then the plunger is released to change filters and the meter reading taken. A scale attached to the filter case then indicates the color temperature which corresponds to the second meter reading.

As meter cells may vary a little in color sensitivity, the filters of the attachment are graduated in density and may be balanced to correspond to the meter sensitivity by moving one or both sidewise. The meter is quite satisfactory, and appeals to many because it is inexpensive and because it permits the use of only one meter unit for both exposure and CT reading.

Another type of meter is one designed and built for just one purpose, that of reading color temperature. The Guild laboratory uses the Rebikoff, a Swiss meter of better than 2 percent accuracy. This meter, instead of the usual scale, has an arc made up of a blue sector, a red sector and a heart-shaped black zero point set in a transparent housing so the needle position may be seen from either side.

A dial is set upon one side of the meter in a position similar to that occupied by the dial of most exposure meters. However this dial is transparent, and beneath it are located the two cells with their filters. The dial itself carries a semicircular black mask so that, as the dial is turned, the areas of red and blue exposed to the light, constantly vary. Because this dial must be exposed to the incident light it is convenient at times to hold the meter in the palm and look down upon it and at other times to hold it up before the face, directed away from you. The transparent case makes the needle position easily visible in either position.

Th dial carries an index point which directly indicates the color temperature of the light. It also carries a symbol of the sun and of an incandescent bulb. When either of the two latter symbols lie opposite a fixed index mark on the case, no filter is necessary for the film indicated, i.e., daylight film if the sun is indicated and an artificial light film if the light bulb is indicated.

So far we have had only one trouble with this meter. It is so sensitive that the user tends to make corrections where none are necessary. In a series of tests made under conditions where the light varied only 300 or 400 degrees from normal, a degree of change ordinarily considered insignificant, the slight correction indicated has resulted in a distinctly improved color balance.

As to the value of a CT meter, if we had to give up one meter we should give up the exposure meter and keep the CT meter. Exposure CAN be estimated with reasonable success especially when the exposure tables are memorized, but CT changes cannot be recognized without instrumental aid. Our color has improved so markedly since the CT control was instituted that we regard it as invaluable.

In closing this discussion one thing should be made clear. You need know nothing whatsoever about color temperature theory. Your exposure meter is calibrated in numbers. Those numbers have definite meaning, but most people know nothing except that they are the "meter reading" and these have just as much success with exposure meters as do those who know the specific nature of the units indicated upon the meter scale. Just so in the CT meter, you need not know what Kelvin degrees are, you need not know what color temperature means. All you need to know to use the CT meter with every success is that a certain number on the meter indicates a certain filter with the film you are using.

For example, suppose your meter reads 4800 some afternoon. You refer to the filter table and you find that if you are using daylight film you will need a B½ filter; or if you use Type A Kodachrome, you will use a C1 filter; or if you use Ansco film or Type B Kodachrome you will use a C2 filter. If you use Eastman or Ansco filters, the correct ones will be indicated.

The meter is plainly marked, the filters are marked and all you have to do is to match the two figures without knowing anything about what the numbers actually refer to. Moreover, if you use a Rebikoff meter, you get a plain signal if the light is within satisfactory range of either daylight or artificial light film, and if it is not, all you have to do is to swing the symbol corresponding to your film (sun for daylight film, bulb for artificial light film) under the index and the meter needle will tell you if the light is redder or bluer than it should be and give some approximation as to the amount of unbalance. Then you can, with tolerable success, select an unidentified filter for partial correction.

Color correction is not new, but it has not yet become popular. There is little doubt that when amateurs have had an opportunity to actually see for themselves the tremendous improvement which it makes possible, it will take its deserved place as being just as important as exposure control.

CHAPTER 9

PICTORIAL STEREOGRAPHY

ANY STEREOGRAPHIC EXPOSURE must include such technical considerations as exposure, filters and aperture, and it must also include certain fundamental esthetic considerations which may roughly be divided into two groups. The first group includes those factors which, while not strictly photographic, have much to do with the stereo perception, including the type of lighting to be favored. The second group includes the elusive considerations of pictorial composition as applied specifically to stereography. As no stereographic reproduction can be made without giving more or less consideration to these factors, we shall discuss them together.

The whole subject of three-dimensional photography has often been discussed so irrationally that we must pause for some clarification. In the first place, three-dimensional photography is not necessarily identical with stereoscopic photography; and even more decidedly, binocular vision (or photography) must not be regarded as identical with stereoscopic vision (or photography).

Any photograph which exhibits a definite appearance of depth may correctly be called three-dimensional. Any good photograph examined in a concave mirror exhibits a three-dimensional quality, but it is not stereoscopic.

PSYCHOLOGICAL DEPTH PERCEPTION.—It is evident that we must consider the true nature of visual depth perception before we can arrive at any conclusion about the nature of stereoscopic vision. The several factors which combine to provide the visual perception of depth or distance are:

1. *Geometric Perspective.*—This is inherent in every planar photograph and in good drawings (ancient and oriental art excluded). It is the arrangement upon a single plane of those aspects of an object which in reality occupy three dimensions. For example, a side of a cube is not shown as a square but as an irregularly quadrangular shape with the far side much shorter than the near one.

In actual fact perspective relates to the *size-in-width* element of the depth factor, and is always limited to those planes which are parallel to the film plane. It is the most potent device yet found for lending to a picture upon a single plane, a suggestion of depth.

2. *Contour Interference.*—If a tree is shown in front of a building, the side of the building which lies behind the tree cannot be seen. Hence we know at once that the tree is in front of the building. If the lower part of the tree trunk were hidden by the building, we would know that the tree was standing behind the building. This is the principle of interfering contours, the hiding of objects or portions of objects by other objects which are nearer the observer. Alone, it will give a fairly accurate index of relative depth.

3. *Size Diminution.*—This partakes of both the preceding factors, and is the well-known effect of apparent decrease in size as an object becomes more distant. It is usually assumed to be an inherent phase of perspective, and is usually included as such when the principles of perspective are explained. However, it should really be considered apart from, or at any rate as a distinct subdivision of, perspective, because of its great influence upon the appearance of non-stereoscopic depth.

4. *Light and Shade.*—The forms and intensities of contour shadows are so important that they, together with the careful application of perspective, form almost the sole means for imparting to a plane image a simulation of depth. Just as an angular or broad light gives to the plane image a false appearance of depth, so in stereoscopy does the same light enhance the true stereo effect. (Compare Contour Gradation.)

5. *Haze.*—The effect of haze, sometimes called aerial perspective, aids to some extent in the perception of depth. It is commonly used in planar photography to afford separation of planes (i.e., stereo relief), but when applied to stereography the result is usually an unfortunate appearance of a weak, washed-out print. (Compare Color Perspective.)

These five factors apply equally to planar reproduction, and in fact they constitute the principal devices which are used to suggest depth in the planar photograph. There are two additional factors which are purely stereoscopic, and which must be given careful attention by the stereographer who wishes to attain success in stereo pictorialism.

6. *Contour Gradation.*—Contour gradation is somewhat anal-

ogous to the effect of light and shade. In that, we consider the effect of shadow gradation, and one important purpose of shadow gradation is to suggest, upon a plane surface, the contour of an object. In stereo we have the actual contour shown in relief, so the shadow plays a minor role in that respect. Now the gradation of both shadow and contour play a purely pictorial role.

If the scene shows scattered rocks, the contour gradation is a series of isolated shocks, a jump from one to the next, but if the object shown is the curving wall of a pool, there is a continuous recession of contour which the eye follows easily and smoothly.

Interrupted relief which might not be observed in a planar composition, which might indeed contribute to the continuation of shadow gradation, will in the stereogram be rough and broken. On the contrary, a continuous contour may change in color and be spotted with abrupt patches of shadow and highlight alternating, yet the smoothness of flow is not interrupted. This complete antagonism between planar and stereo pictorial character must be observed, because the planar system alone cannot provide the flow character desired. It is completely overshadowed by the new element of contour gradation. The relation between contour gradation and shadow gradation is that existing between substance and shadow.

7. *Color Perspective.*—Atmospheric perspective has traditionally been a potent device in the hands of the planar pictorialist, but unfortunately many of the locations which provide the greatest amount of pictorial material have such clear air that the haze element is invisible. Here again the stereographer has the advantage because he can always make use of color perspective. In fact it is one factor which tends to lower planar quality while it enhances stereo quality.

Color, like shadow, has an intensity which in part depends upon the size of the area and the distance of the color. Given a certain patch of color, it loses intensity as well as size as we recede from it, and this characteristic persists even when there is no observable haze. It is also perceptible over the relatively short distances within which stereo is most effective, something which is not at all true of haze—unless the haze is a definite mist or fog.

In the stereo color slide, this color recession is so characteristic toward a common neutral tint, that it has been the cause of considerable complaint about color shots. The charge is made that the color film is defective. Not at all: the film simply records the normal loss of color intensity which we see but do not ordinarily perceive. It is just another example of the photograph showing details of a familiar object which escape direct vision.

In the stereo color slide, this color recession is so characteristic of distance that it actually helps in making distance specific. Its importance is hardly surpassed by any of the other extrinsic factors. True, it is not as obvious as size diminution or overlapping contours, but realism is a subtle characteristic and color perspective or *stereo-chromatism* does, perhaps, even more than these to increase the essential realism of the stereogram.

It will be noted that these factors are all purely psychological. None of them is definite, none (except perspective) is subject to measurement, none of them is inherent in the object or scene, and all of them are subject to different interpretations by different people.

The only factor of depth perception which is inherent in the physical conditions of the view and the viewer is that of *differential parallax,* that precise difference between the two members of all pairs of details afforded by the two points of view. This, and this alone, is the stereoscopic factor. The other factors simply afford a greater or lesser intensity to the general appearance of depth perception.

The inherent factor of differential parallax is essential to stereoscopic perception. If it is absent there is no stereo; if it is present there is stereo. This is not true of any of the psychological factors. They may enhance the stereo effect, but they can neither produce it nor destroy it by their presence or absence.

Therefore, when making a stereogram, it is essential that differential parallax be present. This is automatically assured by making the two exposures from different points of view. If it is convenient to include any of the other factors, they will add to the effectiveness of the result in some measure; but if it is not practical to include them, the fundamental stereo effect will be present even if not one of the psychological factors is included. Perspective, of course, cannot be eliminated.

In making the stereogram, it must always be remembered that most of the extrinsic factors mentioned are not peculiar to stereo.

They are factors present in everyday direct vision, but of which we are not ordinarily conscious. We do not realize that the degree of stereo relief which we see in everyday life varies with the lighting, and with other extrinsic factors. We do not realize that the farther away an object is the flatter it really appears.

We have had a lifetime in which to balance knowledge against appearance. Hence a tree trunk five hundred feet distant, *looks* as if it were just as round as one ten feet away, yet we know that *to our vision* it really presents a shape of a flattened oval. In fact when we know this and train our vision we can actually perceive the diminishing relief in the distance, but commonly our *mental police* step in and say, "Now, you *know* that tree trunk is round, so *see* it that way" and we obey. In fact we do not think about it. We see the tree, we know trees are round, the tree stands in relief so we simply accept the relief as full relief with never a question as to whether it is round or flat.

This visual trick is common in almost every phase of vision. We see the invisible because we know from experience what it looks like, but if you want to know the truth about visual perception, show a strange object to a group of five people, let them look at it ten seconds. Remove it and ask for a description. You will get five wholly different descriptions. It has been tried too many times for there to be any question about it.

So we are not introducing technical tricks, merely using in normal stereo the characteristics of normal vision. For example, the practical application of some of these extrinsic factors are:

GEOMETRIC PERSPECTIVE.—This is the factor which is ideally illustrated by a pair of railway tracks or even a roadway extending in a straight line directly away into the distance. Such a strong perspective is rarely acceptable pictorially, but the roadway winding back into the picture is a device commonly used by planar pictorialists.

In stereo the principle is applied by selecting a point of view from which several objects are to be seen in relatively receding planes. It is always advisable to have some object in the immediate foreground to establish the strongly stereoscopic reference. Then a succession of objects farther and farther away leads the eye into the distance and enhances the effectiveness of relief.

It must be borne in mind that this and other devices do not actually increase the stereo relief. They only make more apparent the relief which exists, just as when we look down a wooded glade we obtain a sense of greater distance than when we look out over the ocean or across a vast plain. The enhancement of effect is no more and no less than is given to actual direct vision under similar conditions. This is true of all the psychological devices.

CONTOUR INTERFERENCE.—In selecting the point of view, any objects which are located partly in front of other objects more distant will enhance the stereo depth. The comparison of the glade and the open plain applies here as well. The effectiveness is increased just as it is for direct vision.

One need not fear for the confusion which exists in the planar photograph—those accidental mergers which tie up objects in the foreground to those in the background. The classic example of having a tree growing out of the head of the subject need not be feared in stereo, for the tree will appear in its correct position far behind the subject, and the two will interfere no more than if a similar distance divided them laterally.

SIZE DIMINUTION.—This will be seen in any composition in which the two preceding factors have been given place. It is as automatic as perspective, provided there are objects included which serve to bring out the factor.

In this connection it may be remarked that the surprising and frequently ridiculous size relationships seen so often in planar photography are never encountered in stereo. For example, take the photograph so often made for reasons of comedy in which a man is stretched out upon a park bench or the like, and photographed with his feet a yard or so from the lens and his head eight or nine feet away. The feet appear to be about two feet long. When the same thing is made in stereo, the man appears to be proportioned with complete normality and appears in the position he actually occupied.

The same thing is true of the perspective of tall buildings. The stereo camera may safely be tipped upward to include the top of any skyscraper. When the picture is viewed, all sense of falling backward is lost and you seem to be looking upward in the most natural manner. In viewing such stereograms, the realism is enhanced by holding the stereoscope so the head will be tipped at an angle similar to that necessary to view the original scene.

All of the so-called distortions of violent perspective are lost in stereo, and the stereogram has a wholly normal appearance. Perhaps there is no stronger evidence than this that the conventional photograph is highly artificial, while the stereogram is wholly realistic and does actually reproduce direct vision to the last detail.

LIGHT AND SHADE.—If you look at a large white ball with the light coming from directly behind you, the shape of the ball is not definite. It may be a flattened or an elongated ball, but you cannot be sure. If a planar photograph is made, the ball has the appearance of a disc, but in a stereogram exactly the same vagueness of form will be noted which is characteristic of the direct vision.

If the ball is lighted from above and at one side, the contour shadows make its shape unmistakable to direct vision. To the planar photograph these shadows impart a character which enables the shape to be "read." That is, we do not actually see it standing out in relief, but we can see from the shadows that it does have a round shape. The stereogram gives us the same definite perception that is seen in direct vision.

If a disc is skillfully painted with imitation contour shadows, it does not readily fool direct vision, nor is the deception effective in the stereogram. Both show it for what it is, while in the planar photograph the painted disc and the true ball are hardly distinguishable, if at all. Thus it will be found that stereograms are more decisively visible if a quartering light is used. This applies to portraits and to landscapes, to large objects and to small.

Dramatic lightings may be freely used in stereo, because the absence of the modelling light does not eliminate stereo relief. But empty shadows should not be used, nor should light be used as a positive element in the composition, for in the stereogram the light will follow the contours of the surfaces upon which it falls, and these will not have the same pictorial weight as in the planar photograph. In a planar photograph a shadow or a highlight is in essence a solid. In stereo a shadow is simply a shadow without form other than the form imparted by the surface upon which it falls, while light is simply light. These values are those of real life which is considerably different from the "solid" values they have in planar composition.

One exception to this is the definite beam, as from a spotlight or a sunbeam from a window. If made visible by dust or smoke, this beam will have the same position in space it exhibited to direct vision and so becomes far more effective than when used in the planar photograph. Anything which has definite visible form, whether tangible or not, will have that form reproduced.

COMPOSITION.—Among the usual elements of composition, the value of unity, harmony, and balance are as important as in planar photography, but it must be remembered that the pictorial "steel-yard" must now be applied from side to side as usual and also from near foreground to far distance as well, something entirely new in pictorialism. The patch of sky or the dark cloud no longer has its power of balance, because it is in the far distance and its "balancing weight" is much less than in the planar picture.

Composition in stereo is more difficult and more complicated than in planar pictorialism, but for that very reason it has potentialities which the planar form could never exhibit. To make use of a mathematical analogy, one might say that the planar pictorialist is limited to addition and subtraction, while the stereographer has the possibilities of division and multiplication as well.

Stereo composition is at present largely unformulated, which perhaps is just as well, for too much formalization of composition creates a stiffness and artificiality which has very little in common with esthetics. However, enough has been said to point out the general path to be followed.

The point of great importance in relation to stereo composition is that such a thing actually exists and must be taken into consideration. Once aware of the necessity for three-dimensional composition, the stereo pictorialist will lose no time in attacking the problem.

Strangely enough, among present-day stereo enthusiasts the shibboleths of the old pictorialism are still regarded as being potent. The result is highly amusing, because more often than not the attempt to compose according to the planar standard simply results in a stereogram which actually is inferior to one in which no attempt at composition has been made. For example, haze or atmospheric perspective included in a stereo no longer suggests a soft and mysterious distance. The distance is there in all reality, but the haze often appears to be simply the washed-out tone of a poor print.

Natural and Pictorial Beauty.—The beginner in photography who has ambitions toward the pictorial, makes endless negatives of "perfectly beautiful" scenes, and almost without exception the prints bring only disappointment. He then starts to study the rules of pictorial composition, and slowly he learns that very rarely does the beautiful original produce a beautiful picture. On the contrary, the prints he eventually exhibits will be made from subject matter which would be passed by the casual observer without the slightest suspicion that it had pictorial possibilities.

Pictorialism is based upon a set of wholly artificial standards. No one can ever claim that there is any beauty in a water faucet or a couple of eggs upon a kitchen drain board, yet pictures of such subjects have been made; pictures which no discerning critic can say are not beautiful. Thus the artificiality is not the result of preciousness, but has a very solid foundation. We are not dealing with certain schools of thought or faddism. It is a solid, inescapable fact that many of our most beautiful scenes sink into insignificance when photographed, and that many of our most beautiful outdoor photographs have been produced only because the photographer has developed his power of camera discernment. This is true because the values of an object in space are not its values when reduced to a plane. In the planar picture mutual effect of two objects distantly separated in space, but adjacent in the plane, must be carefully considered. Hence it is inevitable that in any planar picture the values must be decidedly different from those of the original.

In stereo this is not true. The values of the original are reproduced in the stereogram, hence the stereo slogan which has done so much to make it popular, "In stereo you get exactly what you *saw*," and that is true. The stereogram is a truthful reproduction of the original, which is never true of the planar reproduction.

The beautiful scene almost always yields a beautiful stereogram. However, this is apparent to the beginner more than to the experienced photographer. The writer has been deeply amused by the criticism of stereograms offered by pictorialists. It is quite obvious that such criticism has been made while studying the print directly, not the stereogram in a viewer. Such criticism is not only unjust, but its absurdity is manifest to anyone, skilled or layman, who hears the criticism while studying the stereogram in a viewer.

His comment is most often "Why, that is not true! That is not visible here. No such condition exists."

The stereogram cannot be criticized except when correctly viewed, for the subject of the criticism is not a photographic reproduction, but a synthetic image which is actually created within the brain and which cannot be "seen" without the simultaneous viewing of the two units. Moreover, as much as we like projection, it is an error to undertake serious criticism of a stereogram as viewed by projection. This should only be done while the stereogram is viewed in an accurately orthostereo viewer.

Let us take as examples two very commonplace errors made by the beginner. First we have a small lake, perhaps a mile across. The near shore is nicely curved and presents the requisite trees and shrubs. The whole is idyllic. But the sweep of water is the thing which gives the scene its beauty. The poor beginner makes his print and is dismayed to find his beautiful lake a mere smear a quarter-inch wide across the print, with the trees at one side rising abruptly to cut the composition in two.

The stereographer makes the same shot from the same position, but he has no disappointment because his stereogram reproduces the broad expanse of the water, giving it the weight it has in the original. The water is not a quarter-inch strip, but a surface extending a mile back into the distance. The relative pictorial values are just about upon the scale of one quarter-inch to a mile!

The next error is that typified by the profusion of growth in a swamp. Most people think of a swamp as an expanse of soggy grass and mud. On the contrary it is a place of luxurious growth, tall plants and shrubs, gigantic trees, lush flowers, and mirror-like pools. It is a subject which no amateur can resist, yet again the planar print is a disappointment. The growth is so luxuriant that the print presents a confused tangle of detail, all more or less in a monotone of gray. One can point out the various features, but the spirit of the swamp is missing, and the print is simply another failure.

In the stereogram, this detail is resolved into its original three dimensions. We can peep through the tall leaves of a lily to see the sparkle of the swampland pool. The rising columns of the trees with their patterns of cast shadows lend emphasis instead of confusion. We look deeper and deeper into the depths of this unknown terrain, and the stereogram preserves the spirit of the mysterious which the sight of the real thing brings.

The plane picture depends upon emphasis of some object or group of objects. These must stand out from the rest of the composition by reason of tone, contour, or psychological emphasis. In the stereogram the almost perfect monotone of the swamp picture attains far greater emphasis in the viewer than the most carefully composed plane picture. The emphasis is that of nature, not the artificial emphasis of the pictorialist.

Beauty in the stereogram depends upon the taste of the stereographer. If he selects a truly beautiful subject, the stereogram will automatically preserve all of that original beauty.

The pictorialist who turns stereographer must also use care in selection. If he follows his usual method and seeks to make a picture of some very commonplace subject simply by careful treatment, he will meet only with failure. This is the reason why pictorialists rarely become enthusiastic stereographers and why they usually condemn stereography calling it a purely record medium. The stereogram will reveal the commonplace subject as commonplace. The magic of pictorial composition is gone. The stereogram is the only reproductive medium known which will reproduce an original in its exact original appearance.

The stereo-pictorialist must rely upon nature for his beauty and be content to record it as it is. On the other hand, he has unlimited choice of point of view, lighting, selective arrangement, and so forth. The only thing that he must remember is that his choice depends, not upon the tricks which can be used in plane photography, but upon the effect of each choice upon the actual appearance of the subject which is to be stereographed.

There is sufficient beauty in nature to satisfy the stereographer, certainly, so instead of trying to create beauty from ugly raw material, let him be content to present existing beauty in its most appealing aspect. Such is the basis of stereo composition.

There are no limitations as to subject matter. Nothing is unsuitable except a subject which is already planar. There would be little point in making a stereogram of a flat page of a newspaper. Anything which has solidity, which lies in more than one plane, is a subject which will provide a better stereogram than photograph.

The idea that stereo is not a medium for esthetic expression and is suitable only for purely record work, is wholly wrong. Stereo is capable of producing results which are as beautiful as those of any other graphic art, if not more so. The fact that we have not perfected a method of attack, that our taste has not become trained to the third dimension, argues only our own shortcomings, not those of the medium.

Generally speaking, the attack is one which must be worked out individually. We can observe the rules in so far as we know them, but the ultimate judgment must be based upon the effect obtained, just as it is in any pictorial work.

There are at present several stereographers who are already making progress in the field of stereo pictorialism. Many of these are Stereo Guild members, none of them from the ranks of the planar pictorialists. It grows more and more evident that the stereo pictorialist is a genius apart and the ranks must be filled from those heretofore unknown. The planar pictorialist, through long years of habit insists upon bending his stereo composition to fit the rules and limitations of planar composition which are intolerable and fatal to stereo.

We shall have cause to mention a few of these. This does not mean that those mentioned are the only ones. We should like to give credit to the many stereographers who have done outstanding work, but because of space limitations we shall mention only a few of those whose work is typical of some specific form of stereography. It is so much easier to discuss an actual stereogram than some synthetic ideal which does not exist.

The new stereo pictorialists have already shown a surprising variety in treatment as well as a high and admirable degree of individuality. Much of the work is excellent, most of it worthwhile. Any subdivision such as the writer may attempt comes only from the necessity of having some kind of classification which will make discussion possible.

Scenics.—One stereographer bemoaned the fact that he could not get to the West where "You can stumble, fall down and get a grand picture from the exposure you accidentally made while falling." That belief is widespread and every stereo exhibition has scores of scenes made in our National Parks. They are definitely things of beauty and no one would call them stereographic failures. But such scenes are not the only ones worthy of reproduction. In fact such scenes depend upon the majesty of the original and demand only technical skill on the part of the photographer.

On the contrary there are many scenic subjects whose beauty is revealed only to the observant, and when such a scene is used to make a beautiful stereogram, the stereographer deserves more credit than when his subject is such that a deliberate effort would be required to produce a poor picture.

For example there was such a subject reproduced by Faulkconer; the locale, the Indiana woodland; the time, early spring; the central subject a modest little waterfall. At first glance the slide seems to be in monochrome, similar to a brown-black toned slide. Nor is there anything in particular to recommend the composition when viewed as a planar picture, but when the stereogram is viewed as such, the whole thing changes. The monochrome resolves itself into tones of gray, green and brown, accented by a small tree filled with brilliant red and a smaller shrub sprinkled with white. The whole thing is a subtle composition, the first glance does not reveal the scene. It grows and continues to grow upon one, as element after element impresses itself upon one. Finally when it has been absorbed the spectator realizes that the scene is one of breath taking beauty and that it involves a subdued but highly intricate color pattern.

This scene is a highly successful scenic stereogram but one for the connoisseur.

Another subject is the pictorial representation of historic sites, a field in which Short is doing excellent work, although his specialty is the general scenic beauties of the Atlantic Coast from Florida to Maine. Autumn foliage is a subject which attracts many workers, but there are few who concentrate upon the color pattern regardless of the spatial pattern.

Figure work is a fertile field, but the usual pictorial euphemisms of planar figure study are not appropriate to stereo. There is a straightforward realism in stereo which is easily adapted to fantasy but which is incompatible with the little hypocrisies dear to the heart of the portrait and figure photographer. Dramatic lighting is more useful in stereo than in planar work, but if light is to be used as a spatial solid the beam must be made visible by suspended particles such as smoke or powder, if it is to be used as light it must not be given the pictorial weight of a solid.

Smoke, soap bubbles, tenuous veils, in short all objects whose physical mass is subtle are reproduced in stereo without taking on the appearance of being carved from cardboard as in planar work. These accessories to the figure have been used to good advantage, and occasionally as primary subjects rather than as accessories. Dunnigan has done excellent work in this field.

Stereo nudes are plentiful, good stereo nudes among the rarest of all stereograms. Among those whose work has come to our attention, we admire that of Hilborn. His nudes are living models, in unconsciously natural poses of everyday life. They are for the most part girls of natural grace who are not posed in stiff, formal, ridiculous poses, but who are living life naturally and easily, without clothing. The whole spirit of most of the Hilborn studies is that the models are simply not conscious that such a thing as clothes exists, and that there is nothing at all strange or unfamiliar with the condition of nudity.

But we cannot catalog every possible subject for the stereo pictorialist. We must proceed to generalizations if this chapter is to be kept within reasonable limits of space.

Modern Treatment.—The planar pictorialist argues that he is free from the bonds of realism, that he can embrace the whole universe of impressionism. That might evoke a number of statements which perhaps should be left unwritten. The writer has a deep admiration for some of the truly great impressionistic painters, but he has never yet seen a photograph presumably made after the impressionistic, modernistic or surrealistic schools which appeared to be more than a meaningless conglomeration! Perhaps the physical limitations of the medium prevent such a purely spiritual expression; perhaps the limitations lay with the photographers. At any rate the planar photographer has a real problem before he can bend the characteristics of the planar photograph to a genuinely impressionistic result—but the stereographer has no such limitation. His medium presents him with the possibility of retaining all the subtle elements of realism, all of the inimitable coloring of nature combined with a presentation which is more unreal, more fantastic and at the same time more harmonious than even the manual artists have achieved! Truly, stereo is the photographic medium *par excellence* for genuinely abstract presentations.

The stereo abstraction may be a wholly normal subject, given a definite atmosphere through considered treatment. Another, although using a normal original, attains a fantastic appearance through pseudoscopy. Then too, there is a third type which is purely abstract and is achieved by making a stereogram of an original which never existed in the form reproduced. For example a moving *point* of light is registered as a continuous *line*. But let us consider a typical example of the first type.

The subject, a dead tree, fallen, with white limbs reaching toward the sky from the surface of a river. Not so much of a subject perhaps, but treatment made the picture. The stereogram was made at night with flash. There is no light in the picture, no reflections from water or background, only those gaunt, ghostly limbs stretching upward. Nor was there the safe haven of the artificiality of paper, the thing was real, with all of its atmosphere of fantasy, of obscure premonition, of the atmosphere of death. It was only a few dead branches, inanimate, yet that picture carries more suggestion of terror than any I ever saw upon a plane surface. It is simply a stereogram of intangible atmosphere. We have seen three such stereograms by three different pictorialists. All were highly effective.

But now to the second type, what we might call, and with very good reason, the stereo surrealist school. The technique is absurdly simple, the absence of transposition, pseudoscopic viewing. It is a trick often used to make "puzzle pictures," it has been used repeatedly to emphasize the form of certain objects, but when the method is combined with a nice discrimination of form and color, the inversion of relief causes such a change that the subject is not only unrecognizable, it can often not be recognized when its identity is known. Yes, it is the simple shifting of elevation and depression into their reverse phases. The result is in effect a pure abstraction. There is not only color without apparent cause, just color valuable for its effect alone, but there is that which no painter of the abstract has even dreamed of achieving, a definite pattern of relief which is as detached from reality as is the color. This, too, has been used by many stereographers with a wide variety of subjects. (See Chapter 16.)

The disinterested person will very probably find the stereo abstraction more attractive than the painted one. Perhaps it is because the stereographer has the aid of nature to preserve proportions while form disappears as such, perhaps it is the subtlety of tone, color and contour gradation in which photography (plus stereo) is unexcelled, but whatever the reason, the effect is an utter sublimation of realism into pure impression.

There is another type of abstraction which has been given a great deal of attention. Perhaps many of you recall the Picasso story in *Life,* telling of the efforts of the artist to paint pictures with light, that is by waving a flashlight around before the camera. If so you may be surprised to know that for months before this article appeared stereographers were playing with just such "light pictures." But they were all in three dimensions and in multicolor! Dahl produced some excellent examples early in the game, and many have followed. We saw one in which a fiery female figure stood life size in a dimly seen garden, with multi-colored veils streaming behind her, all "painted" with flashlights and colored filters.

Line was abandoned as the sole medium early in this movement, now the light source varies from a pinhole to a beam four or five inches wide, so that splashes and waterfalls of fire may be produced.

This may not be art, but it is highly amusing. One amateur said he had to quit it because he used up twenty magazines of color film in one week playing with what he called "pyrographs" or fire pictures, not an inappropriate name.

FANTASTIC REALISM.—Directly opposed to this non-realism are the super-realistic stereograms made with electronic flash, and those made with stroboscopic lights (rapid succession of exposures upon one film). Not only do we see leaping figures frozen in midair and such subjects which are more or less familiar to us, but we have a group of such subjects which reveal exquisite beauties never before seen by man.

Perhaps the most outstanding work of this kind is done by the Kents. The subject in general, birds, the one specific stereogram in mind at present, a cardinal (red bird), in the air, braking descent preparatory to alighting, but a good two feet away from the landing place. The slide is perfect. Every feather visible, the scales on the leg skin clearly visible, in short all detail as clear as if the bird were stuffed, yet the taxidermist does not live who could impart that air of tenseness as the widespread wings are controlled with exactitude, and the whole body just ready to land. Nor is the color inferior to the other qualities of the slide. In short it shows what has happened before our eyes time after time yet which we have never been able to see because of the inefficiency of our vision.

Certainly that is a record shot, it has great value of scientific nature, but despite that, there have been few photographic pictures which could rival it in pure pictorial value! In fact, recalling the statement of the conventional pictorialist "Stereo is fit only for record work" one is tempted to reply, "Perhaps, but in stereo even the records can be superlative pictures."

But life is too short for recrimination and quarrels. The fact is indisputable that stereo offers quite as many pictorial opportunities as does planar photography; stereo offers several pictorial opportunities which are impossible to the planar photographer by reason of the inherent limitations of his medium; stereo pictorialism presents a challenge because its potentialities have not yet begun to be explored; and because the stereo picture is appealing to everyone inasmuch as it represents the realism of nature expressed by the individual stereographer instead of being a cold artificiality appreciable only by those who have been schooled in the complex theory of pictorial composition of a rapidly passing era.

Distance Limitations.—The question of distance limitation involves only personal preference and effectiveness, not any fixed rules. It is true that the older stereo technique did try to impose such limitations and there are even formulae which prove mathematically the existence of limitations imposed by natural law. The trouble with these "laws" is that they are transgressed daily by the new stereographers who never heard of them, and the results are quite satisfactory. A "law" which can be ignored without perceptible result certainly has little authority!

We have a formula to tell the amount of separation between objects which can be seen at various distances, and the formula would be dependable if only human vision were uniform; but the sad fact remains that no individual can predict what another can and will see. Therefore the formula can only give values which apply to those individuals whose vision is accurately in accord with the laboratory standards, perhaps one person in a thousand. We have another formula which proves conclusively that normal base stereo cannot be used at a distance nearer than—well ten, eight, five feet, take your choice! One marvels indeed at the power of mathematics—or should one say the dexterity of the mathematician? There is a good, sound formula to prove just about anything that anyone wishes to prove. Again the trouble with the formula is that it is meaningless because it does not even approximately conform to demonstrable fact.

What you can do with stereo depends upon your stereo sensitivity, and with all due regard to the theorists, stereo sensitivity involves more than stereopsis, at least more than the term stereopsis is assumed to include.

For example, there are two objects, both at a considerable distance; one is slightly nearer than the other. According to the formula, the distance separating those two objects must be at least such-and-such to enable you to see that one is nearer than the other. When you actually look at such objects you (as a rule) can easily see the separation and by careful observation you gain some idea of the amount of distance between them. Here stereopsis is superior to the formula. If they are moved closer together by a certain amount, conditions change. When you first look at them you can tell which is nearer, but if you study them you lose assurance and cannot tell which is nearer. Here the tenuous stereo sense has operated but stereopsis is now undependable. This subtle sense is difficult to identify but the writer feels sure that it is only the normal operation of dynamic parallax. As long as the eyes move from object to object, the stereo sense is most acute, and as soon as the eyes become fixed, the acuity drops. At least this is true for general conditions and there is no reason why it should not also explain the discrepancy between the delicacy of the stereo sense, and that of stereopsis as usually defined by measurement.

One thing is undoubtedly true, the conventional stereo limitations are certainly far more restricted than is warranted by average normal vision. But we must remember that these limitations were worked out by men leading a largely sedentary life, by students, by city dwellers, by those in whom we should expect to find the lowest degree of stereopsis. When the average of outdoor dwellers, foresters, hunters, seamen, farmers, small town and village dwellers, and particularly those who habitually make use of stereograms are examined we find the actual value of stereo infinity jumping to from two to three times the stated limit!

As for near distance, there seems to be even less logical reason for its imposition. There is no near limit for stereo. The nearest distance the writer has employed is (theoretically) 1.5mm, using a micro objective of that focal length. However, not to quibble, the nearest distance at which stereo may be used with a normal lens separation is the nearest distance at which the homologous images fall upon the film area provided, a matter of inches, not of feet. Of course, as explained in the chapter on closeup work, this involves a discrepancy in field and loss of picture area; the tall, narrow panel is not esthetically attractive, but as far as stereo is concerned, the image is reproduced and it is reproduced with that degree of relief which would be seen by the eyes at the same distance.

The trouble lies in the "mental policing" which has been mentioned before. We are not consciously aware of the flattening of round objects by distance and similarly we are not aware of the exaggerated relief which we actually see when an object is held close to the eyes, but stereography is certainly not responsible for the vagaries of human vision. The stereogram represents just that degree of relief which would actually be seen by direct vision, always provided of course that the lens separation is equal to the interpupillary. The mechanism of parallax is as automatic as that of perspective. There is one factor, however, which does exist in the extreme close-up: those made at a distance of about one foot or less. The dissociation of accommodation makes the extreme convergence noticeable, and the actual muscular tension, as it changes to follow the extreme depth changes, can be felt—but not painfully. The effect is rarely noticed unless the convergence depth is considerable; and it is rarely experienced when the original distance exceeds 18 inches.

True, many stereographers, particularly those of the old school who pride themselves upon their orthodoxy, will refuse to look at a stereogram made at two or three feet, exclaiming that it is "a caricature," "intolerable," "a travesty." I often wonder if they can really be sincere, if anyone is really capable of such self-deceit, if anyone can refuse the actual evidence of his own eyes to such an extent.

There is always the proof of the pudding. The chances are that you have a camera which focuses down to 2½ feet. Make a picture of a rose, for example, at this distance. Compare the stereogram with the original, looking at the latter from the same distance of 30 inches. The stereogram is no more difficult to view than is the real rose! The stereogram shows no more exaggerated relief than does the actual rose! And moreover nothing but the stereogram made at 30 inches can show the true appearance of a rose seen at 30 inches.

Short has done remarkable work with outdoor subjects. One is a group of small salamanders in a setting of moss and violets which is worthy of acclaim. Although made at about 18 inches, there is nothing in the slide to indicate the fact. Only the size of the known objects provides a hint, but nowhere is there any indication of depth distortion. Brooks also does superb floral work at very close distances as well as definite macro. All of his slides can be viewed with complete comfort and exhibit wholly normal stereo relief.

Our frank advice to you is wholly to ignore all such "laws" which can so easily be demonstrated to be meaningless. We do have stereo laws, real laws, laws which can be demonstrated and which are always in effect. Those we respect; but we cannot respect "laws" which have been promulgated simply because they substantiate the defective stereoscopic vision of some one individual or group of individuals.

Mathematics Versus Suggestion.—Just a word about mathematics. This is an exact science, the nearest approach to the absolute man has made. It is invaluable in most human activity. To question either the exactness or value of mathematics would be absurd. The trouble is that in stereo, theorists have used perfectly sound mathematics to "prove" their inoperable theories, and because the mathematics are sound, the reader accepts the proof. The fault usually lies in the assumption of a false premise, which is, of course, not evident in the mathematical presentation.

But when mathematics explains (not proves) phenomena which have been substantiated by the only tenable form of proof, actual demonstration, we discover the full value of the science.

Still, there are discrepancies which cannot be explained clearly by anything but analogy to other sensual experience.

There certainly is a limiting distance beyond which the eye does not distinguish parallactic difference. There is beyond question a true stereo infinity. Moreover that limit can be precisely evaluated provided we can devise some accurate measurement of the fundamental sensitivity of the particular individual involved. Once the basic evaluation has been made, the physical stereopsis of that individual can accurately be predicted. All this is of the utmost value in certain stereoscopic studies.

While officially stereo infinity lies at 670 meters, somewhat less than a half mile, among outdoor people, experience and observation indicate that the limit actually exceeds a mile. It is doubtful that anyone has a stereo infinity at a distance greater than 2½ miles. But, if you make a stereogram of a scene which embraces a depth of five miles or more, you can actually see in the stereogram, the *natural visual* relief extending to the full limit of the scene. You can even see this in a stereogram in which the depth is 20 or 30 miles, as in some scenes which include distant mountain ranges.

Why can you see relief through a depth several times as great as the value of stereo infinity?

The explanation is the familiar one. The stereogram shows you just what you would see if you were looking at the real object. When you see such a scene, you are not conscious that your perception of stereo relief ceases at about a mile, more or less. You "see" the relief right back to the limit of vision. Why?

In this chapter we have already discussed several extrinsic factors which enhance the *appearance* of relief although they do not affect the true relief. As true stereo relief becomes less and less evident, these extrinsic factors take over and there is a gradual replacement until, at stereo infinity, they have taken on the whole load of relief.

Stereo perception does not mean the ability to see that depth is present, it does not mean that contours can be interpreted. That can be seen in a planar photograph, and a person who has unfortunately lost one eye often has a very good judgment of distance. The perception of stereo relief is that sensation which enables us to *see* (not judge or interpret) the most minute details of differences of depth. It is something impossible to describe to those who have not experienced it, something which can with difficulty be distinguished from the extrinsic evaluations when it is described to those who have stereo vision, but which is instantly and obviously apparent as soon as a stereogram is viewed.

The difference is overwhelmingly great, yet it is subtle. For that reason, even when one is aware of the problem involved and makes every effort to determine the boundary between stereo and extrinsic depth evaluation, the limit can be only approximately defined.

Because the stereogram reproduces all of the effects of the extrinsic factors as well as those of the intrinsic parallactic factor, the stereogram shows you what the eye would have seen. True, those who have studied the subject for years can see the flatness of distance either under direct vision or when viewing the stereogram.

But after all, this is merely the splitting of technical hairs. You are not interested in the psychology or the physics or the mathematics of stereo. You want to make attractive stereograms. That is no doubt the full extent of your goal, even as it represents the ideal ultimate of stereoscopic photography.

Then, the one thing you want to know is this: The limitations of the normal stereo camera are the limitations of a normal pair of eyes, because "What you see, you get."

At the same time, objects relatively near, say at distances of three to 20 feet, are the most clearly delineated to vision because truly familiar objects are usually seen at such distances. You will find that stereograms made within these limits will usually afford you the greatest degree of satisfaction. This is not true because of any limitations imposed, but because it represents that visual zone which is the most satisfactory in direct vision; and any exceptions which apply to vision apply to stereo.

Chapter 10

THE NUDE IN STEREO

Probably many of you who read this have no experience in pictorial work, either in photography or any of the arts. If so you probably wonder why the importance of the nude is stressed to such an extent. In short, why photograph the nude?

There are many reasons. The nude is the human being; the clothed figure is hardly more than an advertisement for the clothing industry. You cannot effectually pose the draped figure until you know, thoroughly, the form and function of the body which supports the clothes. Then too, the human figure, particularly the female, is the most beautiful object we know. This is not a matter of the forbidden or of the unknown. It is a simple matter of color and texture, of contour and shadow gradation, of line and inherent grace of movement. If a clay figure could be made which exactly duplicates the body, it would serve almost as well as the living human. However such imitation is impossible, for at each movement there are subtle changes of the underlying skeleton and muscular structure which are reflected upon the surface. One of the great attractions of the nude lies in its infinite variety.

The nude figure comprises the sum of all the important problems which the photographer has to face. If you can make a good nude, you can make a good photograph of anything. Nothing else can give the training in lighting and posing which this does, and nothing can lead to such a long series of disappointments; that is, if you take real pride in your work and are not satisfied with a mediocre result.

But all of this has to do with technique. There is to this problem another aspect, which is so important and so wholly absurd at the same time, that it must be straightened out. This is the layman's conception that the nude is offensive. For the most part we have two great groups. One group states that the nude is obscene *per se*. The other group simply replies that the artist should be above such considerations and be permitted special privilege in the matter. Both points of view belong to an age which could produce the inquisition and the witch hunt. Both are so utterly absurd that they should be ignored were it not for the fact that these two groups are numerically so great.

The first is perhaps the more excusable. True, it is difficult to conceive of the unwholesomeness of the mind which can possibly perceive anything offensive in the human figure; but that is still more easily understood than the mind which believes that while the nude is offensive, it must be made use of by a restricted element of society for artistic purposes. The latter group prates of idealism, and neutral attitudes, which is sheer nonsense. The very ones who use the statements disbelieve them. They are excuses, not reasons.

The whole situation arises from the fact that as a nation we are incredibly adolescent. The question of sex is involved, of course. But the whole trouble lies in the general unwholesome attitude toward sex. After all what is it really? It is the sole force which is responsible, of course, for the population of the world; but more than that it is the sole force which has resulted in our progress, which is directly responsible for every great accomplishment of man, of all great art, music and literature, of all invention and discovery. It is a scientific fact that it is the factor which prevents man from stagnating, from becoming dull, stupid, mean, treacherous and generally repulsive.

The origin of our national fear of sex is difficult to discover. Of course it all stems from the older eras when a woman was a chattel, a thing purchased and owned purely as a plaything for man. But while we have progressed in every other way, we still make the degradation of sex a principle of social progress! We permit the most disgusting abuses of eating and drinking, a man may take to drugs or dissipate his whole substance in gambling and we are indulgent, but if he is "guilty" of the most natural sex activity he is condemned. It is simply beyond any intelligent logic.

Yet those who are most bitter against any idea of sex refer to it constantly throughout their lives. Such words as "he" and "she," "man" and "woman," even "boy" and "girl," or "king" and "queen," "horse" and "mare" and so on through hundreds, yes thousands of words, are differenced only by sex. These very people are the ones who would rebel most strongly against becoming asexual. In fact, the psychologists inform us that those who are most rabid in anti-sex crusades are those whose minds are preoccupied by the subject.

Sex next to life itself is our most vital driving force. It is the most precious gift we possess. It alone gives us a touch of divinity and makes of every one a creator. It is not only pure and wholesome, it is the most sacred thing known to man. If man cares to deliberately defile it, that is his misfortune, but it does not affect the status of sex itself.

The wholly innocent person is unaware of sex, and the nude is the very mirror of innocence. But, and this is important, when a bathing suit is donned, does it add to modesty? Again our psychologists tell us that the brief covering only serves to make conspicuous the areas covered, where before they were but components of the whole without emphasis. More practically it is known that pictures made with base intent always make use of a certain drapery to enhance the suggestive effect. In short the producer of objectionable pictures and the anti-sex crusaders favor the same degree of obscurity. We should hardly care to point out that similar minds think along similar lines, but there it is.

On the other hand, there is no new situation which loses its novelty quite as quickly as being in the presence of the nude. For example, I recall one picture which was fairly elaborate. There were some six or eight nude models in the composition, and work had been proceeding for several hours. Finally the chief was satisfied and signalled for lights and the exposure. Nothing happened. The cameraman and the electrician had become bored and had started a sharp argument. As I was near I had heard the whole thing. The subject of the argument was, you will be surprised to learn, the abilities of two rival baseball pitchers of the season. The presence of a half-dozen very beautiful nude models meant no more to these men than the painted background. Later I asked the electrician about it. His reply tells the whole story. "Aw! You get fed up with naked dames in ten minutes. If they'd put some tights and ruffles on 'em and let 'em dance, you'd have something!"

To sum up the situation, there is nothing more inherently objectionable in the nude than there is in a new automobile of which you might wish to make a picture.

It is true, of course, that highly objectionable photographs are made and circulated, but these offend good taste far more than they offend morals. However, because so many of our fellow citizens limit the term "moral" strictly to sexual morality the law has been forced to take cognizance of the fact.

It became necessary for the law to create a line of demarcation upon one side of which poses would be acceptable, on the other side objectionable. The result was hilariously funny, but after all it was as well done as could be expected when a physical limitation is applied to subjective reactions tinctured by idiosyncrasy. The law simply says that if the pubic hair shows in the picture, it is necessarily objectionable, but if it does not show, the picture is acceptable! The processing laboratories accept that legal differentiation, so if you want your color films returned, be sure no pubic hair is shown in the pose!

Of course it is absurd! It is perfectly easy to make a photograph with the pubic hair fully displayed yet to have that the most innocent of poses. At the same time it is even easier to make a photograph in which the pubic hair, the breasts and the face are all concealed and to have that a pose of the highest suggestiveness. For example see some of Boucher's paintings, the prized possessions of some of the great museums. But as long as the difference lies in the *mental attitude of the model,* (and the physical expression lies in nuances of muscular tension too vague to be verbally described, but instantly apparent to vision), what can you do about a legal differentiation?

Too, when you have certain people, many of them active in anti-nude crusading, who find unlimited suggestiveness in almost any photograph of an attractive woman, and when at the same time there are thousands of people who have no reaction whatsoever to a nude study other than to admire its beauty, how can you apply a differentiation? If we should allow laws to be based upon the mental wholesomeness of the individual we should be lost.

No, ridiculous as it is, undignified and unseemly as it is, the law is perhaps as good as can be expected as long as some kind of limitation must be imposed. Of course, the only sensible position for an intelligent society is to have no such limitations at all. Any kind of censorship is but an evidence of the desire of one group to impose its ideology upon another, the germ of dictatorship. It may be assumed that most adults are capable of guiding their own lives, particularly as long as they happen to be so fortunate as to possess that one characteristic whose absence seems to be typical of the usual "sex" crusader, namely, good taste.

In time this will come. In time, and I expect to live to see the day, all sex taboos will be things of the past, and then we can work freely with the nude just as we do with a rose or any other object of superlative beauty.

There has been a great deal written about the pose. One school "idealizes" the model by obscuring shadows or by the use of some absurd drapery which only accentuates the features which the photographer thinks he obscures. He should learn the true nature of the nude. Another school assures us that only those poses are permissible which shriek to high heaven of artificiality. Their argument is that the offense lies in naturalistic poses. They too have been contaminated by the universal poison.

Consider this. Except for reasons of physical comfort, there is no reason why you should not converse, play bridge or eat lunch with one or more nude people. Of course, the average figure being what it is, this might not contribute much to esthetics, but much of our lives is subjected to unesthetic influence. Consider also that clothing is merely a collection of rags hung upon the framework of the body. The original purpose was protection. Today designers of clothing are quite frank in saying they are guided by the importance of making women more attractive to men and to hide the deficiencies of the natural figure.

You think this extreme? If you ever use as a model a girl who has a "fashionable" figure you will never again doubt it. The emaciated, flat-breasted, masculine figure which is "fashionable" is utterly hopeless for figure work. Rather select a model who is somewhat "dumpy," not extremely so, but too much so to be fashionable. You may probably find a figure which approaches perfection. Women do not like this statement and argue against it, but their mirrors tell the true story. The feminine figure has breasts, a waist of certain constriction and widened, oval hips.

But most of all, clothing hides deficiencies, in some instances almost deformities, which are so common. It might be said in passing that the most vigorous enemies of the nude are the unfortunate women who need such camouflage.

Therefore, the presence or absence of clothing should not be regarded as of more than the most insignificant importance. And this in turn leads us back to the original question of the pose.

The pose of the nude is best when the action expressed is wholly normal. Lounging in a chair, lying on a day bed, playing with a kitten, picking flowers, eating lunch, reading, swimming, or anything else which is normal and which gives rise to normal physical motions. The only requisite is that the model be wholly unconscious that the state of nudity is in any way unusual.

One writer has cautioned against posing the nude out doors without a blanket or some such protection. Such consideration is admirable of course, but the blanket introduces a false note, and I must add that this man's models must have been far more delicate than those with whom I have worked. They seem to care no more about the presence of rocks, sticks and stones than would a man. And certainly when you take away the model's clothing for a pose in natural surroundings, the blanket is definitely out of harmony.

The selection of a model is often difficult. It is not so difficult to find a model, but it is difficult to find one who enters into the spirit of the work, who will try to work with you in your problems of composition, one who will learn and advance in ability as you do. Of course you can always hire a professional, but this is inadvisable. First the rates are extremely high. Few of us can afford $50 an hour. In the second place, the professional is accustomed to professional photographers, whose work is purely commercial and whose work is carried on in an atmosphere of blasé boredom. She will be contemptuous of your first stumbling efforts, and will never be in sympathy with your work. The idea of trying to create a picture for the simple joy of doing it lies beyond the comprehension of the commercial world. No, by all means find a sympathetic amateur. Your progress may not be as fast, but it will be much better. Moreover you will have a chance to develop your own pictorial individuality without the influence of the stereotyped commercial world.

Before starting the actual posing, you should give some time to a study of art anatomy. Any pose which can exist is one which superficially interprets the function of bones and muscles beneath the skin. Become at least somewhat familiar with this underlying structure if you wish to avoid poses which are unnatural and awkward. A whole volume could easily be devoted to this one subject, so instead of trying to present a too brief resumé, we shall only advise you to obtain a dependable reference text, (your local library can possibly supply it) and go through it conscientiously.

When starting the first session with your model, you will both be somewhat self-conscious. There is no use trying to do any camera work as long as any trace of this feeling exists. The model will probably lose it before you do. At any rate, have another woman present, preferably the mother or a sister of the model. Put in the first study period by having her assume certain poses illustrated in the art anatomy. See for yourself the skeleton and muscles as they function. Once you have the key it is surprising how clearly you can really see these submerged motions. Have your model leave off her robe even during rest periods at first. Cultivate the complete and wholesome normality of atmosphere in the studio. A single 30 minute period at most should suffice.

The next session can be devoted to elementary figure work. If you can possibly find a copy of Fred Peel's *Shadowless Figure Portraiture* study the poses and especially the fragments. Use one period and at least 15 exposures of the elbow alone. Do the same with the knees, then to the ankles with feet, the shoulders, the head and neck from the rear so as to exclude the distracting element of the face. Give very careful attention to the hands and wrists. Of course the model need not be undraped for this type of study, but it is highly advisable that she be so. Just so long as you continue to think there is anything in the least abnormal in the state of nudity you will fail to produce really good work.

The torso from the rear is worthy of several sessions. With each change of pose there is a shift of the line of the spine. This line has naturally the recurved form which is characteristic of the Hogarthian Line of Beauty. Other lines branching to one or both arms illustrate harmony of line. Alteration of masses by shifting lights gives opportunity for endless studies.

The torso front introduces more problems. The simplicity of the back is gone. The breasts make up one distinct area; the abdomen another and they are separated by the waistline. This division must be handled to eliminate any division of mass, and at the same time you have a complicated problem of contour. When you have mastered the elements of a static pose, go ahead to others and note the change of both breast and abdominal lines as the model leans forward, or raises her arms, or when she lies supine.

When you have made at least 100 fragmentary studies you are ready to start serious figure work. Again simple, natural poses are the best. From your study of anatomy and the fragments you have made you should be able to see grace or awkwardness of line in any part of the figure. If the line is right, note the masses, study contours and the effect of lighting upon them.

If space were available it would be possible to give a number of possible poses, and to give several warnings as to what to avoid, but if you find you need them, there are several such texts available on the market. The better figure photographers however have developed their own taste in the matter. It is advisable however to present a few "don'ts":

Avoid dramatic poses, theatrical ones. Despair, worship, fear, adoration, any strong emotion should be avoided. Your model might be able to give a fair facial expression to such emotion, but not to her body and always remember the body tells far more of the mind than does the face! The same thing applies to the precious and artificial poses so popular a half century ago. Avoid the allegorical pose as you would the plague. Stick to the normal, everyday pose. You have a model, for the moment the archetype of man's indispensable and adorable helpmeet. Photograph her in character. Do not ask your model to be an accomplished actress as well as a model.

So much for the question in general. Now what about the nude as it appears specifically in stereo? Stereo does impose an additional load upon the photographer of the nude, just as it does in all pictorial work. The planar photographers have repeatedly said that in stereo the nude ceases to be a nude and is simply a naked woman. Surely that is what any nude should be!

In all stereo work we are faced with the task of making reality beautiful. The artist simply omits objectionable features; the planar pictorialist hides them in some "dramatic" shadow, the stereographer either removes the element or works it into the harmonious whole of the composition!

The stereographer is forced by his medium to abandon the decadence of an effete civilization and to return to the unsullied wholesomeness of nature. More than that he must extend that same attitude to every minute feature of his scene. That paper plate in the background, a souvenir of some picnic party, will not be a mere white patch easily removed by retouching. It is a paper plate, round and light in color and foreign to the setting. See it and remove it!

Nor can you indoors depend upon tonal mergers to effect your composition. The dark wall behind the model's head will be far behind her and you cannot merge the two. You can kill all detail, but the relief of the lighted part of the body will establish it in a plane in front of the wall.

In the pose itself, you cannot disguise an awkward elbow angle by swinging the arm back to make the angle more obtuse. As long as that angle persists in any direction it preserves its awkward appearance. Forget foreshortening, it doesn't exist. That is a feature of planar reproduction.

Do not study the pose in the finder, you will be deceived by the planar effect. Do not study it from a position beside the camera at first, you will see a different aspect. Study the pose by looking just over the camera. Base your judgment upon the appearance of the model as you see her. The stereo camera will reproduce what you see.

Then of course, learn to use your eyes. Your first attempts will be disappointing, and you will swear that the picture does not resemble the original pose. Oh, but it does! Precisely! The trouble is that you have not yet learned to see. Most people do not actually see one-tenth of the things upon which their eyes fall. You will be disgusted with yourself at first because of the many disturbing elements which you overlook. Take plenty of time. Study the pose. Have your model shift the pose slightly, or better yet, make several exposures in each of which there is but a minor change.

Study all of them. Select those which you like best and then continue the study until you decide why you like them.

Show all the poses to the model. Have her select her favorites. See if they are the ones you chose. (They will not be.) Find out why she prefers them. Explain your choice to her. The discussion will help both of you tremendously.

If you have a projector, project the slides. Block off one lens of the projector and study the planar picture. Then change to stereo. Note the great change. This will do more to teach you the difference between stereo and planar than could be done by a book twice the size of this one.

When you have had a little experience, start studying the model stereoscopically. Study the pose over the camera. Then move to the left, then to the right. Study the pose from several angles. Try to obtain a pose which is satisfactory from every angle.

Next obtain a pose which is fully satisfactory from the camera position, but which is decidedly unsatisfactory from the side angles. Make this exposure also. Study the two and compare them. You will find that the pose which was satisfactory from all angles is decidedly superior to that which was satisfactory only from the camera position.

This is true because when we look at an object, we make use of stereoscopic vision subconsciously. It operates all right but we are not specifically conscious of it. Therefore we concentrate upon the planar effect. But with the stereogram we remain clearly conscious of the stereo relief. Mentally we shift our position to look around corners. We try to estimate the appearance of the subject from other angles. This seems to be carrying an argument to the hair-splitting stage, but one trial will convince you of the undeniable reality of the fact.

In planar work a model is often moved a few inches out of natural position, or she is instructed to look slightly more toward the camera to give a better view of the face even though she is looking off into space. This is known as "faking." Do not try it with stereo. The fake is obvious in the stereogram.

Then too there is the oft-repeated statement that women in a photograph appear shorter and stouter than in real life. Frankly I do not see it that way, but perhaps those who are not trained to analytic vision are so deceived. At any rate I have had others speak repeatedly of the fact that stereo does not have this effect. I have had several women say about a stereogram, "Oh! I like that. It doesn't make me look fat as I usually do in a photograph!"

Another point. Often a model will wear her shoes in the studio only to kick them off at the last moment. Avoid this. The shoe marks the foot, and often the dye rubs off upon the toes leaving a decidedly unwashed appearance, which is far more obvious in the stereogram than in a planar photograph.

Very often too, the model will have a scratch or bruise upon her ankle or calf. Cover the mark with makeup before the picture and blend the edges carefully. Slap-dash makeup is as apparent in stereo as in real life.

Another error which is made is to leave some jewelry upon the model. Do not do it. Jewelry is clothing which turns the nude into a semi-drape and ruins the whole atmosphere. Rings are easily forgotten, but I could never understand the reason for one model posing with an elaborate wrist watch as her only article of apparel.

Facial makeup should be kept moderate. In fact, heavy makeup in any stereo is a mistake. If the fingernails are enameled the toenails should be covered to match, but as a rule the better result follows when all nails are natural. The fingernail enamel is the stepping stone between nothing and jewelry just as that lies between nothing and clothing. It is the touch of the artificial which can adversely affect the result. The same is not true of facial makeup as long as it is used to accent natural features. The unpleasant habit of many girls of repainting the shape of the lip is as ludicrous in stereo as it is in real life, and not a bit more deceiving.

The hair is a matter of argument. Of course any elaborate hair dress is out of place. But as few models today have long hair, this is not a problem. Any *simple* style of hair dress will usually serve. Here too remember the three dimensional relief of stereo. A hair dress which might appear simple in planar might reveal too clearly the artifice employed, when the stereogram is viewed.

When you can make really good stereo nudes, start dressing your model. First go to the bathing suit. Note the difference. First of all there is the color disturbance. No longer is there the flow of natural color. Even a "flesh" colored bathing suit does this.

Next note that the beautiful breast line is ruined, and has become a shapeless bulge. A torso study which is beautiful in the nude now becomes ridiculous. There is an ugly accentuation of the hip line. In short all of the esthetic attraction has gone.

Next add hose and shoes to the bathing suit. What is the result? For the first time you do have a definite suggestiveness. You will not like it.

Next have the model dress in all of her clothing, less the outer gown. This may be stepins and brassiere, or it may be a slip or whatever she happens to use. Here you have the secondary foundation upon which the dress rests. The curve of the lower spine is gone. The recurve beneath the buttocks is concealed. The feminine contours have been transformed into a set of curious curves ending in almost geometrically flat planes. Without your prior anatomical knowledge you would have no conception of the true framework beneath.

The characteristic shape of breasts and hips disappears. Both are compressed into shapelessness. By contrast the waist seems to bulge. The whole figure becomes amorphous.

Finally the outer gown is applied. Now what have you? The foundation used has ruined the figure, and now the gown can only decorate the shapeless figure beneath. So the gown itself is decorated and made attractive. The natural beauty of the feminine figure is replaced by an example of the dressmaker's art, and what we admire is not the disguised figure but the dress!

But no matter. You now have a draped figure with which to work and with which to do your best.

Now I want you to imagine two stereographers, each with his own draped model, both trying the same pose. A has been through the training with the nude, B has never worked with a nude model.

B will be worried. He will say, "Well, I don't know just what it is, but you don't look right. Try walking away and coming back to the pose." The model does so, and there is no improvement. B suggests changed hand positions, turning the body, bending forward and bending back until the poor model has become as stiff as a wooden figure.

A looks at his model and says, "Just a bit more weight on the right leg. Drop the right pelvis line a quarter inch, rotate the left thigh a hair." He studies it a moment. "Center of gravity back an inch and drop the right shoulder just a bit." He looks again, makes the exposure and gets just what he wants.

B works all day and gets nothing because he has not the slightest familiarity with the object of which he is making photographs, he directs in terms of dress instead of terms of bones and muscles!

Even the actual folds of drapery usually respond to a good bone position, more easily than otherwise, at any rate. So if you know the figure as a result of personal experience, if you can visualize the figure beneath the gown, and the true figure beneath all the restraining garments, the muscles beneath the skin and the bones beneath the muscles you will be a long, long way down the road to successful stereo figure work.

Chapter 11

ANAGLYPHS

Since the dawn of stereo there has been an endless search for some method whereby stereograms of unlimited size could be seen. The first solution was the original anaglyph. Today this is known as the chromatic anaglyph, because we have a superior new type, one which approaches the ideal. This is the polarization anaglyph, which is more commonly known as the Vectograph.

It is known that the stereo impulse depends upon the simultaneous stimulation of the two eyes by two different stimuli. It is also desirable that these two stimuli should be placed so that no excessively abnormal vergence is needed to view them.

It is also known that in additive color mixing, any pair of complementary colors will produce white, and that this theory is borne out in practice to a considerable degree. It is further known that in subtractive mixing, two complementaries will produce black.

It would seem, therefore, that if a mixture, for example, of orange-red and blue-green will produce white, the separate stimulation of the two eyes by red and green simultaneously should produce a sensation of white through stereo fusion. If this is true, then a red picture and a green one presented separately to the two eyes should produce an achromatic image (neutral or white). If the red image is blanked out by a red filter and the green by a green filter it should produce the necessary stereo differentiation.

Thus, the first anaglyph consisted of a stereogram made by printing a picture in red, and another picture in green was printed directly over it. This was viewed through a pair of "spectacles" containing one red and one green lens.

The result was mixed. To some people there was an excellent stereo effect; to others there was a stereo relief visible but upon a background of alternating flashes of red and green. This latter is said to be a visual-pathologic condition, but if so it is widespread. The anaglyphic motion picture was first presented publicly three or four decades ago and was withdrawn because of the complaint from those who suffered headaches resulting from the color alternation. In fact, this phenomenon was so prevalent that its name, "color bombardment" was a commonplace in the photographic and motion picture industries some years ago!

The writer experienced definite color bombardment, even from still anaglyphs when he first saw them. The discomfort rapidly lessened, and today the anaglyph, either moving or still, provides perfectly neutral fusion and comfortable stereo. However, the uncomfortable color bombardment effect is constantly met with among many people. It may be that this is something which is subject to a developed visual skill. We have not performed nor are we aware of any such experiments as might prove or disprove this theory. It is simply offered as a question as yet unsettled. The evidence might seem to suggest it, but the evidence is not sufficient in quantity nor has it been subjected to a sufficiently searching examination to warrant a definite statement.

The fact remains that some people view the chromatic anaglyph comfortably, others do not.

The method described above is widely used in Europe for periodical illustration and for the preparation of mathematical drawings, particularly in geometry and trigonometry. A German army periodical was printed with almost 100 percent anaglyphic illustration. Since World War II, in Russian Berlin, a whole series of mathematical texts has been printed with anaglyphic illustrations.

However, strangely enough, the continental anaglyphs are poorly done, the ink colors have not been properly balanced to the filters used, and there is a strong residual image where there should be none at all. In this country we prefer to place the red and blue inks far within the spectral cutoff of the filters, and we achieve an almost total blanking out of the unwanted image. For this reason, we usually print in a blue rather than green for the one color and a fire red instead of vermillion for the other.

Amateur anaglyphs are often made. The images are either toned with blue and pink toners (as used in the once popular Chromatone color process), or they are printed from dye masters in the popular dye-transfer method. In halftone printing, two engravings are made with about a 30° difference in angle. These are then printed in blue and red. For example, a peacock blue and fire red have been used in the Guild laboratories.

Reproduction of Anaglyphs.—The question of restoring anaglyphs to their normal stereo form has often been raised. This is very simple. The anaglyph is copied upon panchromatic film using photographic filters which will separate the two ink colors.

When the same copy is used with both a tricolor A and a tricolor C filter, the A filter will record the blue printed image and the C filter will record the red printed one.

If the anaglyphs are of the polarization type, the camera filter is a simple polarizing filter. One copy is made with the filter blanking one image and the next exposure is made with the filter rotated through 90°. Panchromatic film is not necessary in making polarization anaglyphic restorations.

Polarization Anaglyphs.—This is the process which is known as the Vectograph and for some reason it has never been freely offered to the amateur. The Vectograph process was developed by the Polaroid Corporation and was widely used in World War II with the utmost success. It was later adapted to a unit for home use for ophthalmic therapy by Bausch & Lomb, and has had limited use among amateurs. It is highly satisfactory in every respect and solves many problems as old as stereo. The pictures are in full tone, monochromatic (color is being developed) and have all of the quality of a normal print. They exhibit the unmistakable relief found in normal stereograms, and, in fact, offer a solution to the problem of an album full of stereograms which are to be looked at in exactly the same manner as any collection of snapshots. They may also be projected in any standard single frame projector, and if made as motion picture film they may be projected in full relief by any standard home movie projector.

Polarization anaglyphs are made from normal stereo negatives, but instead of being printed in complementary dyes, they are printed by the dye transfer process in a dye which crystallizes in dichroic form. There are many substances which will react correctly, but the formula developed by the manufacturers is excellent.

The secret lies in the base used. This is an optically active plastic (transparent) base. By printing the image on the two sides of this active base in the correct type of crystalline image, the two images are polarized at 90° to each other. The examination of such a dual print through the usual 3D goggles used for common stereo projection produces the full stereo effect.

Neither the base nor the image is effective alone. Only the combination of the image made up of crystals of the proper type with the optically active base will produce the effect. It need hardly be added that the crystalline structure is not visible to the eye. The images have the full quality of any fine dye transfer print.

The normal Vectograph is a transparency. If it is desired to be used as a print, the back is coated with a solution of very fine aluminum powder in a suitable vehicle. The aluminum serves the same purpose as the white paper in an ordinary print, but to preserve the essential polarization it is necessary to have this reflecting layer of metallic material. Hence the aluminum.

However, the Vectograph is at its best as a transparency. In relative large sizes, 8x10, 11x14, or larger, and placed in an illuminated frame, Vectographs form one of the most striking of stereo exhibits.

The Vectograph would be ideal for home movies if it were not for the complex mechanical installation which would be necessary. Also the quintuple film footage would boost costs, one double length negative, two positives and a transfer base—that is, assuming that the original negative is exposed with alternate right and left frames. The only practical solution would be through central laboratories such as those used now for normal film processing.

There is no such disadvantage with the still picture. Any competent amateur can quickly learn to make good prints, and if he happens to be versed in dye transfer already, he has very little to learn.

The negative is made with an ordinary stereo camera. Enlargements are made on washoff film and developed in warm water. In this step, one negative is reversed so that the prints are mirror images of each other; placed face to face, they correspond. The two images are carefully aligned vertically. Lateral alignment is based upon normal stereo separation. The films are hinged together book-form with adhesive tape, then immersed in the special dye bath. The two films are removed from the dye bath, rinsed and the special base sheet inserted between the two, and the whole run through a photo wringer. The base sheet is stripped off, with one stereo image on the back and one on the front. Viewed with 3D goggles, the image is seen in full stereo relief.

Unfortunately, at the time this is written the Vectograph chemicals are not available, but it is to be hoped that they will again be offered in the near future. If for any reason that is not done, we hope the formulae will be made public. This process is far too valuable to be lost to the stereo world. We have been informed by Mr. Joseph Mahler, the originator of the process that some decided improvements have been made in the process, and that these will make 16mm motion picture film production wholly practical. It will also have added possibilities for the makers of transparencies.

Anaglyphic Spacing.—In printing the anaglyph it must be remembered that this is a true print, held in the hand. We are fully aware of that fact, and the eyes naturally converge upon the physical sheet which bears the image. For this reason it is usually advisable to print the anaglyph so that objects in the plane of primary interest shall be registered as nearly as parallax will permit, leaving greater differences to be exhibited by images of less important objects.

See Chapter 14 for general discussion of polarized light in stereoscopy, and additional material about the Vectograph.

Integrated Analaglyphs.—A third type of stereogram which properly falls into the anaglyphic classification is one in which the two images are divided into narrow vertical strips in which right and left elements alternate. These stereograms are made to be viewed without any filters, viewers or other accessories.

Such stereograms have been made in several types. The original consists of alternate strips set behind a grid of alternating opaque and transparent bars. In theory the right eye sees past a bar obliquely to perceive a "right" element, while the left sees past the bar from the other side to see a "left" element.

In the resulting stereogram, a certain degree of stereo relief is apparent when the eyes are within a certain restricted area. Moving the head to one side or the other introduces either neutral relief or definite pseudoscopy.

To overcome inherent defects, the black bar grid was replaced by lenticular elements so the alternating ray paths could be produced without wasting half the brilliance upon opaque bars and to remove the unsightly grid.

The lenticular film considerably improved the unsightly "prison bar" effect, but it did not make the image three dimensional from every convenient point of view. This lenticular idea was applied to a movie screen after the expenditure of a fortune. But as could have been predicted, it worked only when the eyes were correctly aligned with the screen. For that reason it was dropped only to be re-invented (?) by the Russians after the patent reprints had been made public. This is the much vaunted Russian stereo movie. Of course, in Russia it is possible to maintain audience rigidity by edict, but here the audience pronounces the edict against the exhibitor.

Now let us consider a few elementary facts:

If stereo is to be seen without any type of viewer, it is clear that the rays from the left image must reach the left eye, with no more than a small residue visible to the right eye, and vice versa. If an integrated stereogram displays stereo relief, this condition prevails, and you can actually erect a screen into which holes are cut 2½ inches apart. If you apply your eyes to these holes, you will see stereo. Now imagine such a screen, behind which a number of people are placed.

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1   2   3   4   5   6   7
L R L R L R L R L R L R L R
o o o o o o o o o o o o o o
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Here we have the 7 pairs of eyeholes with 2½ inches between every adjacent pair. If you are looking through pair 4, you will see stereo, but if you move to the left and look through holes which include the R of 3 and the L of 4, you will be looking through a R hole with your left eye and through an L hole with your right eye—and you will see pseudoscopic relief.

But suppose that all of the even numbered pairs are removed, and you are looking through pair 3. You move to the right until your left eye is looking through R of 3; then your right eye is obscured by the blanked out 4L. Seeing but one image you see no stereo relief.

Now suppose the screen is removed. You will still have to assume the same positions to see stereo relief, and if you move to any extent you will either see pseudoscopic relief or neutral (planar) relief. In no position will the relief be of the clear cut, unmistakable type which is common to the normal stereogram and which is exhibited to a high degree by the Vectograph.

There is a definite field for the integrated stereogram. It has been used for years for display in store windows, an excellent adaptation of the method because the alternating stereo and planar aspects cause the image actually to move and to draw attention. If it can be published it will be of greater value. But for stereo quality, no type of integrated stereogram has yet exhibited a degree of sufficient quality to be acceptable to the stereographer, let alone to win him over.

Just what is the situation?

In movies, you must seek the proper head position and you must maintain that position rigidly. There is nothing you can do which will so quickly produce an agonizing headache as holding the head and eyes in one fixed position. If you lean over to whisper to your neighbor, you lose the stereo effect.

On the contrary, if the movies are polarized you wear goggles which are to all intents and purposes identical with the Polaroid sunglasses you habitually wear out of doors, even to the shape of the frames. The only difference is an invisible one, the direction of the axes of polarization. You sit normally, you move about, you speak with your neighbors, and unless you tip your head to a decided oblique angle, you continue to see the full stereo relief upon the screen.

Then what does the integrated stereo have to offer? Inferior relief and stringent limitations in exchange for the privilege of taking off your sunglasses!

In still work it is much the same. Relief which satisfies only those unacquainted with true stereo, changing relief when the head is moved, necessity for remaining in one of several fixed positions. You must make an event of looking at the picture. On the contrary, you hang a Vectograph upon the wall in an illuminated frame and you can sit back and enjoy it from any angle and from any part of the room, just as you would any picture.

There has been a great deal of time and ingenuity spent upon the integrated stereogram, and it would appear that this has been done in order to achieve something which has already been achieved in a perfectly satisfactory manner.

Finally there is the possibility that the integrated stereogram will be used for published reproduction. Again we wonder why. Right now we can publish excellent stereograms, anyone can learn to see them in less than an hour and the quality is infinitely superior to the best the integrated stereogram can ever hope to match, in fact better than the Vectograph can produce. And it is all set, ready for use by anyone at any time.

And the process is proven. For three years the *Third Dimension* has regularly carried stereograms, usually transposed, at times untransposed, but always with a normal or less-than-normal separation. Guild members regularly view these stereograms without a viewer and apparently have found the method fully satisfactory. So, we have a proven method by which published stereograms can be seen by the reader without benefit of viewer. Is this free vision or not? Certainly it is an acquired skill, but so is reading.

We have no axe to grind regarding integrated stereo. Scientifically, it is extremely interesting; there are many uses for it where it will be extremely valuable. There is no denying the great amount of genius which has gone into its development, and certainly stereo is richer for having it. But as a matter of practicality, most purposes served by it, or which may in the future be served by it, are served better by a process existing today and freely available—if only the public would abandon its erroneous, preconceived ideas and recognize the truth about this stereo which we have with us right now.

The trouble with stereo is not so much faults of the process, which are extremely few, but with the public which condemns without understanding. Truly "it isn't the process, it's the people."

See Chapter 13 for historical and other discussions of integrated stereograms.

Chapter 12

STEREO PROJECTION

There are several methods of stereo projection, the oldest of which is the bichromatic anaglyph.

It is well known that filters cause objects of their own color to appear as "white," while complementary colors appear to be "black." Thus for anaglyphic projection of the stereogram a lantern is used similar to the conventional one, but instead of polarizing filters we substitute red on one side and green on the other. Thus the pictures are projected upon the screen in two colors. Incidentally it may be added that only monochrome slides are usable as the effect depends upon the purity of the two colors.

If we project the red-filtered image, which is a black image upon a red ground, and examine it through the red filter, the background seems to become white rather than red. But if we examine it through the green filter, the red background becomes black and the black image is lost in it. The reverse is true of the green image. So if we use a red filter over one eye and a green one over the other we shall have the desired condition of presenting one image to each eye.

The images may be toned (red on white and green on white) but in this instance the image alone is erased leaving a dazzling white space which tends to degrade the brilliance of the remaining image, so it is preferable to use black slides of the ordinary type and to color the background to provide a "blackout" rather than a "whiteout."

Note that this is just the reverse of the printed anaglyph which uses two colored images with white backgrounds.

A serious objection to the bichromatic anaglyph is the fact that chromatic retinal rivalry commonly known as "color bombardment" adversely affects many people and gives rise to distressing headaches. This caused the abandonment of the method when tried for professional motion pictures many years ago.

Polarization Anaglyphs.—In seeking relief from color bombardment, the solution of polarized light was proposed late in the nineteenth century, and a patent was issued more than a half century ago.

It is a well-known property of polarizers, that although both may be transparent, when superimposed in a particular position, that of "crossed axes," they become as opaque as if some very dark film had been interposed between them. However, the polarization of light is an effect which can be obtained only under certain conditions. For example, the beams of polarized light may be projected without altering them, but if they fall upon a non-metallic surface the polarization is lost and they become ordinary light again.

Thus if the images are to be preserved as polarized images, it is necessary to project them upon a screen which has a metallic surface. The most convenient is the familiar aluminum screen once so popular for home motion pictures.

The two images are superimposed upon the screen with their homologous separation at infinity, about two inches. One image is projected through, for example, a polarizing filter with horizontal axis and the other through one with a vertical axis. If we now look at the screen we will see the two confused images. If we look at it through a polarizer we may see the same two confused images, but if the polarizer is rotated we will see only one image. If rotation is continued we again see two images and then we see the other image, and so on. At the zero and the 180-degree positions we see the left image, let us say, and at the 90- and 270-degree positions we see the right image, while intermediate positions permit both to be seen.

Although thin films of polarizing quality had been known for many years, the development of Polaroid made it possible for us to obtain unlimited quantities of a uniform, thin polarizing material.

The polarized films are used in making the projector filters, and for the viewing goggles as well. All that is necessary is to have the axes of the projector filters at right angles relative to each other. True, it is convenient to have these positions definitely vertical and horizontal or at crossed 45-degree positions, but this is not essential. The viewing goggles must have their filters so disposed that the axes exactly cross the axes of the picture images so that the unwanted image is blocked. For example, the left goggle lens is opposed in orientation to the right projector filter, thus blocking the vision of the right image by the left eye.

There is nothing more to it than this. The whole system is so simple that any amateur can purchase a sheet of Polaroid and in a single evening make the projector filters and the necessary goggles. The latter are easily made by removing the glasses from cheap sun glasses and replacing them with the Polaroid. If the projector filter pair is set before a light, the goggle filters are quickly adjusted by turning them in the frames until the complementary projector filter looks black. A drop of glue serves to keep the filter in position. Any projector may be used which will accommodate both stereo units in the slide holder. Slides made on 35mm film with a stereo reflector are the most convenient for this type of projection.

If the stereo film has been made with a stereo reflector there is no transposition problem, but if the image has been made with two lenses (or two cameras) then transposition is required. In projection, transposition is effected by simply revolving the two projector filters in their mounts through ninety degrees.

It is not necessary to project through the camera reflector to superimpose the images. In fact this is not practical unless the reflector is adjustable. The normal half-angle of projection is small, so if we can shift the position of each image by this amount, we shall have them virtually superimposed.

To this end, a filter holder is altered so that it will take a polarizing filter made with its two vertical halves at crossed axes position, and in front of this two thin prisms are mounted with their bases adjacent. Prisms to provide a deviation sufficient to produce the required superposition may be used without introducing great distortion in the image.

Another plan is to have the filter carried in the film gate along with the film. This will do for still slides, but in motion-picture projectors the great heat would soon ruin the filter.

Twin lenses, which consist of two lenses with a chord of each element ground away and mounted side by side have been used, but they are costly to produce and do not provide any great advantage over the easier methods.

Non-Anaglyphic Projection.—The anaglyphic system is not at all essential to stereo-projection viewing. It is possible to view a stereogram projected upon an ordinary screen through the use of a simple, empty box. Holes are cut into this box so that the field of view of each eye is restricted.

Figure 12-1 illustrates the basic principle as applied to viewing a small stereogram. The two eyes *EE′* view the two images *SS′*. Each eye is restricted to its own image by means of the shield *M*

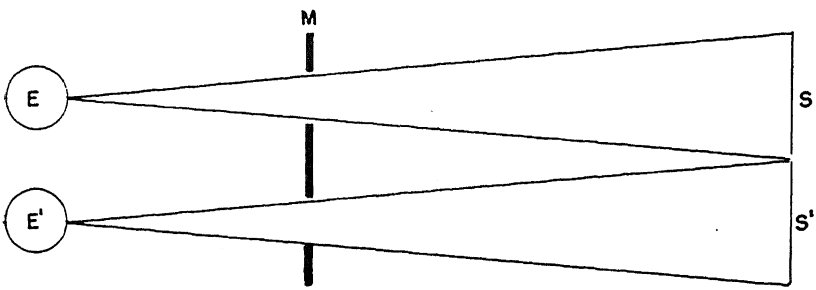


Fig. 12–1. Simple mask for viewing stereograms.

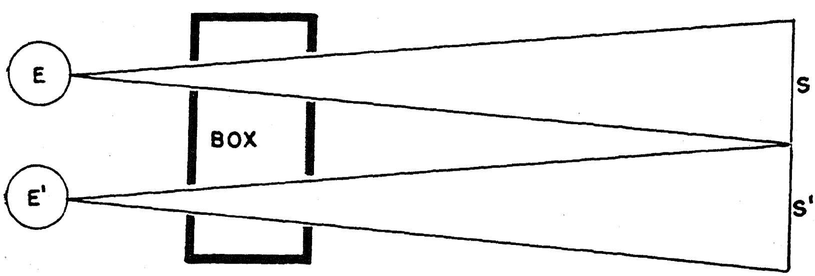


Fig. 12–2. Mask box substituted for simple mask.

through which two apertures are cut. This shield must be accurately matched to the screen distance and image size. For actual use, it is preferable to make a box mask such as is shown in Fig. 12-2. However, inasmuch as the centers of the images *SS′* cannot be separated by more than 2½ inches the method is limited to small prints or to miniature projection.

To overcome this limitation, the stereo pair is projected in the untransposed or pseudoscopic relationship illustrated in Fig. 12-3.

Here a single aperture in the mask serves both eyes, and the convergence of the axes directs each eye to its wanted image. Because of the distance of the screen, usually several times its extreme width, the actual convergence is far less than shown in the diagram. This is a perfectly practical system, and can be successfully

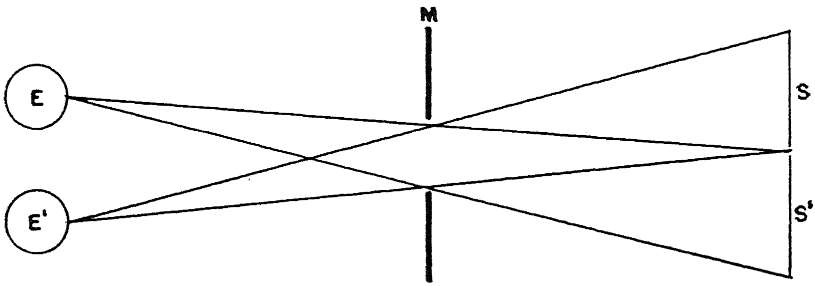


Fig. 12–3. Simple mask for crossed axes screen viewing.

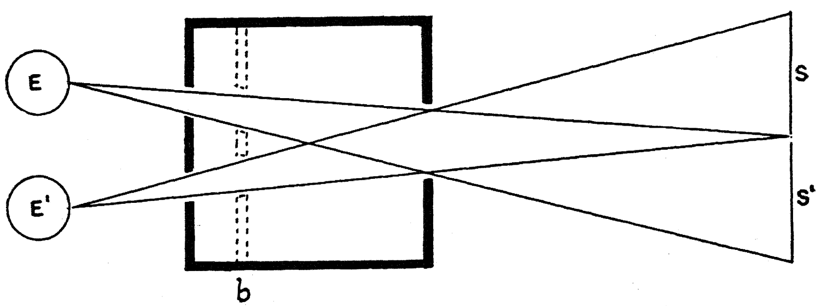


Fig. 12–4. Box mask for crossed axes viewing; b shows the shape of the box when two front apertures are substituted for a single one, making the box much shorter.

demonstrated by using a simple card. It has been used for years for the purpose of viewing stereograms directly.

Figure 12-4 illustrates the application of the preceding figure to a box viewer. The box may be made of cardboard, light wood, plastic, or the like. It has the two eye apertures cut at the correct interpupillary distance, while simple opaque covers serve to alter the limits of the single aperture in the front so that the device may be adjusted to various screen distances and sizes. In practice it will be found that this box is not as successful as the simple screen of

Fig. 12-3. The reason lies in the fact that for the correct convergence, the length of the box would be excessive. Therefore this design is modified by moving the front wall backward, and substituting two apertures for the single one, as shown at *b* in Fig. 12-4. This design is closely similar to that of Fig. 12-2, the difference being that in Fig. 12-2 the outer apertures are centered with the ocular apertures, namely at normal interpupillary separation. In Fig. 12-4 the outer apertures are separated by less than the interpupillary. In this model also it is advisable to provide sliding shutters for the adjustment of the limits of the apertures. All of these require an abnormal relationship of convergence to accommodation, and therefore cannot be used without considerable practice.

The next step in the design introduces the deviating prism shown in Fig. 12-5. Eye *E* observes image *S* normally. The dotted lines from *E′* to *S* show the normal convergence upon image *S*, but if the prism *P* is introduced, it deflects the visual beam and the eye normally positioned to observe image *S* actually observes

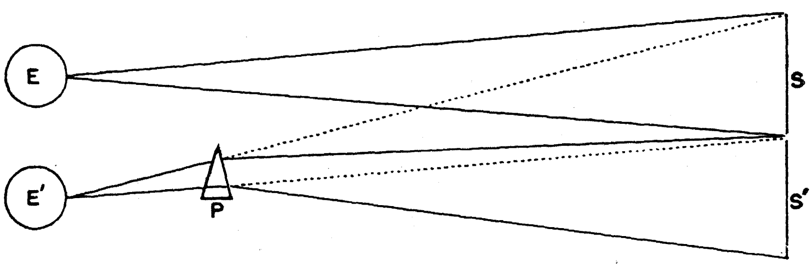


Fig. 12–5. Convergent vision with single prism.

image *S′*, thus providing optical superposition of the two images. However, this is unsatisfactory in that the prism must have considerable power (for example at 3 meters projection distance and a 20-inch image, we have 16.6 diopters deviation) which tends to introduce distortion. Instead, the prism is split between the two fields as shown in Fig. 12-6. This seems to be a simple Brewster stereoscope, but it is far different. The Brewster stereoscope has ocular *lenses* and the fusion is a function of specific *refraction,* but here we have plain prisms and the fusion is a function purely of deviation. The dotted lines show the apparent perception of a

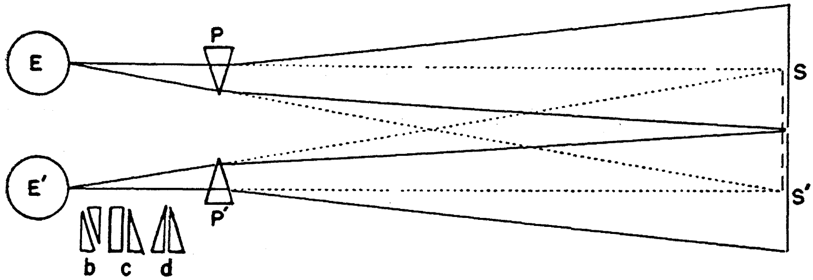


Fig. 12–6. Convergent vision with two prisms.

single central image. Viewers of this type are highly satisfactory once the correct screen distance and image size have been determined.

Figure 12-6 *b, c* and *d* shows the use of a rotating variable prism to make the system illustrated more flexible. At *b* the two rotating prisms are opposed and there is no deviation. At *c* the compensating prism is neutral and the lateral deviation is that of the single prism. At *d* the prisms are in the position of maximum deviation. By simply rotating the outer prism, and by having the outer prisms for both eyes mechanically coupled to rotate in opposed synchronism, a simple movement serves to fuse the images at a great variety of distances and separations.

Figure 12-7 illustrates the Swan prism viewer which has been widely used for X-ray viewing of side-by-side radiographic stereo-

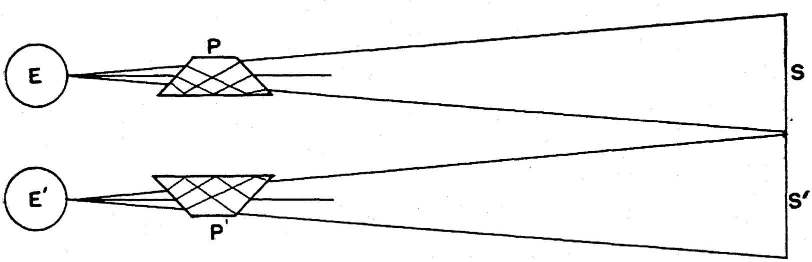


Fig. 12–7. Screen viewer with image-inverting swan prisms.

grams. This prism is also known as an erector prism because it will erect a normally inverted image. This fact in itself should serve as a warning to the stereoscopist. When this viewer is used for viewing a real scene (not a stereogram), it introduces a pseudoscopic effect in which the farthest visible object appears to be nearest the eye. Therefore, when this viewer is used, it is necessary to project the images in untransposed order.

Figures 12-8 and 12-9 illustrate one of the most elaborate of commercial viewers. The prisms 1, 2, 3 and 4 are enclosed within a body which resembles a small pair of prism binoculars. The in-

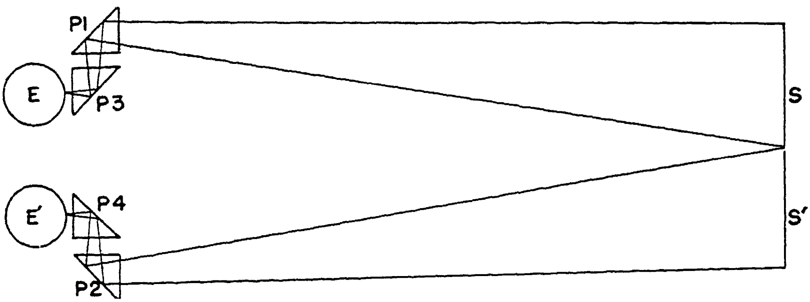


Fig. 12–8. Double prism viewer with prisms P1 and P2 adjustable.

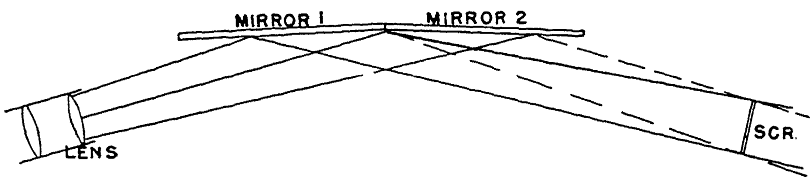


Fig. 12–9. Two mirrors for superimposing two stereo images upon a screen.

ner prisms *P3* and *P4* are fixed, while *P1* and *P2* are mounted to swing upon a vertical axis. They are connected by an external, jointed bar which in turn is screw-actuated. Turning the screw rocks the prisms in opposite directions and thus brings the two images rapidly into the desired superposition.

There are many types of special viewers, but other than those which have been described, there remains only one more significant type, the shutter type. This shutter, as applied to still projection, consists of an alternating shutter in the projector synchronized with a shutter supported before the eyes. The left eye is obscured when the left image is blocked from the screen, and vice versa. Thus the essential eye-image relationship is preserved, and if the alternation is sufficiently rapid there is no annoying flicker.

Although not a stereo projector, there is one novel projector so closely associated with stereo and so often used in connection with it, that it should be mentioned here. In Europe it is common practice to provide single projector units for attaching to the better cabinet-type viewers, to project one of the stereo halves. Sawyer's Inc. has a similar projector which projects two-dimensional pictures from the stereo reels of the Sawyer Viewmaster. The usual Viewmaster reel has the title of each scene printed in such a way that it is visible while the pictures are in the viewing apertures. The projector has a prismatic system which makes these titles visible at one side. Another feature is the micro-controlled mechanical pointer which makes it easy to point out individual features of a scene, even though these are made upon 16mm film. This is one of the smallest practical projectors made, and even though the present model is limited to two-dimensional projection, owners of a Viewmaster library will find it a welcome addition to their viewing equipment.

However, let us now turn our attention to stereo projection as it is being practiced by thousands of amateurs throughout the country.

This modern stereo projection is thoroughly practical and is accomplished by the use of well designed, commercially made projectors.

For individual viewing of the stereogram, most stereographers prefer the hand viewer, but this is obviously inconvenient for group use and when the group is large, a class or the audience at a lecture, the use of hand viewers is impractically slow. It is fortunate that stereo projection is as simple and as satisfactory as any type of projection. Even though it does fall short of orthostereo results, the loss is probably more theoretical than practical. In short, stereoscopic projection has been proven to be thoroughly satisfactory.

Those who have seen modern stereo projection, now predict that stereo movies will soon be developed; they do not know that stereo movies were presented in a Broadway theatre a quarter century ago, and in many other theatres throughout the land. They do not know that polarized light stereo movies were featured at both the Chicago (1933) and New York (1939) World's Fairs.

There is little to be done in that field, it has all been done time after time and any amateur can, with a minimum of ingenuity make his own stereo attachments which will enable him to make and project perfect stereo movies. This will be discussed in a later chapter.

Not even the modern polar-stereo projection of still slides is as new as most of us think. Both Leica and SVE made stereo projectors upon this principle before World War II, and shortly after that the Depthro was made. However at the time this is written the Stereo-Vivid projector is being widely sold and is giving satisfaction. The makers of the Realist camera have announced a 1000-watt projector which is scheduled to make a very early appearance, and others are being planned.

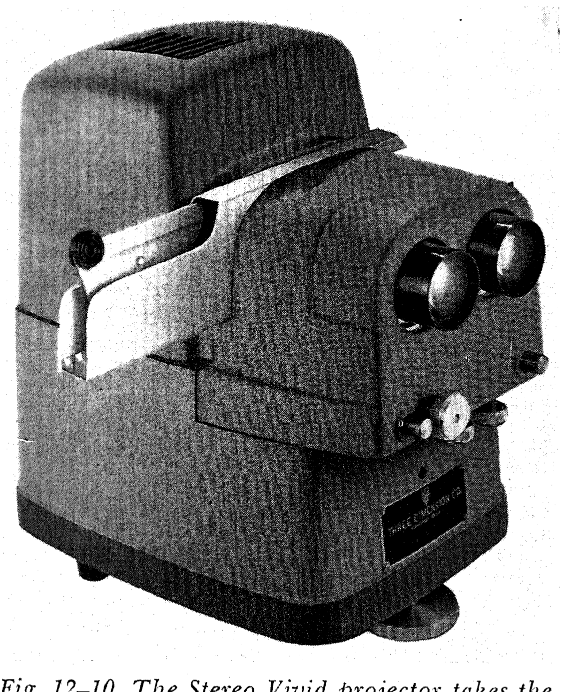


Fig. 12–10. The Stereo Vivid projector takes the standard 35mm stereogram, measuring 1-5/8x4 inches.

The Stereo Vivid is a well made instrument, the body of sturdy castings instead of the usual sheet metal. The lens housing moves backward and forward bodily for focusing while within the housing the separation and vertical relationship of the two lenses may be adjusted by conveniently placed, large knobs. The lamps are dual 500-watt, cooled by a fan set in the base of the lamp house. The lenses may be had in different focal lengths, and of excellent quality, coated type. In short the whole instrument is well designed, well made and wholly satisfactory in operation.

We are sorry we cannot give all details of the Realist projector as it is not yet available, but with the quality of the Realist camera in mind, there can be little question about its quality. The doubling of light output will be of value to those who appear before

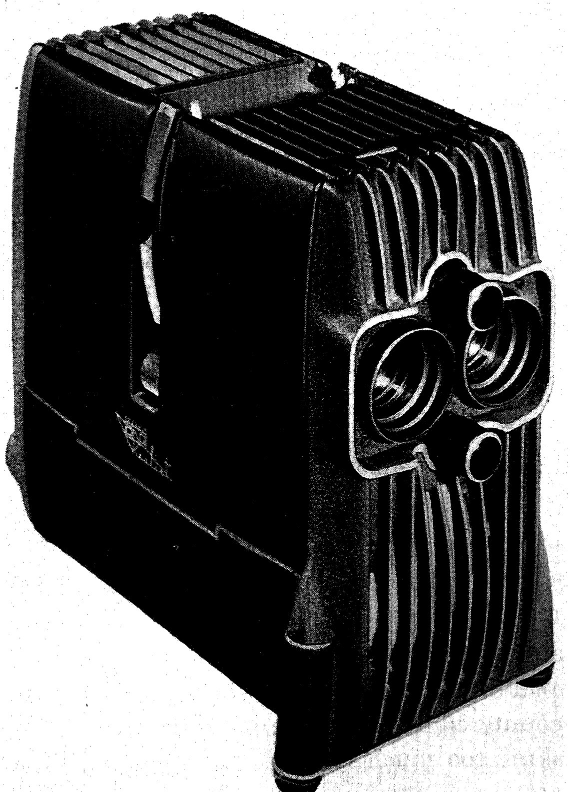


Fig. 12–11. Realist projector, companion to the Realist camera, projects the standard 35mm stereograms.

large audiences, but we have found the 500-watt output quite adequate for a 50x50 inch screen, as large as can be viewed with comfort in the ordinary living room.

We have received advance information concerning some of the details of the projector. The general appearance can be seen from the illustration, which also shows the top-insertion revolving slide holder which the manufacturer tells us adds considerably to precision slide alignment.

The cooling consists of a low turbulence (quiet) blower of two speeds, the high speed for use with 750- and 1000-watt lamps for large screen professional projection. The projector, as a matter of economy will be available with f/2.8 lenses instead of the standard f/2.3, and with a single speed blower for home use. This model uses only 500-watt lamps, but, because of a newly designed optical system, we are told, even this home model will fill a six-foot screen with considerably more than adequate brilliance. The professional model with 1000-watt lamps will fill a 12-foot screen with full brilliance.

The "standard" home stereo screen is 50x50 or about 17 square feet. The six-foot screen is 36 square feet in area or more than twice as large, so the 50-inch screen should be very brilliant. The 12-foot screen, of course, is four times as large as the 6-foot size and about 12 times the size of the 50-inch.

We are told that with this projector and permamounts, an unlimited projection exhibition can be screened without any necessity for projector adjustment, including focusing. The construction is cast metal of modern design as shown in the illustration.

PROJECTION PROBLEMS.—Stereo projection itself is entirely satisfactory, but those who use the projectors often contribute to the dismal failure of the exhibition.

We certainly do not wish to appear as an advocate of carelessness or slip-shod technique, but the fact remains that the gravest trouble encountered by projectionists in the stereo field is a direct result of taking too much care.

Shortly after the stereo projector came into general use there were repeated reports of people becoming violently ill at exhibitions. It is true that spectators were made ill; it is easy to make almost anyone ill by proper manipulation of the projector. But people are sea-sick and air-sick and car-sick every day and it does not result in any permanent defect or serious condition; and being stereo-sick is very closely allied to these forms of nausea.

The explanation is simple. You are accustomed to a motionless horizon, and when you find the horizon tipping insanely this way and that, the eyes try to retain it as a fixed reference line with the result that extreme dizziness followed by nervous upset of the stomach follows. In stereo, the eyes see only one picture and that in full relief. When the eyes are forced to constantly alter their relationship while keeping the picture unaltered, the same thing happens, it is the exact reverse of sea-sickness. But as there is no visible phenomenon to account for the sickness, the victim assumes that he has been struck with some very serious visual affection, and the fright simply increases the discomfort.

I have spent long periods with the projector, deliberately producing these conditions. All I felt was a slight eyestrain and a vague physical discomfort . . . but then I'm a fairly good sailor so perhaps I should not use myself as an example. You will find however that as a rule those who are most prone to sea-sickness will be most easily affected by stereo.

This all comes as a result of the projectionist readjusting the projector for the mounting discrepancies of each slide. He carefully spaces them laterally and carefully aligns them vertically and by then it is usually time for the next slide. As a result the spectators' eyes are continually on the jump without them being aware of it.

This practice in turn results from the stress which has been laid upon the necessity for super accuracy in projection slides. Practically all of the stereo world has joined in this. I contributed my own small share to the paean of praise for accuracy and worked out systems for "projection mounting." Then through accident I discovered the solution.

I was unexpectedly called upon to give a stereo exhibition before a group who had never seen stereo projection, and the slides to be used were a series which would be familiar to this group. These slides had been mounted as usual with no more than ordinary attention to "precision mounting." With great misgivings I gave the exhibition, and then asked if anyone had experienced any perceptible discomfort. Everyone replied in the negative and asked for more slides. Another series was run, a total of more than 100 slides. Still no complaint, a fact I could not believe, because I had adhered to the first law of projection *"Do not alter any projector adjustment while the image is on the screen"*; also the second, which is, "Have no spectator nearer a 50-inch screen than fifteen feet." The reason for this rule is that the discrepancy of images upon the screen remains constant and the nearer the spectator the greater the visual angle involved in such discrepancy. It does assume, however, a full screen picture.

Later, the slides used were checked for alignment. Lateral separation varied ten inches and the vertical alignment was out a full three inches in one slide, and more than two inches in a few! According to theory, such slides should have been very painful to view, but not one spectator admitted the slightest degree of discomfort after viewing more than 100 slides; and most of the spectators were seeing their first stereo projection! At 15 feet a three-inch difference means almost two prism diopters, when $\frac{1}{2}\ \Delta$ is supposed to be the limit of vertical difference.

Precision mounting is certainly desirable, as is precision projection, but above all the important factors are those just stated about never touching an adjustment with the picture on the screen and not having spectators too close to the screen. It is desirable not to have any spectator nearer the screen than the projector itself, when using five-inch lenses.

So much for generalities. We can now discuss details.

Projection follows the general stereo law that the right eye shall see its image, while in the corresponding field the left eye will see the left image. However, the individual images are so large they cannot be placed side by side in the usual manner. (This would necessitate a wide divergence of the eyes, a feat impossible to most people when more than a degree or so is involved. It is true that side by side projection is possible by retransposition and using convergent vision or "crossed eyes," but this too is often painful and has only academic interest).

The first problem then is that of projecting two images in approximate superposition in some way which will permit one image to be extinguished without seriously affecting the other;

and that this extinction can exist simultaneously in two opposite phases. That is now done by the use of polarized light. If the two pictures are projected by polarized light, with the two axes of polarization at ninety degrees, and if the screen has a non-depolarizing metallic surface such as aluminum, the first half of the requirement is met. Viewed with the naked eyes the screen will show the two images in confused superposition.

If the left eye is now provided with a polarizer (analyzer) which will black out the right image, and the right eye with a filter to black out the left image, each eye will see its own image, and the slight discrepancies of position will be compensated by slight movements of the eyeball. Because of this the left image should never be more than two inches to the left of the right image, otherwise the eyes would have to diverge, but the left image can move to the right several inches (involving convergence) without discomfort. The ideal position is that in which images of objects at infinity shall have the left image two inches to the left of the corresponding right image. Thus infinity vision will be almost parallel, and all nearer objects will require greater convergence, just as in direct vision.

If the polarizing axes are reversed, or if the slide used is not transposed, relief will be reversed. To try this, project a normal slide, then remove the viewing goggles and reverse them with the ear bows pointing away from the face. In fact many slides make very interesting subjects viewed in this way.

VIEWING EXPERIENCE.—When someone unfamiliar with stereo first looks into a hand viewer, he will often either be unable to focus the image or he will see two images. This exasperates the stereographer who usually thinks it is pure stubbornness on the part of the spectator. It is the result of a common condition, one almost universal.

From our earliest visual experience, we are accustomed to focus upon an object at some distance and to converge upon that object at the same time. No matter what the distance there is a degree of accommodation (focus) and a degree of convergence which are fixed for that distance. You never have occasion to use the one without the other. No matter what two muscles are thus coordinated, if they are never used individually, habit soon makes the dual motion a single one. After perhaps 20 or 30 years of unbroken duality of accommodation-convergence you are called upon to keep accommodation relaxed (infinity) but to exercise convergence normal for close objects. You simply cannot do it. You either lose zero accommodation and focus with convergence, thus blurring the single picture, or you find convergence following accommodation to zero and you see two pictures, or at least you do with pictures of close objects.

It is remarkable that most people can break this bond sufficiently to view stereograms, within a few minutes, and a little practise thereafter makes the two motions wholly independent. Nor does this developed skill interfere with the normal cooperation when it is required.

However in the projected stereogram, accommodation is not for infinity, but for some 15 to 20 feet, and unless there is some object nominally nearer than ten feet, the discrepancy is less obvious so that many who are unfamiliar with stereo find projection easier than the use of the hand viewer.

In any event, the more experience you have with stereo viewing the easier it becomes. This is true of both hand viewing and projection. And the more you see of stereograms the more sensitive you become to stereo relief. It is known to be a fact that viewing stereograms improves your perception of depth in direct vision.

Slide Mounting.—The stereogram is supposed to have both images parallel in every direction, laterally, vertically and all intermediates. This of course is nothing more than is assumed to be true of any stereogram whether for hand viewing or projection. In practise however it is often found that the two images are slightly out of parallelism. One image may be slightly higher than the other; the vertical axes of the two may lie at a slight angle rather than being parallel, or in the case of an extreme closeup, the two homologous images may be too close together.

There is another factor which may be present. The two images may be perfectly parallel, but the horizontal axis may not be parallel with the edge of the mount, which would, in projection cause one image to be higher on the screen than the other.

To insure correct mounting a gauge is used. This is a transparent base upon which are inscribed vertical lines crossed by horizontal ones. Although usually the gauge has four vertical lines, only three are used for slide gauging. The fourth is used for checking the homologous spread of closeup objects before the film is cut.

An image of some object at infinity is placed over the guide line 2. The homologous image in the second picture should lie upon line 4. Some image of a closeup object is then placed over line 2, and its homologue should lie between lines 3 and 4. If it lies at the left of 3, that is between 2 and 3, the convergent displacement is too great for comfortable viewing by inexperienced people. The gauge is based upon a maximum convergence of two prism diopters.

The alignment of objects along line 2 is noted and then the right picture is examined. The same objects should be aligned similarly. Suppose along line 2 there is a church steeple at infinity, and a telephone pole which is relatively near. In the right frame the steeple should line along line 2, but the pole will lie between lines 3 and 4, because of stereo parallax. Examine the left picture carefully. Suppose the pole leans slightly to the left at the top. Note carefully how much it leans away from line 2. Now slide the stereogram so that the right pole is adjacent to line 3 or 4, and see that the amount of leaning is the same as in the left picture.

In judging verticals you cannot align several objects in the left picture and then align the same objects in the right because their relative positions are different. Therefore you must align by reference to objects at infinity or by some part of a single object.

Aligning horizontals is much easier. You simply look to see if any horizontal gauge line passes through identical images in both pictures.

When you have carefully aligned a slide, project it and without viewing goggles examine the image. Homologous objects should lie at the same height upon the screen, and they should also be separated horizontally not more than about six inches for closeup objects. This of course assumes the projector to be in adjustment before the test is made.

Many stereo projectionists make use of a set of control slides for preliminary adjustment of the projector. But it must be remembered that the controls themselves should be checked from time to time to make sure the film has not become misplaced in the mount. However as both images are printed upon the same base, the only error which will occur is that the image base and the mount base may not remain in parallelism.

Slide 1 is for horizontal spacing. The distance from the guide line to the farthest indicator is 65mm and represents parallel axes as for infinity. The indicators are spaced 1mm, which is equivalent to a two-inch displacement on the 50x50 inch screen. Thus if the index line is superimposed upon the second line, infinity images will have a screen spacing of about two inches.

These slides are designed to produce comfortable viewing of a 50-inch screen by inexperienced spectators at distances of 10 feet (or more) from the screen.

Slide 2 is for vertical alignment. The spacing is 0.3mm which will give a screen displacement of about 2/3 inch. This is very near normal tolerance and even when no visual discomfort is noticed, the maximum tolerance should be kept to two divisions.

Adjust projector with these slides, then run through your collection and check your pictorial slides against the standards.

Slide 3 is a combination slide for check testing. Take it with you with your regular slides and just before the real exhibition, check the positioning and adjustment of the projector with it. It should not be substituted for 1 and 2 for the critical adjustment of the projector.

Slide 4 is a personal test slide and projection demonstrator. Note that no matter what your position in the room the line of circles points directly at your chest, and apparently moves as you move to preserve this alignment. If you move away from the screen the line lengthens, if you approach the screen, the line draws back. This extension and compression of space shows the inevitable distortion of projection under ordinary conditions.

Anyone should be able to fuse the first four circles, one after the other, from the projector position; a little practice will extend this and experienced stereo observers should have no trouble fusing all seven.

Once the projector is aligned with the control slides, it is ready for projection of aligned slides with no further adjustment. It must be emphasized however that the remarks concerning mounting which have just been made are all supplemental to the instructions given under the main discussion of mounting.

DEVIATION.—In any discussion of the amount of error permissible upon the screen, there is one factor which must be considered. This is the distance of the *spectator from the screen.* The control slides have been based upon a spectator distance of 10 feet minimum. Of course at greater distances the effective error grows less. The reason for this is that the error of significance is determined by the arc through which the eyeball must rotate to compensate for it.

For such purposes the unit of deviation is the prism diopter (see Appendix), which has a value equal to the acute angle of a right triangle whose short leg is 1/100 the length of the long one. For our purpose we assume the interpupillary distance to be 65mm. Half of this distance is 32.5mm. One hundred times 32.5 is 3250, so at a distance of 3¼ meters (about 140 inches or just under 12 feet), each eye deviates one prism diopter. Because both eyes converge in opposite directions the total convergence is two prism diopters.

However if the object viewed lies at 24 feet, the deviation is only a half diopter per eye and at six feet it becomes two diopters for each eye, in round numbers. For this reason it can be seen that to cause the eyes to converge upon a point, the nearer the point the greater the motion of the eyeball. In the projected image, we have *two* separate points, so the eyes do not converge to the amount normal for the screen distance, but their divergence is controlled by the separation of the homologous points in the image, and this is variable because we can move the images upon the screen in relation to each other. Moreover, the differences in the homologous separations of images of various objects in the same slide will of course present variations, so that the spectator while looking at a screen whose distance is fixed, will have to vary his convergence just as he does in looking at real objects.

It is very easy to have such variation in a series of slides that the spectators' eyes have to range from parallelism to sharp convergence, and as this is dissociated from accommodation, it is tiring. Even worse is the fact that the eyes normally do not diverge vertically. The eyes see the same object, and while lateral convergence is constant, there is no reason for vertical deviation. If one stereo image is higher than another, there must be vertical deviation to bring them into visual alignment, and being an unaccustomed and unnatural movement, it is painful. Hence it is necessary to keep the vertical error much smaller than the lateral. And, as we have stated, it is essential that the permissible error be computed for some minimum screen-to-spectator distance and that no one be allowed to view the screen from any nearer distance.

Exceptions.—It is assumed that stereo fusion will not take place unless the eyes are so positioned that the two retinal images occupy exactly similar positions with regard to the macula. However, there are people who seem not to find excessive vertical displacement uncomfortable and who can fuse stereograms badly out of alignment. It has been suggested that these people have the ability to fuse images which do not occupy similar retinal positions and hence can fuse stereo images without the necessity for compensating small errors of deviation by actual rotation of the eyeball. This is another point about which we do not have sufficient information to make a definite statement, but it is of great potential interest.

Specific Dimensions.—Errors of greater degree seem to be accepted in the stereoscope than in projection. No explanation is offered. However in practice we have found that projection of 50-inch screen size is almost always successful when the minimum spectator distance is 20 feet, that it is usually successful with the minimum of 15 and at 10 feet we have found 50-inch screen projection definitely not satisfactory. Experiments made with slides compensated to show similar degrees of error at the three distances, did not yield comparable results. The same differential remained. Therefore there must be a factor which involves the total field angle as well as the angles of error. Reducing the screen size made the 10 foot projection fully satisfactory when errors were kept within specified limits.

The actual tolerance, of course, depends upon the spectators who view the pictures. We have found that 2.5 prism diopters laterally occasionally gave trouble to individuals who spend most of their time indoors, while those who spend a substantial part of their time in the open were not disturbed by lateral deviations as great as five prism diopters. As far as vertical deviation goes, some individuals can tolerate three prism diopters, but no slide should be projected which will call for a greater vertical deviation than a half prism diopter.

Most of the Guild slides are based upon one-half and three prism diopters, but many of you will perhaps find the 2.5 lateral maximum better if your friends are largely indoor workers.

These limits are not those of actual tolerance, but those which provide comfortable viewing for continuous periods of one to several hours duration.

The following tables give the deviations of prism diopters as measured upon the surface of a screen for spectator distances of 10 and 20 feet.

Deviation	*10 feet*	*20 feet*
½ prism diopter	0.6″	1.2″
1 prism diopter	1.2″	2.4″
2.5 prism diopter	3.0″	6.0″
3 prism diopter	3.6″	7.2″

Remember, it is not the projector-to-screen distance, it is not the size of the screen, it is not the focal length of the projector lenses which is important. *It is the displacement of the two images in inches upon the screen surface, and the ratio of those distances to the distance from the SPECTATOR to the screen.*

Close-up Compensation.—We have seen that the use of the hand viewer necessitates a separation of convergence and accommodation. The accommodation is that for the slide itself and if the viewer is correctly adjusted this will be infinity. On the contrary the convergence will be that normal to the original distance of the object as reproduced by parallax, and normal to the parallax itself.

In projection, we have the accommodation normal to the screen distance. With the usual five-inch projector lenses and a 50-inch screen, this distance is about 22 feet. The convergence is not directly related to the distance of the object, nor is it related to parallax. In fact the convergence is variable and under the control of the projectionist. This is one point of difference between the stereoscope and the projection screen.

A set of experimental slides was made and used as a basis for testing. One was a landscape showing clouds which made excellent indicia for the infinity setting. This slide was used to set the projector so that there was a 2¼-inch separation on the screen with the left image at the left and vice versa. This arrangement provides, for a spectator with 2¼-inch interpupillary, strictly parallel vision for infinity.

The second slide was that of a child, full figure. There was a separation of 1¼ inches upon the screen, but showing positive convergence. In short this image was displaced 3½ inches from the infinity position. This positive convergence was that demanded for a point some 13 feet from a spectator at the projector position.

The third slide was the same child, but with the camera at such distance that the frame line cut the figure at about the waist. This slide gave a 3¼-inch positive convergence on the screen or made it necessary for the spectator to converge upon a point about nine feet before him.

These computed convergences were checked by holding a white rod between the spectator and screen and moving it until neither rod nor screen image showed diplopia. The experimental and computed distances were remarkably close.

The fourth slide was a close-up of a hibiscus made at a camera distance of three feet. There was a 5½-inch positive displacement which corresponds to convergence at about 6½ feet in front of the spectator. This was a noticeable departure from normal. Viewing is easy enough for one experienced in stereo, but difficult for a layman. For instance, we have:

Parallax distance	36 inches
Convergence	78 inches
Accommodation	264 inches

Of course in normal vision, all three would be for the same distance. This brings up the problem of altering these close-up slides so that the discrepancies are lessened.

The fifth slide was an identical shot of the hibiscus, but one in which the mask had been cut in two and moved apart to give a minimum homologous separation of 64.5mm. The screen showed a 2-inch *negative* separation, or one-fourth inch less than infinity which involves a convergence normal to a distance of almost standard stereo infinity. Still, this was much more "comfortable" than the first close-up.

A sixth slide was made, just like the fourth and fifth, but this time the compensation was such that the separation was 63mm. When this slide was projected, the point of actual convergence was about 13 feet from the spectator and nine feet from the screen. This was an extremely comfortable slide to view and analysis shows:

Parallax distance	36 inches
Convergence	156 inches
Accommodation	264 inches

If all slides are so compensated that there is no convergence point nearer than half the screen distance, slides may be projected without projector adjustment for separation. Presetting the projector for substantially parallel vision at infinity gives greater leeway in slide compensation.

It may be added that there is always a wide variation in the subjective interpretation of distance. With the hibiscus slide just described, one spectator saw the flower about a foot in front of the screen, another saw it at about four feet from himself (approximately parallax distance), and others saw it at other distances with no close similarity among the group with a single exception. Two spectators placed the flower at about 10 feet. Distances were determined by coincidence with a marker target which was moved along until one or another spectator would say it was in the position of the flower. (Note that this is NOT the distance at which there is only a single image seen of both flower and target. It is purely subjective spatial orientation.) The distances from spectator to target were then measured.

In working with either stereoscope or projector, one convention of stereo must be mentioned because it has led to confusion more than once.

It is customary to speak of the "left" image and the "right" image. There is nothing in an image which makes it inherently right or left. Either film may be used as either the right or the left. Of course there is that difference common to planar pictures as well as stereo, that when reading matter or other positive indication of right or left is included in the picture, the image should be oriented to correspond. However, this is a matter of convenience and has nothing to do with stereo *per se.*

If you place a stereogram in the viewer, you see it normally. If you remove it, turn it end-for-end and replace it, you have the film which was originally at the right before the left eye and vice versa. The stereo relief is unaltered. Therefore *either* image may be left or right without disturbing the stereo relief. What then is the distinction?

It is the *relative* positions of the two. The stereo position is that which causes the eyes to *converge* when looking at a nearer object; while in the pseudo position, looking at nearer objects necessitates a *divergence* of the eyes. This must not, however, be interpreted as suggesting that the convergence of itself is significant; the direction of convergence is simply an index to the lateral distribution of parallax.

Therefore remember that when we speak of a right image or of a left one, we are simply using a convenient, and brief, convention which must not be translated too literally.

TOLERANCE.—It must be remembered that the absolute alignment of any slide is impossible. Man cannot achieve the absolute. The goal is an error which is so minute that it ceases to exist as far as visual perception is concerned. In fact, even that limit may be passed because we do have a certain tolerance of visual error. Because this tolerance varies among individuals and is greatest among those who are familiar with stereo viewing, it is advisable not to depend upon it, but to mount slides with all precision possible. You will find some spectators, new to stereo, who may object to a greater horizontal separation than six inches and a vertical displacement of more than one inch as measured upon a 50-inch screen. Thus a displacement of one inch is a ratio of 1:50, which means roughly a half millimeter in the original slide which has a height of about 24mm. (Twenty foot screen distance.)

As we have stated, we have found "new" spectators who accept ten inches laterally and three inches vertically, but to use slides of such error is a grave mistake. Just because it can be done in some instances, do not use it as your standard.

Before making an exhibition, project all slides with the aligned projector. Do not make any adjustments. If any slide shows more than six inches laterally (except for extreme close-up) or more than 1½ inches vertically, remount it. Play safe!

MOUNTS.—There is some grave question about the danger to slides from projector heat. Even with a well-cooled projector, a slide which has been projected for a half minute or more will be uncomfortably hot to the hand.

Some stereographers believe that the glass mounted slide which retains the heat for a long time, is bad. They use rigid open mounts. Others believe that the glass absorbs the heat and keeps it from the film. For what it is worth it may be said that in the Guild laboratories, the open, rigid, cardboard mount is used, and projection of any one slide strictly limited to a fifteen second maximum.

RETRANSPOSITION.—Remember, the dual lens projector retransposes the images, so be sure to check your projection for right-left position on the screen. Project a slide, close the right eye. Cover one lens of the projector, then the other to determine the image which is "left". This image should *never* be so placed that any of the infinity images are more than two inches to the left of the other image.

Many projectionists simply give infinity images coincidence. This works very well when no close distances are present, but if there is an extremely near object, this makes necessary a certain divergence which is not advisable.

But above all, during the projection, readjust focus as little as possible and do not touch the aligning adjustments. Should this ever become imperative, ask the spectators to close their eyes until the adjustment has been made.

PROJECTION SUMMARY—

1. Gage slides for parallelism and lateral continuity.

2. Mount films with the homologous images of the *farthest* objects spaced 65mm or the normal infinity setting. This applies even if the farthest object was really only five feet from the camera.

3. Gage films to see that the range of separation does not exceed 1.5mm at most or preferably 1mm (3 to 4.5 prism diopters).

4. Gage films to see that the vertical error is less than 0.25mm.

5. Preset projector for focus separation and vertical alignment before the spectators arrive.

6. Be sure projector is level and the two apertures aligned vertically.

7. Do not allow any spectators to approach nearer the screen than the distance for which you have compensated, preferably not nearer than 15 to 18 feet from a 50-inch screen.

8. Slide thickness may necessitate adjustment of focus during the projection, but do NOT touch either of the stereo alignment adjustments while anyone is looking at the screen. (Careful slide mounting and a preview for checking before the public performance will make such adjustment unnecessary.)

If you will do these things you will not have any difficulty with projection and you will be assured that the spectators will thoroughly enjoy the projection with no uncomfortable results.

CHAPTER 13

APPLIED STEREOSCOPY

STEREOSCOPIC reproduction is not at all limited to the amateur photographer. It finds a wide application in the diagnosis and treatment of diseases and maladjustments of the visual apparatus. It is used to excellent advantage in military work, particularly in aerial photography. In advertising it has already gained high favor. Students in schools obtain visual impressions of places and objects which could not be obtained in any other way. Scientists have found it to be the only photographic method which meets their demands fully. In the medical profession it is widely used for teaching purposes, and hardly an X-ray installation is without its Wheatstone viewer for stereo X-rays. Stereoscopic photography is now being used to record installations in factories, keep check upon field work by engineers, record results of scientific work in the field, and of course in the more elaborate stereogrammetry it is used for actual surveys.

New applications are appearing almost daily, not the least interesting being its use in recording evidence for both civil and criminal trials.

THREE-DIMENSIONAL VOGUE.—It is now the fashion to use the term "three-dimensional" in both apt and inapt connections. No phrase used in the discussion of pictures has been more overworked or more abused. Very serious efforts have been made to convince the public that three-dimensional pictures are something quite new, and totally different from the old stereogram. They either ignore or do not know the fact that any truly three-dimensional picture must be stereoscopic, for the latter term is specifically descriptive of "depth vision." It might be remarked in passing that the phrase "three-dimensional" is often applied to systems which are unsound, and even to some whose only pretense to relief consists in the name itself!

It must be added, however, that there are three-dimensional pictures which are certainly not *ortho* stereoscopic.

Although "three-dimensional" is less than stereo, it is more widely known and it is recognized by those to whom the word "stereo" means nothing. At the same time the almost universal practise of advertising slide viewers, projectors, lenses and the like on the basis of "three-dimensional effect" (when they are not truly stereoscopic) is to be deplored.

No other pictorial art has ever been subjected to the false publicity, the inoperative systems and inventions and the intentionally false representations which have dogged stereoscopy throughout its life of more than a century. Hardly a year passes without the announcement of the discovery of some revolutionary three-dimensional process, only to prove it has nothing "three-dimensional" in it other than the name. This has been one of the most popular of pastimes in the motion-picture field.

Single Image Relief.—It is well known that when a single picture is viewed in a concave mirror or through a convex lens it does take on an appearance of "unflatness," but so vague is the relief that it cannot by any stretch of the imagination be called stereoscopic, yet that is just the word used to sell these inoperative devices. Even some of our reputable magazines permit the use of the term for selling concave mirrors, probably because of editorial ignorance of true stereo.

A stereoscopic effect is one in which the true, natural quantitative relationships of all objects and planes within the field of view are normally reproduced. Nothing less than this can truthfully be called stereoscopic. As we have seen that this effect can be obtained only when the two eyes each receive a differentiated image, which in turn necessitates two photographs, it is obvious that a true "single image" would send identical stimuli to both eyes, and that therefore stereoscopic perception of a single image is fundamentally and basically impossible.

Integrated Stereograms.—However, the single image ideal is approximated by the integrated type of stereogram. Loosely applied, this may be used to describe the anaglyph and the Vectograph as well as the bar-screen type of stereogram, which is ordinarily called the Parallax stereogram. But inasmuch as *all* stereograms are made possible only by parallax, the term becomes vague and meaningless. "Bar-screen" or "grid" describes the process specifically and leaves no room for confusion. In all of these processes the two images occupy substantially the same positions upon the supporting base, and are differentiated by color (anaglyph), polarization of light, (Vectograph), or by an opaque grid (bar-screen) or a lenticular grid (grid). In each instance there is a sharp differentiation into two distinct and different images.

FREE VISION.—The aim, of course, has been to introduce some system which would make the viewer unnecessary, and to a certain degree success has been achieved, but this degree is slight. All of these experimenters have overlooked the essentially vital factor that the full realism of true stereoscopy can never be realized in free vision nor *by any system which dispenses with the stereoscope for viewing.*

The essential factor involved is that of visual-psychological isolation. This factor is so fundamentally important that it is incredible that it could ever be overlooked. The only excuse is that those who work toward this goal seek only an appearance of solid relief, not the realistic recreation which is the sum and substance of stereo.

Visitors to New York (for example) often take home as souvenirs, small metal models of the Empire State Building. One of these small models is the full equivalent of the free-vision stereogram of the same building. Both are tiny, solid appearing models, nothing more. The dual stereogram viewed in the stereoscope is not anything like this. It provides the visual isolation which gives to the spectator *every visual stimulus he would receive in looking at the real thing.* In short, provided with a good stereo outfit, the spectator does not look at a picture, he sails away upon a magic carpet to New York and actually looks at the building itself. He sees the original, not a picture.

This is not an exaggeration for emphasis, because when you view stereogram, you actually do see the real original, even though you are not in its physical presence. The explanation has been called metaphysical. It is not. It is based upon an accepted fact of vision which is not widely known.

You say that you "see an automobile," inferring some kind of direct physical contact with the automobile. What actually happens is that you do receive a direct optical image of the automobile in the eye. That image is perceived, as is the one from the other eye. But in the brain these two images are mixed and from the mixture is produced a *third* synthetic image, which is produced wholly within the brain itself. This image is then psychologically projected into space so that it occupies the same position as the real object. Only thus can we have stereoscopic vision. Incidentally this is accepted theory and will be found in authoritative textbooks of physiological optics.

So if you "see" an automobile, what you actually see is an artificial image projected from your own mind. If you see a stereogram, you see an identical artificial image, synthesized in your brain and projected in exactly the same way. The image is placed in space at exactly the same distance. In fact, the only difference is that existing between two different external stimuli, but from the retinal reception on the two processes are identical.

The true fact is that you never actually "see" any object stereoscopically, you only see the artificial "mockup" which you have created yourself. Thus in stereo, although you will not want to accept the fact, you actually and literally see exactly the same thing you would see in observing the original object.

The difference between the free-vision stereograms and those seen in the stereoscope will always remain the difference between a tiny model and the real thing. As a matter of fact, free-vision stereograms have very little advantage over the ordinary flat photograph, aside from their novelty. Make them commonplace for five years and people will not care whether they have them or the old planar type.

The stereoscope is a fundamental and essential part of that stereoscopy which actually re-creates realism in its fullest detail. Second is the use of a good projector in a fully darkened room. Other systems fall too far short of realism to have more than novelty appeal, with the exception of the Vectograph whose stereo quality makes it a true member of the stereo family.

THE BAR-SCREEN.—Ives invented the system in 1903, and four years later Lumière Autostereo plates were marketed. These plates were backed with a grid of fine lines spaced from the emulsion by the thickness of the glass base. A dual diaphragm in the lens caused the images to fall upon this grid from the two sides so that the "shadow" of a grid line from one lens aperture fell exactly between two grid shadows from the other aperture. Thus, although the whole image was composed of alternate fine strips from the two stereo images, the image as a whole would appear to be normal, except for a suggestion of a line pattern caused by adjacent parallactic differences. The process worked all right, but the picture was of course crossed by vertical black lines which were visible and marred the picture. Later the use of lenticular elements embossed upon a plastic base was suggested by both German and French experimenters, and in 1925 such grids were successfully used in France. Among the details introduced were specially shaped diaphragm apertures and a moving diaphragm which caused a slit aperture to move across the base aperture. And these things are now almost a quarter century old, and of course the essential characteristics have long since become public property.

Briefly, the lenticular grid makes the stereoscopic depth apparent throughout a greater viewing angle than the line grid, but nevertheless the junction of the elements produces a line effect. The only way to overcome the line effect is to make the grid so fine that the lines are invisible as such. With a screen as fine as this, registration becomes difficult and the images are processed by reversal, a complication which removes any process from full practicality, even though it is widely used. No process can hope to be truly successful until there is complete freedom of reproduction, preferably by the usual negative-positive process.

The equipment necessary for making the bar-screen stereograms consists of a camera; a lens whose diameter permits the use of two apertures with a center-to-center separation of 65mm; and the essential grid screens which may be either integral with the sensitive material, or separate. (Eventually the large-diameter lens may not be necessary as the writer has been informed that applications for patent have been made covering a system which permits the use of any normal small camera lens, and which also maintains the vital grid angle with accuracy.)

Under present day conditions, unless one is lucky in having old equipment from which to draw parts, the initial cost will run to about five hundred dollars, and the results are not worth it! The writer has made a great many bar-screen stereograms using screens of various types, both line and lenticular, and it is his considered opinion that as far as good quality stereoscopic photography is concerned, the process is of little interest.

On the contrary it must be said that as far as commercial application is concerned, particularly if these pictures eventually can be printed in periodicals, the method has perhaps greater potential commercial value than any other. But it has only the slightest resemblance to that result which the stereographer knows as stereoscopy.

The stereoscopic effect in the bar-screen is considerably less realistic than it is in the Vectograph, for example. The Vectograph presents an unmistakable, an unchanging, and normally undistorted true stereoscopic image. The only objections are the resemblance to a miniature model, the absence of orthostereoscopic dimensions, and the absence of visual isolation. For these reasons not even the Vectograph can replace the conventional stereogram and stereoscope among stereographers. When one surrounds his eyes with the hood of the viewer, it is like opening a door to distant places. There is almost a bodily transportation, something which the hand-held free-vision image can never imitate.

Still, the bar-screen is an ingenious method, and one follows the history of the work by Ives, Lumière, Bessière, Draper and Winneck with deep interest. The mere fact that for our specific purposes the method is inferior, is no reason why these men should not receive our admiration and respect.

The original suggestion for the use of the grid came from Berthier in 1896. Acting upon his suggestion, Ives in 1903 invented the system, giving it practical design. This was greatly improved by Estanave in 1906, and upon his improvements were based the Autostereo plates of 1907. To overcome the necessity for viewing the print from the one correct viewing angle, Lippmann suggested the lenticular base in 1908, and proceeded to make grid stereograms, using the lenticular grid.

Estanave elaborated the use of the bar screen and in 1910 introduced the "magic picture" which by a slight side shift changed its nature, but later he went back to stereoscopic effects and greatly improved Lippmann's lenticular process in 1925, the same year in which Bessière made use of the same process.

Brewster in 1860 suggested that the parallax involved in images made by different portions of a large lens was sufficient for stereoscopic effects. Lehmann in 1878 produced such effects, and in 1900 Boisonas made some improvements upon the dimensions of the apertures used. Thus the lens was waiting when the grid process was introduced, the final steps in the optical development almost coinciding with the initial efforts to produce the grid stereogram.

The parallax found in all images formed by lenses is often overlooked, but it is one of the fundamental factors in all photography. Only the pinhole has practical freedom from parallax, all other photographic images having a certain degree of inherent stereo parallax.

As first pointed out by Brewster, if a lens whose diameter is more than 65mm be provided with two apertures situated at the ends of a horizontal diameter of the lens, and two images are made by alternately covering the apertures, those two images form a normal stereo pair.

It follows that if this is true of two portions of the lens separated by the normal stereo base, then *any* two points in a lens will form images which will exhibit parallax corresponding to the locations of the two apertures. It is known that when a stereo pair is made with a separation as small as a half inch, the pair will exhibit a visible degree of relief, so it follows that any lens in ordinary use must form an image in which there are definite stereoscopic pairs of images.

If three test objects are set up in a line receding from the camera, and if the lens is focused upon the central object, the images of the other two objects will be blurred. This is normal experience. However, if the lens be provided with two relatively small apertures and the same picture made, the central image is still sharp, but the other two now show two overlapping, relatively sharp images instead of the original blur. Thus the photographic image really consists of an infinite number of infinitely sharp images, which appear collectively to be sharp or diffused depending upon the degree to which they are superimposed in exact register.

It can be seen then, that among the other images, a pair exhibiting stereo parallax is included in every photographic image. It is also apparent that even where the image is "in focus"—that is, exactly superimposed—the superimposed images have parallactic differences, hence cannot be superlatively sharp. The larger the diameter of the lens, the greater these differences and the greater the departure from the ideal monocular, pinhole definition.

This phenomenon gave rise many, many years ago, to a very clever device. A lens cap was made which included a vertical bar across the center of the lens. The width of this bar was from 1/4 to 1/3 the total lens diameter. This gave a clear differentiation between the two stereo images when placed over any lens. When focusing the camera, it was only necessary to bring the two images of any object into close coincidence to produce a sharp focus upon that object. This was the forerunner of the rangefinder. It is as good as any focusing device when used with any camera equipped for visual focus, although the larger the lens diameter the better the result.

The writer introduced his own variation of that device by applying filters of complementary colors to the two sides so that the image which is being focused not only comes into superposition but exhibits natural color, while other objects are tinged a distinct filter color, red or green, for example.

Thus it is that an image, although not visibly diffuse, does have a dual, even multiple, character. The presence of this fundamental difference of stereo parallax, although in no way giving to the planar photograph any degree of stereoscopic relief, does give to the image a degree of planar realism never achieved in the small-lens image. It should be emphasized that this effect is one of diameter alone, not of relative aperture, nor of focal length, nor of degree of correction. It is simply the presence of images whose natural parallax includes that degree of parallax normal to vision. The "realism" of the portrait is simply an unconscious recognition in the planar image of those fundamental elements which are normal to vision *prior* to the synthesis of the stereoscopic image.

STEREO PARALLAX AND SOFT FOCUS.—Soft-focus portraits have always been popular, but their origin is not widely known. The admired absence of razor-sharp outlines should not be the presence of actual image diffusion. It should be the quality imparted by the old-fashioned, huge portrait lenses which had such apertures that they did include this normal degree of stereo parallax. The "soft focus" is simply the difference between the parallactic images at the point of best registration. It is a visual effect normal to everyday vision, and it has a characteristic quality quite different from the conventional soft focus, and one which cannot be imitated by uncorrected lenses, or aberrating glass discs. You cannot obtain it from a sharp negative during the enlarging process. The only way in the world to obtain this original type of "soft focus"—which is still sharp enough to reproduce every hair on the head—is to use a lens whose actual aperture exceeds two and one-half inches. If you use that aperture you cannot help obtaining the soft-focus effect. It is a matter of stereo parallax, not loss of definition in the usual sense.

This fact has been recognized from time to time by "inventors" who reason that if the picture includes the necessary differentiated images of stereo parallax, then the image must be stereo. Some of them went so far as to place a vertical bar across the front of the lens to produce two images differentiated in the same print, and then insisted that these were stereograms. All the time they neglected the one fundamental point: In any true stereogram, the eyes must be able to fuse the images of any object within the entire field, and at the same time the "double" or "ghost" images of other objects must be separated as in normal, direct stereoscopic vision. Although this fact is elementary, not less than a dozen inventors have at one time or another "invented" this half-way stereo which is not stereo in any sense of the word.

Pseudoscopic Pictures.—One interesting phase of stereoscopy is the pseudoscopic picture. This is a stereogram in which the left and right pictures are left in their original negative positions, that is, untransposed. The effect is to reverse all depth dimensions, bringing the far distance close to the eyes and removing nearby objects to a remote position in space.

This phenomenon is interesting, but it also has a practical value. Through familiarity, we are prone to fail to appreciate true spatial relationships and take them more or less for granted. We may grasp the fact that the stereogram is faithfully reproducing three-dimensional space, and still fail to appreciate the various relationships which go to make up this spacing. The pseudoscopic picture so emphasizes these differences that planar separations unperceived in the stereogram become very distinct. This makes the pseudoscopic picture of definite value when examining certain microstereograms and other stereograms of scientific interest. No stereographer should neglect the study of pseudoscopic prints of various objects. The pseudoscopic picture has also demonstrated unusual potentialities in the pictorial field. Many objects, a rock strewn seashore, for example exhibit in pseudo a wholly abstract form, yet through the retention of natural dimensions and color, such pictures have a quality only equalled by the best of our modern artists.

A characteristic of the pseudoscopic picture usually ignored is that, contrary to the stereogram, those parts of the picture which appear nearest have less parallax than those farther away, which results in a peculiar emphasis of depth, a gradually increasing depth distortion which adds to its value rather than detracts.

These pseudoscopic pictures are true stereo in reverse, and should never be confused with the false stereograms sometimes called pseudo-stereograms. These false stereograms are pictures with absolutely no stereoscopic relief, but which by some device or other have been given a vague appearance of roundness or false solidity. Although often widely heralded as "stereoscopic," "three-dimensional," and the like, such claims are definitely false, and should be so recognized. They should never be tolerated, and they owe any measure of acceptance to the fact that the general public is wholly ignorant of the realism of the true stereogram. It seems strange that any pictorial medium which has once known universal acceptance and which is so widely popular today should be so wholly forgotten that the greater part of our population should never have seen an example. Yet this is true of stereoscopy. Fifty years ago a home was not complete without its stereoscope. Today there are hundreds, even thousands of people who sincerely believe that stereoscopy was an invention made during the late war.

The term "stereoscopy" is used advisedly, for it is a part of the new teaching that stereoscopy pertains *only* to pictorial reproduction. This, too, seems incredible, yet there are war-time students of stereography who insist that stereoscopy has no place in normal, direct vision!

The fact is that in the year 1870 every photographic dealer sold stereo equipment, and every photographic amateur (of which there were even then more than fifty thousand in this country) was familiar with the process even it he did not practice it. It is well known that the vogue for daguerreotypes began to die out before 1860, but nevertheless stereo-daguerreotypes were made and in demand! And since that time, while equipment has been improved, there has not been one fundamental addition to the known physical laws of stereoscopy. Basically we practice today the same system that has been used almost a century.

Throughout the full life of stereoscopic reproduction, dating from the first observations of Wheatstone in 1833 and the work of both Wheatstone and Brewster through the following decade, stereoscopic photography has been in unbroken and consistent use. Since the beginning of the century it has been of great value in X-ray work; and it has proven to be the most successful photographic medium for medical reproduction. It has been used in engineering and construction as well as in many other professions.

In schools, stereograms have been used for visual education for years, and it is curious to note that although the average adult is wholly unfamiliar with the art, there is one company whose business in stereograms is said to amount to more than a million dollars a year, and has been at a corresponding level for years past.

Just a year or so ago stereo was generally acknowledged to be dead and buried, a relic of the horse-and-buggy days. A few months ago, the photographic world was amazed by the rapidity with which its popularity was growing, surpassing the famed rise of the miniature camera. Today those not in stereo are seriously concerned, and one commonly hears conjectures as to how soon planar photography will pass out of existence except for specialized work. That is an event which, of course, will come to pass eventually, because no system of photography can expect to be permanent until its reproduction of reality is perfect. Stereo itself will pass on before the advance of superstereo in which we shall have the scene projected in space, not with an appearance of space as we now have, but an actual projection in space around which we can walk and examine from every angle. Oh, yes, that will come—sooner than many of you think. But when it does, it will have color, motion, sound—and perhaps odor as well. When that is accomplished there remains but one more step, the re-creation of the scene in such a way that the human spectator can enter the scene while retaining normal spatial relationships which would exist had he entered the real scene. There is only one major problem in the way of that. The camera sees, not a solid, but a shell which has no rear half. This sounds like fantasy, but it is child's play compared with the fantastic things among which we now live, radio, television—rockets and atomic power!

Chapter 14

POLARIZED LIGHT APPLIED TO STEREOSCOPY

THE POLARIZATION OF LIGHT is one of the most interesting phenomena encountered in all optics. To go into the details of the actual procedure would take far more space than we have available. Moreover, many of the more beautiful of these phenomena pertain to some of the more complex reactions of polarized light and have no bearing upon our subject. For that reason we shall content ourselves with a very simple explanation of the one polarization phenomenon which has to do with stereoscopic observation.

Light travels as a "ray" from the source to some given point which may be illustrated by stretching a cord between two posts. The cord represents the line of travel of the light. The light itself is an electro-magnetic vibration whose direction is outwardly from (perpendicular to) the line represented by the cord. If now the cord is replaced by a string of Christmas tinsel, we might assume the central core to be the line of travel and the out-thrust tinsel strands the direction of vibration. This illustration is at some variance from the actual theory, and wholly neglects the projection of the wave front, but its simplicity more than outweighs its faults from the standpoint of advanced theory. We are not students of advanced physics, but only trying to arrive at an acceptable, if crude, explanation of the polarization of light.

Suppose you spray the tinsel cord with glue and then pass a coarse comb along it with the teeth held vertically. The tinsel will be "ironed out" and instead of a large round rope, it will be a thin ribbon standing vertically. If you treat a similar cord with a comb whose teeth are horizontal, you will produce another ribbon which lies horizontally. These ribbons now represent two light rays which have been polarized, with their axes of polarization at ninety degrees. The polarized ray retains its full amplitude of vibration only in one plane in which its own axis lies. A ray may be polarized at any desired angle.

Now if the tinsel is allowed to dry so that it will retain its ribbon form against a considerable force, we can illustrate the polarization phenomenon with which we are concerned.

Imagine one of the combs held with its teeth perpendicular and spaced about an inch from it, another with its teeth horizontal. If you pass the vertical tinsel ribbon through the teeth of the first comb, which can be done easily, it will not pass the teeth of the second comb because the edge of the ribbon lies across the teeth of the second comb. However the second (horizontal) tinsel ribbon can be passed through the second comb but not through the first.

The action of a polarizer is crudely analogous to that of the comb upon the glued tinsel. It permits the passage of a ray of light which is vibrating in only one major plane. If a second polarizer is held before the ray in such a position that it would polarize the ray at right angles to its first polarization, the ray of light cannot pass.

We have the apparent paradox of two substantially transparent bodies which freely transmit light in a certain position, but when given another relationship they become opaque and will not transmit light.

This cancellation of light by a second polarizer when light has already been polarized, is widely used. Inasmuch as light is polarized by reflection at some angle from any non-metallic surface, much of the daylight about us is polarized. Thus the glare from a paved street is largely polarized and the use of polarizing goggles eliminates this glare without a corresponding reduction in the normal light intensity. The same thing is done by the photographer who often eliminates undesirable reflections, as in a window, by using a polarizer over the camera lens.

Polarized light is used widely in the study of crystals and minerals under the microscope, but it is used with certain accessories so that the polarization may be that just described and known as "plane" polarization, or it may be circular or rotary polarization. The light may be split into two rays which are differently retarded by the specimen under examination. The two rays are mixed, and in mixing they interfere, producing very beautiful color effects which are of great value in the study mentioned. But these effects are outside our province.

Polarized light may be reflected and if the reflection is from a metallic surface, the polarization is retained, but if the surface is non-metallic the polarization is lost. This fact is of the first importance when polarization is used for anaglyphic stereo projection.

Many years ago, indeed about a half century ago, when stereo was highly popular and when polarized light was a prime favorite among both amateur and professional scientists, a patent was granted upon polarization anaglyphic stereoscopic projection.

According to the specification, this patent called for a double projector which projected two superimposed images upon the screen. Each projection lens was fitted with a polarizer. Those who were to see the projected image in stereo relief were provided with a pair of polarizers to be supported before the eyes. The axes of the viewing polarizers were to be crossed as were those of the projector so that each eye saw nothing but its appropriate image. That is exactly the nature of the polarization projection which we have today to the last detail. And the patent is dated before 1900!

However, the drawings and specification both were made around the use of Nicol prisms as the polarizers, which made the system both bulky and costly. These prisms were not specified because polarizing films were unknown at that date, but simply because the Nicol was the acknowledged supreme polarizing agent of its day.

Polarizing Films.—The general use of polarizing agents today is largely due to the development of a system by which polarizing films may be made to a given standard, and in quantity. The idea that the polarizing film itself is new is erroneous. In the *Quarterly Journal of Microscopical Science* for January, 1854, Dr. Herapath gives directions for making the films of iodosulfate of quinine, markedly similar to the commercial films which we have today. Many attempts have been made to produce these films, often successful ones, but because of the quality and uniformity of their product the Polaroid Corporation produces most of the polarizing films used in this country today.

The fact that a single film mounted between two relatively thin glasses will perform in all major respects similarly to the very bulky and costly Nicol and similar prisms, has placed in our hands the availability of unlimited variations of polarization of light.

THE POLARIZATION ANAGLYPH.—The use of the polarized anaglyph has become commonplace, and practically every stereo amateur has seen examples of such projection. Inasmuch as we have already described this procedure in some detail in an earlier chapter, we shall not repeat the description. It will be remembered that the two stereo unit images are projected through two polarizing films whose axes lie at right angles; that they are projected in approximate superimposition upon a metallic surfaced screen; and they are viewed through spectacles composed of two polarizing films whose axes are at right angles and which are oriented with the projection axes to produce the necessary cancellation.

THE VECTOGRAPH.—A different type of polarized stereogram, and one which is both deeply interesting and commercially practical, is the Vectograph. We are not going into the detailed theory of the Vectograph, because it is somewhat involved for those unfamiliar with the simpler phases of polarization, and because the stereographer has no call to make use of such knowledge.

Vectograph in Projection.—The Vectograph, as first made, consists of the substantially transparent base with a different image upon each side of this base. It can easily be understood that it can therefore be projected, just as any transparency or lantern slide is projected. We also know that polarization is not affected by projection *per se,* so if we use a standard aluminum-surfaced projection screen (which does not depolarize the light), we have in this stereogram a slide which may be projected normally and viewed with the standard 3-D goggles. Cloth, beaded screens, plaster, and the like will show both images even when the correct viewer is used.

Inasmuch as machines were long ago developed for printing motion-picture films in two colors for the early color processes, there is no reason why Vectographic motion-picture films could not be made, thus providing stereoscopic films which could be projected with any standard motion-picture projector and viewed with spectacles as easily worn as ordinary sun glasses.

Vectograph as a Transparency.—Because there is no reasonable size limitation, large Vectographs can easily be made and displayed as transparencies in public places. These would be especially suited for demonstrations at industrial exhibitions, for example, and in museums. Instead of individual viewers, a series of strips of polarizing film about two and a half inches wide running vertically would enable anyone simply to look through them to see the transparency in full relief. Of course the pairs of strips would have to be separated to prevent the use of the opposed strips which would produce a pseudoscopic effect.

Vectograph as a Photograph.—If the Vectograph is to be used as a normal photograph for mounting in a book or the like, one side of the finished product is flowed with an aluminum paint of special grade. This provides a non-depolarizing reflecting backing for the print. This is in every way similar to the doretype which was at one time highly popular as a portrait medium.

Vectograph in Medicine.—One of the principal roles of the Vectograph is in medicine. At present stereo X-rays must be viewed in special viewers which are extremely large and cumbersome. The usual viewer will occupy a floor space of about three by six feet, and stand five feet high. The surgeon who is to follow the X-ray as a guide in operating must study it beforehand and then take only a "flat" film into the operating room. If the X-ray is a Vectograph and the surgeon is provided with half-goggles of polarizing films, he can observe the X-ray in full relief while actually operating.

General Application.—In fact, there are many more applications of this process, some of which were proven during World War II when hundreds of Vectographs were made from aerial films. The process is attractive to stereographers, even though it does lack the orthostereo quality as do all "viewerless" processes. It is an interesting type of stereogram and for many purposes it has certain advantages over the conventional double stereogram. There is hardly a question of superiority, rather a question of the suitability for any specific purpose. When orthostereo is demanded, a viewer must be used because it is an integral part of the ortho technique, but when it is simply desired to obtain stereo relief without ortho proportions, the simplicity of the Vectograph has much to recommend it. The fact that the viewer (which resembles a pair of sun glasses) and several prints may be carried in the pocket is an unquestionable advantage.

Also see Chapter 19.

Chapter 15

TYPES OF STEREOSCOPY

One ordinarily does not think of asking of stereoscopy, "What kind is it?", simply because stereoscopy is not something which we think of as being capable of division and classification. One thinks we have stereo or we do not have stereo, but this is not entirely true.

When the term is not qualified, we consider stereoscopy as being orthostereoscopy, but already we have had occasion to discuss stereoscopy which is really the genuine thing but which is certainly not ortho.

Orthostereoscopy.—This, the normal form, actually reproduces upon the retinas images which are identical with those which would have been produced by the original objects, disregarding of course the non-essential factor of motion which may be present, but not necessarily so.

The orthostereogram, or rather the stereogram viewed orthostereoscopically shows us the appearance of the original object in *full life size at full natural distance and in full, natural color.*

It is true that color is not usually included in the definition of orthostereoscopy, but it is hardly less important than other factors, because it is an essential factor of stereo relief, wholly aside from the added attractiveness it gives the picture. This has been fully discussed elsewhere in this volume. Inasmuch as orthostereoscopy is by definition, fully correct stereoscopy, the term can hardly be accepted if it does not include color.

Heterostereoscopy.—This is a mixed form, such as using a viewer unrelated to the camera, or any of the "free-viewing" devices. The projected image (in the absence of controlled spectator position), the Vectograph, and the bar-screen processes all fall into this class. The heterostereogram shows us true parallactic relief which bears a definite relationship to the real relief, but not necessarily in normal proportions. The relief may be exaggerated much more than normal, as in some aerial views.

Ordinarily the reproduction presents neither full life size nor true natural distance. In using viewerless methods, the perception is that of a small relief model held in the hands.

HYPERSTEREOSCOPY.—This is a form of stereoscopy which is, as pointed out by Helmholtz, to all practical intents and purposes *telestereoscopy*. It is the result of using a stereo base which is greater than the normal separation, sometimes as much as several feet. In any event, the increase in base is disproportionately large compared with the increase in the focal length of the lens (if any). It usually denotes a wide base with the normal lenses.

HYPOSTEREOSCOPY.—This is just the opposite of hyperstereo and denotes a base less than normal. Some stereographers erroneously use a narrow base when making any stereogram nearer than 10 feet. The technique is of value when making very close-up photographs, at distances of 20 inches or less, when otherwise there would not be sufficient overlapping field to produce a good stereogram. Hypostereoscopic bases as little as a tenth millimeter have been used in microscopic work, but for that purpose the method is less satisfactory than the convergence or rotary method.

METASTEREOSCOPY.—This is commonly referred to as orthostereoscopy, but it must be remembered that orthostereoscopy not only presents objects in full life size and at full natural distance, but it does this for every object within the field. Metastereoscopy reproduces one original object in its natural proportions, usually much larger than life size; but when more than one plane is introduced, objects lying in planes other than the principal plane are not reproduced in the same proportionate relationships. It might be said that metastereoscopy is the orthostereoscopy of a single plane. It is typified by the carefully produced stereomicrographs usually referred to as "ortho." It might also be called the normal stereoscopy of the microscopic field.

PARASTEREOSCOPY.—This is the peculiar composite of compressed space and normal relief characteristic of the stereo-telescopic field. Although the field appears to have only a portion of its true depth, objects within that field appear to have their full natural relief. Thus a three-times parastereoscopic field would appear in such a manner that a wall 300 feet distant appears to be only 100 feet away. That is, the space is compressed to one-third its true value. But at the same time every object within that space appears to have its full degree of relief, and does *not* appear to be compressed to one-third its depth. Here we have a distinct separation of spatial relief and solid relief.

Parastereoscopy is the nearest approach to orthostereoscopic results we can obtain combined with any effective telescopic effect. It results from increasing the focal length of the taking lenses and increasing the base in exact proportion to the focal length. A two-times "para" involves a base of 130mm and lenses of twice normal taking length. Any departure from this proportionate increase throws the result into the general heterostereoscopic class.

Any true stereogram may be classed as one or the other of the foregoing, and many of course meet the characteristics of two classes, but at least it is a working classification which eliminates much confusion and which has proven sufficiently definite for practical use.

CHAPTER 16

TRICK WORK

TRICK AND STUNT PHOTOGRAPHY with the stereo camera is divided into two parts; that which is conventional camera trickery applied to the stereo camera, and that which depends wholly upon stereo principles and has no counterpart in planar photography. Naturally there are some tricks which are more or less borderline, as for example the false impression given by using an abnormal camera angle. This is common practice in planar work, but when so used it lacks the unreal appearance which makes it a part of trick work.

DOUBLE EXPOSURE.—This is done too often by accident to be unfamiliar to the stereographer, but the accidental shot is merely confusion while the planned double exposure can be made highly effective.

There are two kinds of straight double exposure. The simplest

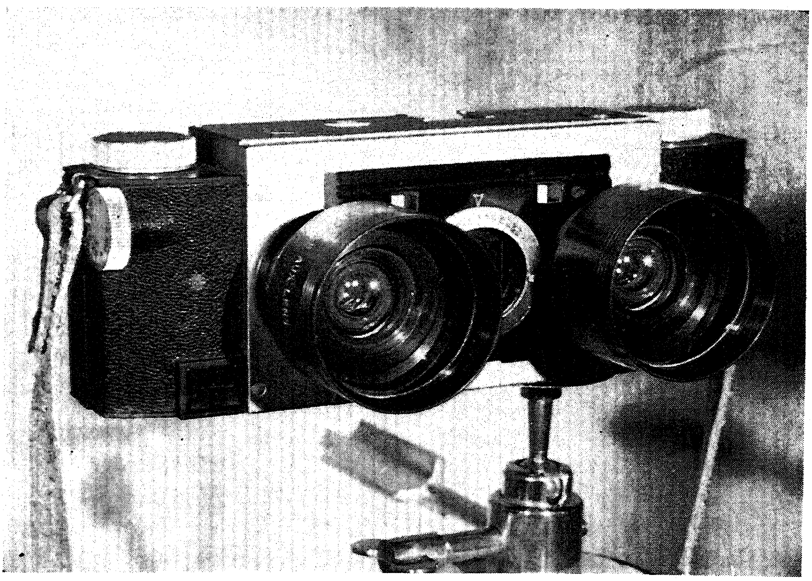


Fig. 16–1. Wide angle lenses may be used in stereo as easily as the close-up type of supplementary.

is that which involves two uncontrolled subjects. For example you may make an exposure of a model seated in a chair. The pose must be comfortable so that it can be held for several seconds while preparing for the second exposure. It is essential that the camera be mounted upon a rigid tripod.

After the first exposure, which should be less than normal but not less than ½ normal, a second model is introduced, and a second exposure made. The sum of the two exposures should approximate the full normal exposure.

The first shot records the first model and the background and the second exposure repeats this. However the second exposure has the second model in place. The background behind the second model will receive a short exposure as will the second model. The result is one which shows the second model as a ghostly figure through which the background is seen. The background is darkened just enough to suggest the semi-solidity of the second figure.

This is an old trick in ordinary photography, but it does not prove very effective in planar work because the second figure appears to be painted upon the background. In stereo the ghostly figure stands out in space with the background behind her. This gives the complete illusion of a fully transparent figure standing out in space. A true ghost. This is not difficult and provides possibility for many amusing shots.

It might be added that the sum of the two exposures may equal 1½ times normal with no ill effects.

MASKED DOUBLE EXPOSURE.—This is a somewhat more ambitious version of the double exposure. The simplest "mask" consists of arranging some part of the background so that it will be in deep shadow. The exposure is made, for example, with a male model who is smoking. A cloud of smoke before the deep shadow provides an efficient setting for the second shot. This shot may be made freehand, but it is essential that the position of the deep shadow be remembered with some accuracy.

The second model is now posed against a dark background, and the second exposure made. The figure of the model is placed in the position occupied by the deep shadow, and the finished result will show the second model in line with the cloud of smoke.

The worst difficulty in this type of work is that the dark background for the second shot must be large enough to fill the whole film area. The actual size of course depends upon the distance between camera and background, and this in turn determines the size of the model.

In the first type of double exposure, the second model is introduced into the scene, and the position is recorded automatically. But in the separate exposure method, it must be remembered that distance will be faithfully reproduced. For example if the man is seated 10 feet from the camera, and the second model is also placed 10 feet away, the figure will appear to be in the smoke cloud. But if the second model is only 5 feet away, then the figure will be much larger than life size and will be suspended in air between the observer and the smoke cloud. This is the easiest and least effective way.

If the model is 20 feet from the camera, the size of the figure will be in miniature, but it will be seen behind the smoke cloud, and of course a very large black background will be required for this purpose. The position in space can be controlled as explained later in the chapter.

One way to eliminate the large background is to make use of camera masks, but as there is no precision finder or ground glass focusing available on the usual stereo camera, the arrangement must be made by approximation. These masks are made of black card or heavy black paper. An area is cut or torn from them to leave an opening corresponding to the position of the model. If the masks are situated about one inch before the lenses, the blocking will be effective and the nearer the mask to the lens, the broader will be the vignette border. As the mask is moved away from the lens the open area grows smaller and the edges become sharper, but even when using distances of 3 to 4 inches the edges will still be satisfactorily softened. If the mask is placed very near the lens surface, almost in contact, there will be no masking, but a variation in exposure can be seen. In short, any portion of a lens theoretically covers the entire film, and practically the effect is nearly enough the same to prevent effective masking so near the lens.

A variation of the old motion picture mask box can easily be made. This is a rectangular box with flaring sides. It may be made 2 inches wide by 6 inches long, extending 2 inches from the camera. The masks are cut from pieces of 2x6 black paper. If the paper is laid out in two squares with centers 70mm apart, the corresponding areas may be cut with little trouble. But if for any reason these masks are to be used with a background which shows any detail, that is, a background not solidly black, the relative positions of the apertures must be cut to place the aperture where you want it.

With the black background the mask has no spatial position, and the same care is not necessary. Inaccuracies will result in a certain stereo discrepancy at the edges of the space where only one image appears, but these may be disregarded. No one will see them unless attention is directed to the error.

Such masks make it possible to reproduce distant figures in miniature without the use of an impossibly large background.

Another method is to have the model and black background in one room, the camera in another and to shoot through a doorway, using the non-illuminated room in which the camera stands, as an extension of the black background.

Duplication.—This is still another variation of double exposure. The mask box will be needed, or a special lens cap mask. It is necessary that the masks be carefully adjusted, something which can be done when the camera is empty, placing a strip of matte celluloid in the film track and using it as a ground glass. If the mask segment is too large there will be a double exposed strip down the center, that is a light strip which spoils the effect. If the segments are too narrow there will be an unexposed strip in the center which is even worse. The straight side of the mask opening must be cut so that the dividing line comes exactly at the film center. Once this has been determined the masks may be used at any future time with full assurance. If the mask box is used, the matte celluloid is used to mark the central dividing line on the edges of the mask box.

Set the two masks at the same side, left, for example. Pose your model at that side of the normal film area, in some pose suggesting a companion. An old favorite is to have the model seated as though playing bridge. Make the exposure. Then place the masks to cover the opposite side of the lenses and pose your model again on that side of the table. Make the exposure. If the masks are correctly adjusted you will have a perfect stereogram of the model playing bridge with herself.

The duplication trick requires more care than the usual double exposure, and is rarely used except when it is desired to show a person twice in the same stereogram. The result is so obviously impossible that it always arouses great interest.

A variation consists of making the first exposure as usual, then reverse the masks, make a halftime exposure without the model and a second halftime exposure with the model to show the model playing bridge with her own ghost.

It will be seen that double exposure involves (A) exposing the same film area twice, as in the ghost effects or it may involve (B) exposing two different areas of the film in sequence. The latter requires a considerable amount of care in matching the edges of the two areas, and both demand a rigid tripod to support the camera immovably during the two exposures.

There are times when two casual, freehand exposures may be made upon the same film. One of these which we saw showed an attractive girl seated within a showcase in front of a shop, but because of the confusion of backgrounds this type of work demands the greatest care of all in selecting the setting for both exposures and hence is the most difficult.

There is no limit to the possibilities of double and even multiple exposure, but you must expect disappointments at first. You must learn the limitations as well as the possibilities, but once you get past this preliminary obstacle you can have a lot of fun with the process.

The fact has been mentioned that size differences are faithfully reproduced in stereo, so that the well-known shot of a girl seated in a wineglass, so familiar in planar photography, cannot be accomplished by the methods which have been described. However such shots are easy in stereo, but as they involve the fundamental problem of space control we shall discuss it later in this chapter.

Camera Angles.—Unusual camera angles have been worked to death by the planar photographer, but when used in stereo the results are so novel that the phrase "angle shot" takes on a wholly new meaning.

To make this fully clear, one or two related factors must be explained.

It is well known that stereographers are warned repeatedly to keep the camera level from side to side. The stereo camera may be pointed upward or downward somewhat, but never from side to side, that is with the two lenses off level.

This rule is deliberately violated in making angle shots, but other conditions must be such that this can be done without spoiling the shot.

A second factor is a physio-psychological one. If you see a tree cut down it does not look as it did when standing. You may stand at the butt and look along the length of the trunk but the appearance is wholly changed. There is a certain psychological-visual effect gained by lifting the head to look upward or bending forward to look down. Undoubtedly this has some close connection with the matter of balance.

This, too, is taken advantage of in making shots upward and downward. If you stand near a tree and shoot directly upward, the slide has little effect when viewed naturally, but if you lift the viewer so the head is tilted backward and the eyes turned upward, the vertical appearance is astonishingly convincing. However, as this demands cooperation on the part of the observer we shall leave it with this mention, and return to the true angle shot.

An excellent slide of this type was sent to us recently. The location was in a Western National Park. The terrain was of rugged hills and immense boulders scattered about. The stereographer (F. W. Kent) had posed his model so that she leaned toward a huge boulder at an angle of some 45 degrees, supporting herself by an arm stretched out against the boulder. The camera was tilted so that her body was parallel with the sides of the finder and the exposure made. The result was astounding. There was a perfect stereogram of a young girl, nonchalantly supporting with one hand a boulder some fifteen to twenty feet in diameter which hung over her with no other support than her hand! It was wholly convincing.

Of course there is a trick to it, and it is this: The subject must be so arranged that there is nothing whatsoever in the picture to indicate the camera tilt. In the stereogram just described, model and boulder were silhouetted against the sky. Had there been a tree or a mountain cabin or other normally vertical line in the composition, its tilt would have spoiled the whole thing.

Another shot of the same type was made of a cat walking along a tree limb. As you know a cat usually starts down a tree trunk head first and almost immediately swings about and backs down. This tree limb was almost horizontal, but its smaller branches all tended outwardly. The cat was walking upright along the limb. Nothing but other limbs appeared in the field of view. The camera tilt gave the limb a direction about 10 degrees off vertical and a position chosen which caused the smaller branches to tend upwardly. The result was a cat walking upon fully extended legs down a tree trunk, an impossible thing to do because the position would give no purchase for the claws.

This has been hardly more than a suggestion of the tricks which can be done with the stereo camera, but it should be enough to get you started and to free you from the bonds imposed upon the use of the stereo camera by the conventional rules. Once you know when you can violate the rules, you will find endless opportunities to make shots which will combine full stereo realism with an apparent disregard of physical laws like gravitation.

Most striking of all will be the tremendous effectiveness of the stereograms as compared with the usual trick shot in planar photography.

Parallax Inversion.—There was a time when the photographer who did not fully understand the effects of parallax, and of transposition, simply did not make stereograms. Today it seems that more than half our stereographers have their slides mounted for them, and are not even aware of the importance, or even the existence of the step of transposition.

Perhaps that in itself would not be important, except for the fact that those who are unfamiliar with transposition are not familiar with the appearance of an untransposed slide. Several times now we have received slides with letters requesting information as to the cause of the curious appearance exhibited. This appearance is variously described as "fuzzy," "blurred," "double exposure," "eye-straining" and so on. In fact the slides examined were all sharp, but the trouble with all of them was the absence of transposition. In other words, the two unit images were changed left for right and vice versa.

This has a direct bearing upon the subject of stereo vision itself, and there seems to be little doubt as to the value of the study of such untransposed slides. Such slides are called "pseudograms" to distinguish them from "stereograms." This term is often confused with "pseudo-stereograms." The pseudogram (picture in the method of pseudoscopy) is a differentiated pair mounted in reverse. The pseudo-stereogram is a pair of identical pictures, made from one negative which of course exhibit only that peculiar indefinite relief common to all pictures viewed through a lens and which so many people consider to be truly stereoscopic. So, to prevent confusion, we shall refer to the pseudogram as an inverted stereogram.

The basic effect is that of transposing distances. Those objects far away seem to be near; while nearby objects seem to be far away. Of course, nearby objects obscure parts of those objects behind them, so we have silhouettes of odd shape hanging in the air nearby. But because of the absence of perspective diminution, the fact that the distant objects conform exactly to the outlines of these patches is not at once apparent. This effect has been briefly discussed in the chapter on pictorial work.

In fact, unless there are marked planes and a fairly great variety of them, the effect is appreciable only to the experienced stereoscopist. There is great excuse for the beginner who cannot see what is wrong with one of these slides.

One of the worst types of subject is that which includes several planes, closely spaced, and with a considerable distance between the camera and the first significant plane. Subjects of this kind have confused even experienced stereo technicians for a time, because the inversion of distances is not immediately apparent. Very often the stereoscopist states that the slide is made of two identical prints.

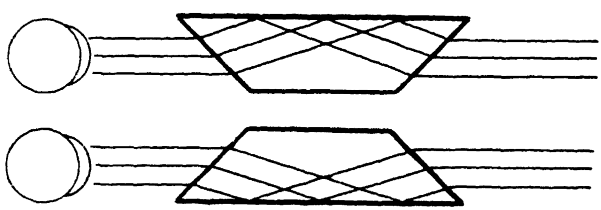
So, if you find among your slides one which for some obscure reason does not look just right; which appears to be somewhat "jumbled" without being fuzzy just try changing places with the two films and see if that does not solve the problem.

It has been said (and written) that pseudoscopic vision is purely a phenomenon of photography, but this is definitely untrue. It is quite easy to see inverted distance by direct vision. One of the easiest ways is to remove both ocular and objective lenses from a pair of prismatic binoculars, and to look through the prisms alone. There is, of course, no magnification, but the pseudoscopic relief is considerably more definite than in a pseudogram, although the image is upside down.

A better, if more elaborate, method is to make a twin barrel telescope and mount in the tubes a pair of Dove prisms. A Dove prism is similar to a simple right angled prism with the apex cut off. In fact an ordinary 90 degree prism may be used but the unused apex takes up more room than the truncated Dove form. The bases of the prisms are parallel, with the apices facing each other. Light rays strike the first oblique surface, are bent toward the base, reflected there, fall upon the second oblique surface and thence to the eye. The reflection at the internal base of the prism has produced a mirror type inversion, that is changed right to left and vice versa. (This is also an excellent way to make a transposing viewer.)

In short, the only thing required to produce pseudoscopic vision is to exchange the right and left elements of visible surfaces! In the pseudogram, the right-eye image is seen by the left eye and vice versa, but in direct vision the reversal is simply that of the scene itself, as though reflected in a mirror. NO! You cannot do this by simply looking into a mirror, each eye must have its own independent reflection.

The action of the Dove prisms is shown here:



The tubes of your pseudoscopic binocular need not be round. In fact for experimental purposes you can make square cardboard tubes. Or you can make cork mounts to slip into short lengths of mailing tube. You can cut two holes in each of two pieces of cardboard to hold the tubes parallel, and there you are. If you wish a more permanent instrument you will find plastic as good as metal and a lot easier to work with.

If you just want one look, you can lay the prisms on a table, then kneel down and look through them. Be sure the shorter of the long faces are turned toward each other. If the shorter face is upward or downward you will see objects inverted, but if in correct position you will see right and left interchanged.

It is an interesting experiment, but of what practical use is it? This experiment proves the importance of parallax, in fact it proves some other facts which have been frequently disputed.

First. Experts in the field of vision are often inclined to disparage the importance of parallax in stereoscopic perception. This is given as *one of* several factors which result in distance perception. Such things as perspective diminution, the overlapping of far objects by those near at hand, and the effect of atmospheric haze, to mention but a few, are often said to have quite as much effect in producing relief perception as the parallax of stereo.

But what happens in pseudoscopic vision? Here every factor other than parallax remains unaltered. Even when there is a strong light to give the contour effect of shadow forms, no difference is made. The inverted parallax overrides all other factors and produces an obvious effect of inverted distance. Inasmuch as the factor of parallax is the *only* one altered, it seems we are justified in saying that the distance perception due to stereo parallax is greater in its influence than all other contributory factors combined!

Second. If the foregoing is accepted, we are then forced to accept the statement . . . "The apparent distance of an object is determined by its stereo parallax." And that too is true. But once more:

Third. If it is possible to alter the parallax without altering the distance of an object, that object will appear to lie at the distance corresponding to its parallax rather than at its true distance. Again this is demonstrable, for it is the very factor upon which we base space control. BUT this statement is attacked often by writers about human vision; some of whom state that other factors, principally that of the diminishing size caused by perspective will prevent the object from being visually accepted at an altered distance. All stereographers who have experimented with space control know how utterly false this is. The realism of space control is the reality of life—and results in one of the few pictures of any kind which can and do produce genuine astonishment in the spectator.

Now let us carry this reasoning to its logical conclusion. It might be said that the external stimulus of stereoscopic perception is parallax; but this is not enough. For any one given distance there is a corresponding parallax. But if the stereogram shows us just one plane in the strictest sense it is not perceptibly stereoscopic; at the same time if we do have a single plane, the parallax normal to that plane is present. Therefore it is not enough simply to have parallax.

If the subject consists of a group of objects all in *precisely* the same plane, each exhibits the parallax of its position, but still we do not have stereoscopic relief, as the image is still confined to a single plane.

Therefore the mere existence of multiple parallax is not sufficient, although it is obvious that multiple parallax is essential.

If there are objects in different planes, each will exhibit the parallax normal to its distance, and these various distances will create a series of different parallax values. Thus we have the establishment of depth in the sense of the establishment of several planes, and we are approaching our goal.

Now I must ask you to bear with me in a bit of repetition: If in viewing a stereogram (or real objects for that matter) we fix our eyes upon a single point and hold it steadily for several minutes—(which by the way is almost superhumanly difficult, because most people do not realize that "steadily" means without shifting the gaze as much as 1/100 inch)—the eye becomes conscious only of the spot upon which attention is focused. The side images are as visible as ever, but they remain motionless and demand no attention whatsoever. The result is that we return to the condition of a single parallax, and there is a definite loss of stereo perception. The instant the eyes are moved from the target spot, the scene jumps back into full relief. In fact this experiment is more strongly marked when direct vision is used rather than a stereogram.

Thus we come to our final factor, the shifting of the eyes from point to point, the focusing of attention, no matter how briefly, upon point after point. Our eyes are constantly in motion, something of which we are unaware until we gaze fixedly at some object and so produce eye strain! Therefore parallax must be dynamic if depth is to be perceived.

To result in stereoscopic perception then we must have parallax . . . this parallax must be multiple . . . it must be differentiated . . . it must be dynamic . . . then and only then do we have that stereoscopic vision which because we always have had it, we regard as a simple and unremarkable thing.

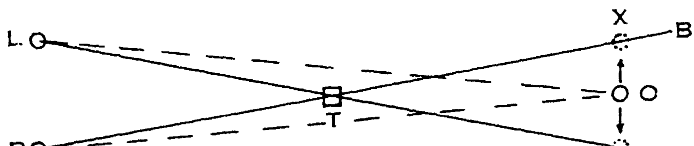
If you wish to know just how important this is, get a black patch and tie it over your eye and leave it there for as brief a period as a single hour. Then remove it. You will then begin to appreciate the fact that stereoscopic vision is something far more important in our lives than being merely the phenomenon which makes stereo photography possible!

These principles will serve to make the explanation of space control more easily understood.

Space Control.—Space control is a type of trick work which is based wholly upon stereoscopic principles and has no counterpart in planar photography. Incidentally, nothing equals it as a demonstration of the full realism of stereo and of the shortcomings of planar photography.

Visual judgment of distance is based upon parallax. To repeat, it is possible to list and describe a half dozen other factors which are supposed to have some bearing upon it, but the fact remains that the actual perception of distance is solely a matter of the parallax involved. In fact, when the parallax is such that the resulting size is unreal or even impossible, the visual perception is unaltered and we actually see objects in impossible size relationships, regardless of all of the other so-called "distance factors" combined.

Therefore, it is obvious that if an abnormal parallax can be introduced, an abnormal distance will also be introduced. The whole system of space control lies in this simple manipulation.

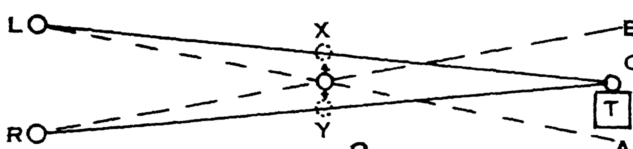


1

In the above figure, L and R represent the two camera lenses. T is a table in the foreground and O is a living model twice as far from the camera as the table.

The lines LA and RB are the parallactic rays which cross in the center of the table T. The dotted lines LO and RO which meet at O are the parallactic rays for the model.

If the two images are exposed separately, and if the model O can be placed in position X during the right exposure, then moved in the direction of the arrow to position Y during the exposure of the left film, it is obvious that the parallax of the model will be identical with that of the table. As a consequence, the model will appear in half natural size, in that spatial position coinciding with the tabletop. If the vertical positions of the tabletop and the feet of the model are placed in correct alignment, the finished stereogram will show a half size, living model standing upon the tabletop. Such is the basic mechanism of space control. Further than this there are only operational details to consider.



2

In the above figure (2), a similar problem is shown, but this time the table is in the background, and the desired result is to show a double sized giantess seated at the table. To increase the effect and make it more definite, a second living model may be seated at the opposite side of the table.

Here rays LT and RT are the parallactic rays for the chair position beside the table T. There is no chair there, but the large chair will appear there. LA and RB are the parallactic rays for the model O, who is seated midway between the camera and the table. In making the first exposure, the model is moved to the position X and for the second exposure to the position Y.

In the first figure the model moves to the left for the right exposure and to the right for the left exposure. In the second example, the model moves to the right for the right exposure and to the left for the left exposure.

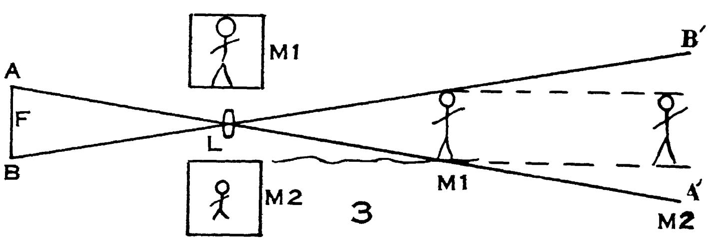
It might be argued that instead of moving the model in the second example, which is somewhat difficult, it would serve the same purpose to move the table according to the first example; and the table is much easier to move than the model.

But consider! If this were done, the result would not be a giantess seated at a normal table, but would simply show a normal human being seated at a miniature table, and miniature tables are not astonishing.

The object which is moved is the object which will alter in size, while all other objects remain in their natural sizes.

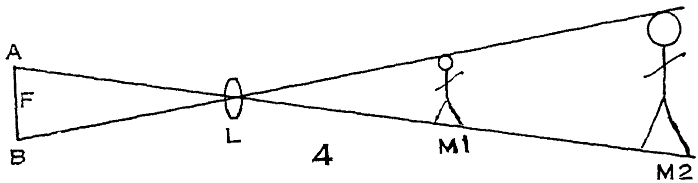
The question will naturally arise as to why there is any size change. A camera lens will form an image of definite size, and that size depends upon the distance of the object. Then how is the size altered?

In any photograph the actual size of an image, let us say the height of the image of a six-foot man, is definite for a given lens and a given distance of the man from the camera.



3

In the above figure (3), F is the camera film, L the lens, AA′ and BB′ the limiting rays. At M1 a man's figure just fills the field but at M2 twice as far away the height of the image is just half that of the film. So the image height in M2 is just half of that of M1. There is a direct relation between the actual size of the image upon the film and the distance of the object from the lens.



4

In the figure (Fig. 4) above, the man who occupies the full camera field at M1, is pushed back to M2, but is increased in size as he moves backward, so that at all times his image fills the film. It will be seen then that the height of the image upon the film is directly related to the distance from the camera, and normally, (because we cannot actually increase size with distance) the size on the film is directly proportional to the distance.

However, the parallax positively defines the distance. If the parallax is for 10 feet and the image size is the diminutive one normal for 20 feet, there is no confusion in perception. You will simply see the miniature figure at a distance of 10 feet. Parallax is in full control of distance.

Therefore, the problem is simply that of moving the object nearer the camera optically (by increasing parallax) while retaining the image size normal for the true distance (and this is automatic). Such a thing is impossible in planar photography because we have no absolute standard of distance judgment, because we have no definite perspective-distance perception and because the planar photograph contains no parallax, the sole source of definite distance perception.

However, let us return to the first part of this discussion where it is stated that parallax is the sole distance determining factor in stereo. Then the whole thing becomes quite clear. We leave (Fig. 1) the model in the distance, and we obtain the small size normal to that distance; at the same time we alter the parallax to that of a nearby object. The stereo result combines the size normal to the original perspective, and shows the distance normal to the parallax used.

Let me emphasize that this effect is not one which you have to persuade yourself to see. It leaps to the eye, just as stereo relief did when you first saw it. Almost always, the first question asked when a space control shot is shown, is "How on earth did you do it?" If the size reduction is only about half, and the model a stranger, you will be asked where you found a midget to pose for you.

But one of the most interesting forms of this control is when a human figure between 6 and 12 inches tall has a place among normally sized people. For example, with a little patience you can show a man seated at a table and standing by his plate a girl holding up a dinner knife as tall as she is!

You have seen the old, old combination shot in which a girl is shown seated in a wineglass. It has been used over and over again in publicity pictures, and the reaction of the laymen is a mild curiosity as to where the huge glass was obtained. When well done it is characterized by reality without conviction and when poorly done there is no reaction. In stereo it is all so different. You see the wineglass a couple of feet away with human fingers grasping the stem, the distance is normal, the size is normal . . . yet there sits the girl, maybe four inches high when standing, but beyond any doubt a real, living human being! And you can do it easily.

You will spoil some film, but the result is worth it.

You will need a mask box which has been described, and you will mask out all but a portion of the field in the center laterally and just above center vertically. Pose the model. It is advisable to have the camera upon a tripod with tilt head.

Memorize the position of the model in the finder, or better yet make a dummy camera with ground glass to mount on top the stereo camera, using simple lenses of 35mm focal length, and outline the model's position with a pencil in both frames. Remember that these exposures must be made separately and the parallax must bring the model to the distance of the glass.

Now make the glass setup, align the glass and the model by means of the memorized position or the dummy camera and expose for the glass. If you use the memory system you will be lucky to get one good result from twenty shots, but with the dummy camera you should get it within the first three or four.

Computation of parallax is easy, but failure often is a result of failing to understand the importance of accuracy of measurement. However working by computation is, as we have said, untrustworthy and tedious. It is much better to work under visual control.

DUMMY CAMERA.—You will need a cardboard box about 2x5 inches in size and at least 2 inches deep, of the telescoping variety or a more permanent dummy. You will also need a piece of ground glass the size of the box or a sheet of matte celluloid. If you wish to make a more perfect job you can use plastic sheet for the box. You will need a pair of simple lenses of about 35mm focus, plus or minus a millimeter. Make holes for these in the front of the box exactly 70mm apart (center to center). (Focal length and separation should match those of the camera you use). Cut out two squares about 1½ inches square from the bottom of the box. These squares should also be 70mm apart center to center. Place the ground glass over the openings, ground side out, and slide this into the part of the box holding the lenses. By sliding the bottom into the top you can bring the dummy to focus. You will then need to make a light framework or other connector so that this dummy can be held in fixed relationship to the photographic camera. The only real difficulty is that the dummy must be made to tilt forward and should have this tilt calibrated for each foot up to 10, after which the vertical parallax can be ignored. (As a matter of fact little trouble will be involved at distances greater than 5 feet.) Vertical parallax is involved only in such alignment as the feet of the model upon the tabletop and does not affect space control. Because this dummy is only necessary when the exposures are made in different places, and as that requires a mask box, it would be more to the point to build the mask box and dummy camera as a unit into which the camera could be clamped when desired.

ANGLE SIGHTS.—For the simpler type of space control, in which the whole thing is shot from one camera position, the best control is a pair of angle sights. These are simply plain sights, such as a plastic or metal tube with cross wires fixed at one end, the other end capped with an eyehole. A simple telescope can be made which makes the cross wires easier to see. Two such sights are required, and a metal strap to support them, one directly over each camera lens. A pivot over each lens permits the sights to be swung laterally and to be clamped in position.

Refer to Fig. 1, the right exposure to be made first. The sight over the right lens is turned until the center of the table lies across the vertical cross wire, and the camera with sights tilted until the far edge of the table coincides with the horizontal cross wire.

The model O is then moved until the vertical cross wire bisects her figure and her feet rest upon the horizontal wire, for example. The exposure is made.

Without moving the camera, the left sight is brought to bear upon the center of the table, and the model moved until the vertical cross wire again bisects her figure. The horizontal wires serve the same purpose in both. The second exposure is now made, and you may be assured that if the model did not change pose between the exposures, you will have the effect you want.

It is advantageous to have a napkin or the like crumpled on the table so the model's feet can be hidden behind them, or make use of a dark table and place the feet in the center of the table allowing the lighter flesh tone to override the dark top.

For best results it is advisable to have the model pose upon a panel or sheet of metal which can be dragged into the new position, as it is almost impossible for a pose to be duplicated with the exactitude demanded in parallax work. If the subject permits a bicycle, wagon, sled or the like to be a part of the picture, the task is much easier.

We have made stereo registration easier by recording the first pose with a Land-Polaroid camera placed just above the center of the stereo camera.

Such work does demand some preparation, a loss of time and film in acquiring skill and you can never count upon perfect results. However, with patience you can acquire sufficient skill to be reasonably sure of making four hits out of five tries. Of course the cooperation of the model is essential, and it is advisable to explain in detail just what is required.

When you, for the first time, see a living miniature, you will probably burn up more film than you should in making these fascinating freaks of nature. And by going a bit to extremes, you can make use of a preserved butterfly to make a subject such as a butterfly with 24-inch wing spread carrying on its back a ten-inch human. Fairy tales come to life . . . and the beauty is that the "faking" is nothing more than a warping of natural law in such a way that the layman can never guess how it is done. All he knows is that his intelligence is affronted by an utter impossibility which is undeniably fact.

As we go to press we are engaged in some new work on space control. It is obvious that because of the successive exposures employed, a single camera will serve as well as a stereo type. The existence of reflex cameras makes alignment much easier than with the usual optical finder. For 6x13 we have used the Rolleiflex with satisfactory results, but in the 35mm field, for making color stereograms to match modern stereo format, some difficulty has been encountered.

At first we used a reflex attachment, but this involved the use of long focus lenses, which was not advisable. More recently we have been using the 35mm Alpa Reflex and have found it highly satisfactory for this as well as other types of successive exposure, 35mm stereo. The extra width of the frame permits gage cropping, and still leaves sufficient film for mounting to correspond to any of the three accepted widths now in common use.

Chapter 17

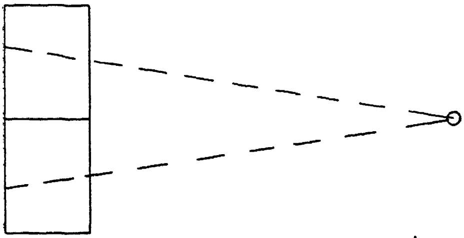
CLOSE-UP STEREOGRAPHY
(Macro - Micro)

There has been a great deal of confusion regarding close-up work in stereo. Indeed there have been many "laws" cited which are not laws at all, but simply principles arising from a desire to present the most attractive appearance in the finished stereogram. For example, there are the many rules which give the minimum working distance at practically every conceivable distance between 3 and 10 feet. In reviewing such statements, let us consider the optics of orthostereo. The angular values of the original direct vision, including that of convergence, are substantially duplicated in the camera. Of course, exact duplication is not possible for several reasons, including the difference among individual interpupillaries, the greater base of several types of cameras and the like. The important factor is that these slight discrepancies exert no appreciable visual effect.

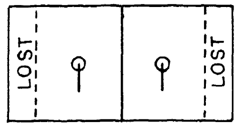
Therefore it is obvious that the actual minimum working distance is the minimum distance of comfortable direct vision, or approximately 16 inches. It is well known that two widely favored cameras, the Realist and the Verascope, have focusing scales calibrated to two and one-half feet and two feet respectively; and that hundreds of owners use the camera at these distances with full satisfaction. There is a reason for avoiding extremely close work, but it is nothing more than an incidental limitation imposed by the camera.

In direct vision we have learned to concentrate upon that object which is the center of interest, and largely to ignore other objects. This "attention" angle is very small, normally, and the duality of other images is automatically suppressed to conscious vision although they are essential in the subconscious perception of the stereo image, that is to the synthesis of the stereo image. Outside this minute angle of acute vision, visual perception extends rather widely and eventually falls off. The sharpest cutoff we have is the diffused image of the brows and the bridge of the nose and the outer eyelids.

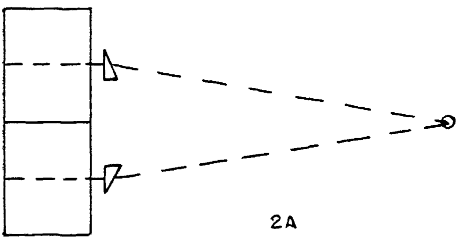
In the camera we have the sharp cutoff of the edge of the aperture, and this is duplicated in the sharp edge of the mount aper-



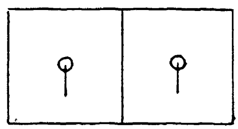
1A



1B



2A



2B

1A. The normal lenses produce images in which the close-up object is recorded upon the film outside the center.

1B. When transposed, this stereogram shows the close-up images nearer than the centers, causing the loss of a wide band at each end.

2A. With prisms before the lenses (or prismatic close-up lenses), the rays are so deviated that the nearby object is recorded at the film center.

2B. This centering of the images avoids the loss of bands at sides.

ture. This is the real reason for avoiding extreme close-ups without compensation. When such a close-up object is photographed, the plane area occupied by that object is not at all duplicated in the two images, so there is a relatively wide "ghost" band at the sides of the viewer field. If objects at a distance are also included, it will be seen that these side bands shrink to an imperceptible degree when looking at the distant object, but return when the vision returns to the close-up object.

Those familiar with stereo disregard this phenomenon as inevitable when both extreme close-up and distance appear in the same slide, but there are many who regard such an appearance as a "distortion." It is nothing of the kind, simply a phenomenon which is part and parcel of the differential homologous distance which in turn is the essential factor of stereo.

Thus, the decision sinks to the level of personal preference, but in stereo there is a habit, and a bad one, of condemning everything which violates personal preference, as a "distortion." There can be no true laws or rules which do not apply equally to all individuals concerned. Thus the establishment of a minimum working distance is akin to the problem of the window. Many workers insist that the window MUST be nearer the observer than any part of the subject; others find that having the window in midplane actually exaggerates the appearance of relief, so there again, as we have said, the matter is not one of rule, but one of personal preference and nothing else.

However, if you prefer to avoid the characteristic appearance of the close-up object, you can do so easily, but it will be necessary to keep the background within a distance which does not exceed the object distance by more than 5 to 10 times. Using a single camera, you may center the object for both exposures by rotating the camera and moving it laterally between shots. There is no limit to the object distance in this case other than that imposed by the working capacity of the camera used. If you use a stereo camera, you may place prisms over the lenses which deviate the optical axes so that they intersect at or near the object.

The background limit of five to 10 times the object distance is maximum and should not be used if the very best results are desired. Actually the deviation of the principal object should be determined, and the background placed at a corresponding distance. According to one school the farthest background should have a deviation of not less than half that of the principal object, but we prefer to keep the background within three prism diopters of the nearest foreground. This will permit the principal object to be placed, for example, one diopter behind the immediate foreground and two diopters in front of the background.

The difference can be illustrated by examples. Assume the object distance to be 20 inches. According to the first method (five to 10 times object distance), this would place the maximum background at 100 to 200 inches, roughly 8½ to 17 feet.

In the second method, assuming the camera has a lens separation of 70mm (half base 35), we may consider 20 inches as equivalent to 50 centimeters. This gives us a deviation of 7 diopters. If we use one-half of this or 3.5 diopters, we place the background at one meter or twice the distance of the object. (40″).

In the third method, if the object lies at 50cm or 20 inches, the nearest foreground should be not less than 43.75cm and the background not farther than 70cm. To substitute approximate equivalents we have: Foreground 17¼ inches, principal object 20 inches, background 27½ inches. We have found such a distribution to produce extreme close-ups which are as easy to view as the normal long distance shot.

The vital point is not the absolute convergence, but the restriction of deviation *range* within one slide to a value which is not excessive for the scene of normal distances. A total range of three diopters in normal slides equals infinity down to 1.16 meters, or just under four feet.

But this can be misleading. The distance of 1.16 meters is the distance equivalent of three prism diopters *for a camera with 70mm lens separation,* but for average human vision, three diopters indicates only about 42 inches. Therefore the range involved in the close-up is that which would appear in a slide to embrace distances from 45½ inches to infinity, but which is equivalent to direct vision from 42½ inches to infinity (provided the human interpupillary is the average 65mm).

It can be seen from this that if you wish to make exact computations, you will have to consider both the separation of the lenses of your camera and your own interpupillary separation. As a matter of fact the examples given are not precise because the camera used actually has a lens separation of about 69+mm, but to make computation easy, the round figure of 70 was substituted.

If you make any such computations you will be surprised at the diversity of result, (as the three inch difference in the three diopter limit between camera and eyes). In actual experiment you will be equally surprised to learn the great divergence from theoretical limits which can be made without the introduction of any visual distortion. In fact most stereographers use the 65mm base as normal for all computations regardless of the camera used. The only exception is that made for extended or diminished base as in hyperstereo, and in micro work where a fraction of a base is used. For anything between 62 and 70, the practical result is satisfactory.

Rotary parallax.—The usual stereo technique involves the use of parallel lens axes. However this rule is violated often enough to make the exceptions interesting. When parallel axes are not used, convergent axis are substituted so that the camera positions resemble those of the converging eyes. The explanation as to why this convergence is inferior to parallel axes is given elsewhere in this book.

We have seen that physically the convergent camera and the rotated subject are essentially the same, so that the convergent camera becomes essentially a phase of rotary parallax.

In speaking of the convergent camera, it has been assumed that the camera is used for successive exposures and bodily rotated between the exposures to converge upon the subject. However, with the rigid stereo camera and simultaneous exposure the technique would seem to be impossible because the stereo camera will not bend. (It may be of interest to know that a convergent camera was made commercially which was adapted to the binocular microscope objectives made for the Greenough type of stereoscopic microscope.) It is possible however to adapt rotary parallax or convergent axes to the conventional stereo camera. This is done by bending the light beams rather than the camera body.

In the paragraph above supplementary prisms are indicated. In practice the magnifying lens commonly used for close-up work is combined with a prism in a single piece of glass. Thus when such a supplementary is applied to the stereo camera lens, there is a simultaneous change in focal length and a deviation of the axial ray. The prism power is so adjusted to the magnifying power that when the object is focused it will also be centered in the two films. Such supplementaries are made in three close-up powers and a fourth weak prism is supplied for those who wish correction at distances less than 10 feet but within the focal capacity of the unassisted camera lens.

As is true of all "rotary" parallax, objects at infinity will be abnormally displaced, due to the crossing of the axes at the object, but this does not interfere if the background is kept reasonably near.

However, there is one factor which must be considered, one which varies with the stereo skill of the individual. When the object distance is small, 16 inches or less, and when it has considerable depth, there will exist a condition of excessive difference in parallax as the eyes move from one part of the object to another. This is known in stereo work as an excessive depth of parallax, to some extent analogous to depth of field.

When there is an excessive parallax depth, the spectator is conscious of the change in convergence in looking from the nearest to the farthest point of the object. Some, particularly those who are new to stereo, find this actually painful. Those who have had more experience in stereo viewing and have developed some stereo skill do not find it uncomfortable, but the sensation remains, including that of a definite time interval in moving from one position to the other. Whether this is objectionable or not and the degree to which it is objectionable, depends upon the individual. As a rule, however, it is advisable not to make full base stereograms at a distance of less than 12 to 14 inches, even when prisms are used to eliminate the ghost side-images. For nearer distances, macro techniques are advisable.

Macro.—The stereo camera is easily adaptable to macro photography, and with suitable supplementaries consisting of prisms with positive correction ground in, it is possible to use the normal stereo camera at distances as close as 10 inches. This is approximately 250mm, and as the usual focal length of the camera is 35mm, the ratio will be approximately 1:7. However it must be remembered that the parallax remains normal. That is, if the object is at 8 inches, the parallax will be that of an object actually viewed at 8 inches; and, as explained above, the relief will appear to be exaggerated and parallax depth will be excessive.

Many workers object to relief which results from any parallax greater than six or eight feet. Personally the writer does not agree. He finds the parallax of 16 to 20 inches quite acceptable, and for many objects even preferable to a compressed relief. It is advisable to limit this technique to a minimum of 12 inches.

Parallax increases as distance decreases. "Greater parallax" refers to nearer objects.

SUPERMACRO.—For that type of macro shot which merges into low power micro, it is ordinarily necessary to use two cameras. Zeiss make a stereo ophthalmic camera for making macro-stereos of the retinal surface, but aside from such complex and costly instruments, the work requires two cameras or a single camera used to make successive exposures.

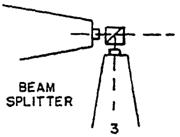
The two cameras should naturally have sufficient bellows capacity to make possible images at least 1:1 in size, and it is preferable if this can be increased. The ideal equipment is bulky, because it consists of two cameras of great bellows capacity equipped with lenses of long focal length. Eight-inch lenses on cameras of some 30-inch bellows capacity are excellent, but the lens boards should be small, if a diagonal is to be used.

The Diagonal.—This is some kind of beam splitting device. It may be a normal beam splitting cube, but unless it has great size, the camera lenses must be in extremely close proximity, and there is only a minimum base available. For this reason, the beam splitter is usually restricted to special instruments used for one type of subject only.

A better device is a 50-50 mirror. This mirror transmits 50 percent of the light and reflects 50 percent (actually there is a slight loss in transmission, but due to the coating used this may be ignored). The better mirrors are dichroic, however, and in color work this is somewhat objectionable as there is a pink correction applied to one and a blue to the other. It is said that this slight color difference is merged visually by the observer, but the writer has found a discernible effect.

However, the mirror does permit the base to be altered at will and a 1½x3 inch mirror will permit from zero to almost 2 inches base.

In using the diagonal, the cameras are positioned at right angles. One of the cameras accepts the image through the mirror (nominally a direct image), and the other accepts the image reflected from the surface of the mirror at right angles. Displacing either camera laterally will alter the base, but the motion is



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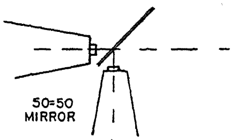

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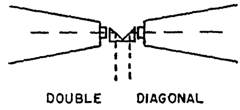

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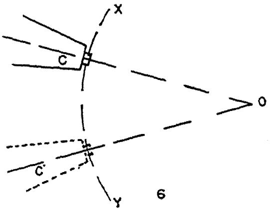

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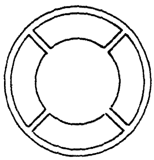
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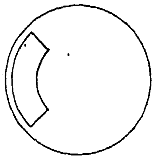
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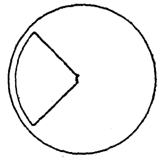
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3. The beam splitter is used with two cameras in macro work when the base is very small. The setting here is zero base.

4. For greater stereo bases the 50-50 mirror permits one camera to be moved sidewise to adjust base. Drawing shows zero base.

5. When small bases are not required, the double diagonal pictured here is easily operated and gives excellent results. The base is changed by moving one camera away from the other.

6. When the camera is used with convergent rays (objects centered), the actual relationship is that shown above. Camera is moved from C to C′ between exposures; object at O.

7. A conventional "darkfield" diaphragm used in microscopy.

8. A stereo darkfield diaphraghm corresponding to Fig. 7, but as used for stereomicrography.

9. A brightfield diaphragm, complementary to that of Fig. 8.

usually given to the camera which lies normal to the object, and that is the camera which receives the transmitted image. The mirror, of course, is placed between the lenses at 45° to both of them.

Double Diagonal.—This is the method favored by most workers, although it has the disadvantage that zero base cannot even be approached. Each camera has a right angle prism attached to the lens, and the cameras point directly at each other. Thus BOTH cameras receive a reflected image. However the smallest base is one which is about 50 percent greater than the lens aperture, the exact amount depending upon the lens mounting, the angle of field and so on.

The lens mounts make it impossible for the lenses to work in approximate contact with the prism, so relatively long focus lenses are necessary to increase working distances. This, in turn, indicates long bellows. The method is most easily applicable to moderate degrees of macro, that is to a size ratio of about 1:1. For enlargements up to about 2:1, the double diagonal may be used with small lenses and small prisms, but for extreme work the prism interferes with the orientation and lighting of the object. Thus, for greater magnification it is necessary to work with a single camera and successive exposures.

ROTARY DISPLACEMENT.—The argument is often made that because the human eyes converge upon an object, the stereo camera should also be made to do the same. We have explained this fallacy elsewhere, but when the object is limited to a group of closely associated planes, the method is quite satisfactory.

In Fig. 17-6, the object lies at O and the two camera positions are indicated as C and C′. It is easy to see that what actually happens is that the camera is moved along the arc XY even though in practice the camera is moved laterally and then turned to bear upon the object. What happens is that the camera has two positions, the difference between which is equal to the parallax used. When this is considered, it will be seen that, *insofar as the object is concerned* similar results will be obtained by rotating the object through the same arc. The object is often easier to move than the camera, and this is a method widely used in higher power macro and in micro stereo. It will be noticed, of course, that when the camera is moved, the parallax involves all objects within the field, while with object rotation only the object itself is affected. Thus, with camera rotation the effect is closely similar to that obtained by normal stereo displacement, but when the object is rotated, only the object will have relief and the background and surroundings will be astereoscopic. Therefore, object rotation is limited in most instances to a single object mounted upon a neutral background.

MICRO.—When the image is some ten times the size of the object or more, we enter the field of photomicrography. This assumes the use of a microscope in connection with the camera. In fact, the fields of macro and micro overlap. It is possible to obtain many magnifications with macro methods which can be obtained with the microscope.

There was a time when photomicrography involved the use of only the objective of the microscope, and to that extent it was no more than an additional degree of macro. However, modern photomicrography assumes the use of the complete compound microscope, although at times the visual ocular is replaced by a special photographic lens system.

Therefore, it is impossible to draw a sharp line between macro and micro so far as size is concerned. We shall, for that reason, consider the micro field to include all conditions in which the combination of camera and compound microscope are used. It may be added that with very few exceptions, the camera is the normal, single, photomicrographic type and not a dual stereo camera. This, of course, indicates the necessity for making successive exposures a technique which is classic in stereomicrography.

THE MICROSCOPE.—Photomicrography, and consequently stereomicrography, is hardly popular among amateurs. Probably the reason is that the compound microscope must be mastered before really good results can be obtained. The possibilities can be shown when it is stated that among those who use the microscope daily in their work, not one in one hundred has ever seen a really well defined microscopic field. There is no instrument in common use, not even the camera, which is so universally abused by its users. The reason is not hard to find. Anyone can buy a camera, shoot one roll of film and get results good enough to make vacation souvenirs; anyone can be shown how to focus a microscope and be taught to handle it well enough to obtain passable results in a few days, so why go further?

As a matter of fact, it takes months or years of practice before one can use the camera with complete confidence and competence, and it takes at least twice as long to learn correctly to manipulate the compound microscope.

Among other elementary things, one must learn how to illuminate, how to control the cone of illumination, how to set the tube length, how to compensate adjustable objectives and how to focus the condenser. If one is interested in making photographs, the apochromatic objective is just as essential as is the anastigmat upon a camera.

Volumes larger than this whole book have been written about the correct manipulation of the microscope, and the ground has not been fully covered. Obviously, we cannot be expected to cover that ground in a single chapter. We must, therefore, fall back upon purely stereoscopic technique, leaving the purely microscopic and the purely photographic techniques to be learned from other sources. We shall, then, assume that the reader has, or can acquire from other sources, the necessary data concerning these techniques.

LOW-POWER STEREOMICROGRAPHY.—The lower magnifications are obtained without the use of the compound microscope, although the conventional micrographic camera is used. This, of course, is really a variation of macro technique. This is a camera, usually mounted upon a vertical bed, with the lens pointing downward. Beneath the camera there should be some kind of stage or raised platform to hold the subject. This stage should have a surface plate of glass, plain and transparent. It should be so arranged that black or white or gray underplates can be placed beneath the stage. There should also be a swiveled mirror beneath the stage for providing strong transmitted illumination. While these things may be purchased, some of the best outfits have been either homemade, or have been based upon a commercial unit to which homemade accessories have been attached. A convenient film size is 3¼x4¼, although anything between 2¼x3¼ and 5x7 may be used.

A great deal of work has been done in this field during the past several decades, but naturally most of it has been in black and white. Because the emulsions and the processing is unusual, any discussion of the work has heretofore necessitated a prolonged treatment of these subjects. Fortunately, stereo is almost wholly color work, and as color is just as essential and just as attractive in this field as in normal stereo, we will not give any space to processing or to a discussion of the various special emulsions used.

It will be necessary for you to establish your own exposure data. This will depend upon the light source used as to color, intensity and distance and upon the color film you use. Remember that sheet color film usually has a slightly different color balance than Kodachrome A. The easiest way is to find some panchromatic emulsion which has a sensitivity two or three times greater than color film. This is used to determine the exposure by test, and from that data you get the color exposure. The first color exposures should be made with ½ and 2x the computed exposure as well as the computed one itself. These three will give you an accurate check upon your computation. If you change your lighting setup, you must change your exposure. Meters can be used, but you must learn how to use the meter for such work, particularly how to compute the increase due to the extremely small effective aperture used.

However, despite these minor difficulties, color is infinitely preferable to black and white.

HIGH-POWER STEREOMICROGRAPHY.—It must be borne in mind that the term "high-power" is relative only, and actually refers to those stereomicrographs made with the aid of a compound microscope. Actual high-power stereomicrography (200 diameters and more), is disappointing because the depth of focus of the objectives used is so slight, and because most specimens have so little thickness. It is not at all unusual for the microscope specimen to be cut to a thickness of two or three microns, and for many types of tissue five microns is the maximum. As this equals roughly 1/5 of 1/1000 of an inch, it can be understood that there is very little depth to be revealed.

Stereomicrographs *can* be made of these subjects, but such work requires great care, and at best the relief is so slight that results are disappointing. Therefore, even in the "high-power" field, the magnifications of one hundred to two hundred diameters are regarded as the useful maxima, although these powers are ordinarily referred to as "low-power" in ordinary microscopic terminology.

As we have said, we have no space in this volume to discuss the technique of microscopy, and if the interested reader has no knowledge of the subject, it is suggested that he obtain a reliable reference book ("The Microscope" by Belling is one of the most practical), and acquire a working knowledge of microscopic technique before undertaking photomicrography.

The technique of conventional photomicrography is followed throughout, with the exception of those steps introduced to produce the desired stereo relief. Assuming the reader can produce a good planar photomicrograph, we shall consider the methods used in obtaining the stereo relief.

Stereomicrography is closely related to ordinary photomicrography, just as normal stereo is closely related to normal photography. The same equipment is used and the fundamental methods are the same. Parallax may be obtained either by lateral displacement of the object, by object rotation or by control of illumination. The last method renders a peculiar appearance which could be called pseudostereoscopic if that term were not already used to designate a different appearance. There is a definite relief. The relief is associated with true relief, but does not accurately reproduce it. False relief is sometimes introduced. Most important of all, the effect obtained by lighting control falsifies the true appearance because in stereo, particularly in stereo close-up, there is a difference in the lighting caused by the different angles of reflection to the two eyes, an effect which we call *illumination parallax*. Just as false stereo parallax will exhibit some kind of relief (spurious), so will false illumination parallax produce spurious relief.

Therefore, it is advisable to use illumination control with restraint and only as an adjunct to physical displacement.

Lateral Displacement.—Due to the great magnification, care must be used in making the displacement or the prints will have to be carefully aligned later. The most important thing to remember is that the displacement is lateral and only lateral. If the object is moved diagonally trouble will ensue.

Some kind of guide bar against which the slide may be moved is practically essential. Fortunately most modern instruments are equipped with a mechanical stage. If this is set to traverse the line of displacement, all that is necessary is to move the stage. The calibrated scales make it easy to move the object through just the distance required.

The motion is controlled by examination of the focusing screen, otherwise the displacement might move the object out of the field. Also because in both exposures the object lies toward the edge rather than the center of the field it is highly advisable to use apochromatic objectives with *special photographic (flat field) oculars*. If this is not done, the curvature of field will introduce image distortion which may be serious if some parts of the object approach the field edge. For this reason, and because the microscope field is very shallow, it is preferable that rotary displacement be used.

Rotary Displacement.—Rotary displacement is not difficult with the microscope. An ordinary slide may be rotated by propping the end upon a match stick, with the opposite ends being raised for the two exposures. However, this is too crude for good work. Some English microscope makers (e.g. Watson) make stereo stages in which the slide lies in a cradle pivoted in the optical plane (surface of the slide). A screw adjustment is provided for controlled motion. This stage is clamped to the regular microscope stage, and rotation obtained by tilting the stage between the screw-set limits between exposures.

The writer uses a somewhat different setup for this work. The microscope used is a petrographic instrument with high stage clearance. Upon this is mounted a petrographic "universal stage," which permits the object to be moved in all directions. Thus the final orientation—so difficult to obtain when mounting a specimen—is obtained and the position fixed by locking the stage rings involved, and leaving the main axis free. The required tilt is then obtained by using the main axis, which is calibrated in steps of ½ degree. The only objection is that such a setup is far too costly for any but the serious worker.

It might be added that the petrographic microscope is used solely because it has working distance to accommodate the universal stage. Polarization is not normally employed, and apochromatic objectives from a biological instrument are used.

Many biological microscopes can be raised high enough to accommodate the universal stage, provided objectives are used whose focal length does not exceed 32mm.

The illumination is provided by special "light funnels" which concentrate the beam upon the surface of the object. Most objects transparent enough to be used with transmitted illumination have insufficient relief for stereo. It is obviously difficult to reproduce a relief which does not originally exist.

Another factor must be considered when the object is "mounted" by being sealed in glycerine, balsam or the like. These substances have a greater refractive power than air, so the *apparent* relief is diminished, sometimes to the extent of 2/3 of the true depth. When making stereos of mounted specimens the rotation should be increased by at least 50 percent to compensate for this loss, if image definition will permit.

The tilting stage is placed upon the microscope stage and fixed to it. Using the centering adjustment of the main stage, and the adjustment of the auxiliary stage together, center the tilting stage so that the crosslines are centered in the microscope field, and remain centered when the main stage is revolved.

Set the main stage so that the crosslines of the tilting stage are accurately "up-and-down" and "right-and-left." Focus upon the crosslines with the objective to be used. Tilt the stage from side to side. Note that the vertical line remains motionless and in focus. If it seems to sway to one side or the other or to go in and out of focus, it is not correctly oriented. Readjust until the tilting does not affect the position of focus of the vertical line.

Observe the lateral crossline. Note that it rapidly loses definition as the stage is tipped. Tip the stage until the good definition and diffusion are about evenly distributed along the line. Near the center the crossline will be sharp, but halfway to the edge of the field it will begin to soften, and at the edge of the field it is definitely diffused. Note the angular displacement as shown upon the scale. Now tip the stage in the opposite direction an equal amount and see if the distribution of focus is the same. If it is not, reset the stage to the correct diffusion and read the scale.

If, for example, the right tilt is 6 degrees and the left tilt is 5 degrees for equal lateral diffusion, the true "zero" would be the mean of $+6$ and -5, or $+0.5$. Then if you wish to make use of a six-degree convergence you would add 3 degrees plus and minus to the true zero to obtain the two stage settings, $3 + 0.5 = 3.5$ and $-3 + 0.5 = -2.5$, so your settings would be 3.5 degrees right and 2.5 degrees left. With this preliminary adjustment, you are ready to proceed with the photography.

In macro work it is customary to use tilts of from four to six or even seven degrees at each side of zero, but in micrography with the microscope the amount of tilt is limited by the depth of field, so that it will often be necessary to limit the tilt to as little as two degrees each side of zero, or a total convergence of four degrees.

The microscope field is always considered to be at the standard reading distance corresponding to a total convergence of some nine degrees, but if we are limited to a four-degree total we place the object stereoscopically at the equivalent of some three feet or a little more, which means a relatively flattened relief, while the flattening effect of any mounting medium increases the flattening. Thus there is a definite stereo limitation imposed by increasing magnification. The greatest tilt allowed by the limits of diffusion imposed by the lateral line diffusion should be used.

Illumination Control.—Illumination control, as developed in the laboratories of the Stereo Guild, is based upon the use of a variation of the Zeiss stereo diaphragm which is used beneath the condenser. It might be added that it is important to use a good achromatic condenser and to be as careful of condenser focus as of objective focus. (Figs. 17-7, 17-8, 17-9.)

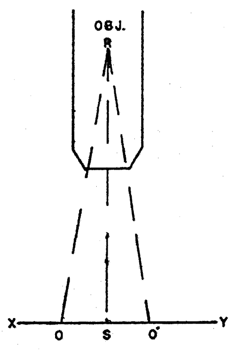
The Guild controls consist of a substage diaphragm in which a 90 degree sector is open. This sector does not extend clear to the center. In the full illumination (bright field) the solid central disc is about 3mm diameter, but when used for dark field, the central solid disc is of such size that the full field of the objective is blocked. In short, this diaphragm is just like the usual dark-field diaphragm, but instead of having almost full annular openings it has only the 90 degree opening. Similar but smaller diaphragms are made to be inserted just above the rear of the objective, inside the tube. The position of the tube sector in relation to the condenser sector is reversed for changing from bright to dark-field.

Although some improvement seems to be apparent in some instances, the value of such diaphragms is questionable owing to the great difference in lighting effect in the two images, far greater than is normal for binocular vision.

In general, in all macro and micro stereo, as in normal photography, the photographic technique is not altered. The stereo element lies in making two exposures of the object with parallactic differentiation produced by alteration of physical relation to the camera lens.

• DEGREE OF DIFFERENTIATION.—In all of these methods there arises but one factor of importance; the computation of the *degree* of change. In general, it may be said that the base changes in proportion to the distance of the object from the lens, but any such basis, although it is widely used, is at best vague. In normal stereo we use a fixed base for distances between about five feet or less and infinity. Thus the first question which arises is whether you will use infinity or five feet as your reference base. That, in itself, introduces too great a variation. Therefore we make use of a definite reference base, and this is derived from the value of the parallactic angle.

In any anortho stereo, the first question to be decided is, "At what distance shall the object appear?" You will keep in mind that the true distance factor in all stereo is the parallactic value. There is ONE and only ONE parallactic value for any given distance. Thus, when you decide the distance at which you wish the object to appear, you have this value. Ordinarily we should choose the arbitrary "reading distance" of 16 inches, but because 15 inches



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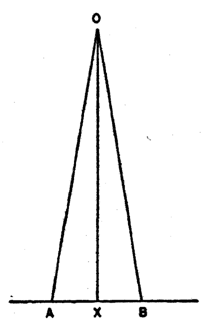

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10. The micro arrangement for lateral displacement. Object S is displaced first to O, then to O′ for the two exposures. XY is the plane of motion and OBJ the microscope objective.

11. The "half angles" ordinarily used in stereo computation as explained in the text.

is very close to a half angle value of 5 degrees, we shall adopt it. Therefore, when you wish the object to appear to lie at 15 inches from the eye, the deviation on each side of zero will be 5 degrees. In the figure, A and B are the eyes and O an object at any distance. Assuming the distance AB to be 65mm, as is usually done, than AB/2 will be the half base, and by marking the center of AB by X, we have either AX or BX as the half base. Then AOX or BOX will be the visual half angle or the parallactic value for one eye (for 15 inches this will be very nearly 5 degrees). By solving the problem for any distance XO, the parallactic value is obtained which will permit you to place the object at any desired apparent distance.

It is inadvisable to make use of any value for XO, which is less than eight inches, as the depth of parallax may be disturbing to fuse.

Using the 5-degree value, a tilt stage will be inclined to 5 degrees each side of center for the two exposures, or a total of 10 degrees. If the specimen is "permanently mounted," the swing will be about 7.5 degrees each side of center.

For lateral displacement, the distance moved is one which will correspond to the length of the short leg of a triangle of 5 degrees apical angle and whose long leg has a length equal to the focal length of the microscope objective used. This is true because when a microscope is correctly focused, it is focused for infinity and the lens distance is actually the focal length. (The free working distance is less because the optical center lies within the lens.) Thus with a 16mm objective, the long leg RS would be a 16mm. The angle ORS is 5 degrees (or 7.5 for a mounted object), and the motion through OS is the desired distance. Remember that OS is the distance *from center.* O′ is the second position of the object and OS = O′S.

LIMITATIONS.—There are always limitations to be considered and in micro work these are somewhat severe. For example, when a stage is tilted, the sides of the field are out of focus because one side is too near the objective (inside focus) and the other is too far from it (outside focus). Therefore, the amplitude of swing is limited and the greater the magnification the less is the tolerance. Even with the 16mm objective, one commonly used for stereo micro, it has been found advisable to obtain a special mount which incorporates a small iris.

It has been argued that this fault proves the superiority of the lateral displacement, but the loss of definition and distortion at the edges of the field, even with apochromatic objectives and flat field oculars, is just about as bad as the violation of field depth limits.

Secondly, high-power stereo, on the order of 1000 diameters, is almost worthless because the field is too shallow to permit the variations in depth which make up relief. The work then descends to the level of making a stereogram of a printed page. If the aperture of the immersion objective is lowered to a degree to make possible any penetration worth while for stereo, the loss of definition is too great. In our work, while we have made stereos at relatively high power, we have found that a good stereo is rarely obtained at powers above 200 diameters.

SUMMARY

We have deliberately refrained from trying to give any details of normal photomicrographic technique as that is a field in itself; but we wish to emphasize the fact that normal photomicrography should be mastered before working with stereo. Stereomicro is nothing more than the stereo technique superimposed upon normal photomicrographic technique. There is nothing new in it for those who know both stereo and micro, other than the manner of the control of parallax. The fundamentals which have been given are adequate to enable the experienced photomicrographer to adapt stereo to his work. The stereographer who would add photomicro to his work will find it highly advisable if not essential, to master photomicrography first . . . and we would also like to add that before venturing into photomicrography he should become thoroughly familiar with the technicalities of microscopy.

It is true that a box camera upended over a microscope ocular may occasionally provide an image which bears a remote resemblance to a microscopic field, but that is a far cry from being a good photomicrograph.

If the micro field is not as clear and sharp and distinct as normal objects seen by direct vision, the microscope is not in adjustment and cannot give a truly good micrograph. Also remember that the condenser focus is NOT provided to enable you to control the intensity of illumination. It should be focused as carefully as the objective and stopped down just enough to cut into the full cone for the objective used. Then use neutral filters or crossed polaroids to control intensity. You will never get a good micrograph with the condenser stopped down to a pinhole. In short you must KNOW the microscope and use it correctly. Then you must learn to make photomicrographs, a very easy step if you have photographic experience and have truly mastered the microscope. Then you add stereo. Assuming you are a competent photographer, it may take you three months to a year to really master the microscope, but from 2 to 10 days after that should give you fair ability in photomicrography and stereomicrography.

For those who are competent in both photography and microscopy, the little volume "Photomicrography" by Eastman Kodak Company, will prove adequate for the initial attempts. It is unfortunate that really capable instruments are so rare and so costly, but many amateurs have done excellent work with only the usual laboratory microscope. However, it is a serious error to try to start with an instrument which has no condenser, and if at all possible the condenser should be achromatic. For the benefit of photographers who are inclined to laugh at "achromats" we will add that the achromatic condenser is the finest made. It is desirable, but not so essential, that the objectives be apochromatic. In any event, obtain the very best instrument which is possible.

In closing we should like once more to remind the beginner to learn how to use the condenser. It is relatively easy to see when focus has been obtained, but the condenser is too often ignored or misused, and very, very rarely used as it is supposed to be used. It may help to remind the reader that it is impossible to obtain a really excellent photomicrograph unless the condenser is given fully as much attention as is given to the objective focus.

Second only to this in importance is the nature of the illumination. Simply to see an illuminated field is far from enough. The light must be uniform, it must be accurately centered, and the image of the source must be brought to its focus in the correct position, substage iris or slide, depending upon the type of illumination used. The difference between an amorphous smudge and a crisp, brilliant photomicrograph lies in a well controlled condenser, condensing a beam of critically adjusted light.

CHAPTER 18

HYPERSTEREO

HYPERSTEREO WAS BRIEFLY MENTIONED in an earlier chapter, but because of its importance and because the subject has been the cause of so much bitter argument, it will now be discussed in detail.

It will be remembered from the preceding discussion, that parallax is the determinative factor in the appearance of distance. The greater the parallax, the closer the subject appears to be. Although not in accord with the classic theory of stereophotography, parallax is the sole determinative factor, any telescopic effect resulting from the use of long-focus lenses being insignificant. This fundamental fact was recognized years ago by Helmholtz who constructed an instrument closely similar to the stereo reflector, but made for direct visual use. This instrument he called the *telestereoscope*. It gives the absolute distance effect indicated by the proportion of its base to the normal base. Thus if such a reflector is made with a 65cm base, objects will appear to be 10 times nearer than when it is not used. However, when used for direct vision, we have no telescopic means to enlarge the perspective value of the scene, therefore it is obvious that the objects viewed will appear to be small, only one-tenth natural size in our example. The whole thing will give the effect of looking at an accurate miniature model very near at hand.

This fact has led, together with sound stereo theory, to the statement that the use of hyperstereo produces a stereogram which has the appearance of being a miniature model, a short distance away.

That argument is based upon a fallacy which is not obvious until it is closely studied in the light of what little we know about subjective reactions.

In the instance of the direct vision telestereoscope, we have the direct comparison with the natural aspect made possible by looking through the instrument, then looking at the same scene without it. The comparison is made with the minimum time interval, and for this reason, the appearance described can be observed.

The stereogram offers no such comparison with the natural aspect, and for that reason we can only guess at the normal appearance. Our ability to perceive differences among the distances and the relief of objects in space, is a most acute one. Because this sense is so well developed, most stereographers assume that it applies as well to size perception when it is not based upon direct comparison. This is not true. For example, if, in a single stereogram, two objects are shown, one of which lies only an inch or so farther from the camera than the other, that difference can easily be perceived, even though the objects lie at about 10 feet from the camera. But if one stereogram shows an object at 8 feet and another shows a similar object at 10 feet, it is difficult to differentiate between them when viewing the stereograms in succession. This inability to carry over standards of comparison from one period of time to another is familiar to those who try to match colors by memory rather than by direct comparison.

The perception of relief and distance is purely a relative thing and not at all absolute. Therefore if in a stereogram the relative positions and proportions are normal, the lack of absolute dimensions cannot be recognized. The sole exceptions are those instances where the skilled stereographer has some extrinsic factors to guide him in the perception of the departure from absolute size and distance.

Because of the great confusion which exists regarding this subject, an experiment was performed under highly exaggerated conditions. The subject was a roadway lined with trees and shrubs which gave a continuous recession of planes. The nearest object within the scene was the foreground only twenty feet away, and a limb of a tree at substantially the same distance. It must be recalled that the stereoscopists who conform to classic rules insist that 10 feet is the minimum distance for using normal base separation, and that anything nearer must be made with reduced base. Therefore 20 feet represents a fair, normal near point for the stereogram.

This scene was stereographed three times, using normal, two-times normal, and four-times normal base. The four-times base is that which would be used theoretically for a subject about one mile distant.

The stereograms were shown to a group of people, laymen, who were familiar with the original of the scene, and who are accustomed to viewing stereograms, although they were not stereographers. The usual comments upon the attractiveness of the scene were made, but no criticism was offered. Then they were asked to point out any visible differences. None did so. Then it was explained that the distances within the picture were condensed by two, and by four, compared with the standard. Still only a few even tried to classify the three prints, and all who tried failed. It would appear quite obvious from such experiments that the serious distortion of the wide base, and the insistence upon the narrow base have little factual foundation.

It must be admitted that the writer was astonished by the result of the test. It seemed incredible that the four times base should not have been seen to be abnormal. Experienced stereographers, of course, would have detected such gross exaggeration.

If there is no foreground object which requires more than about six to eight prism diopters convergence, and if the mounting is based upon homologous separation rather than the standard camera negative format, the really valid arguments against hyperstereo disappear. It might be added that every competent stereographer watches both factors in every print he makes.

FLAT STEREOGRAMS.—Every year there are hundreds of stereograms made with excellent stereo cameras by competent stereographers which are not at all stereoscopic. These are views of distant scenes, particularly in mountainous country where the subject matter is of such huge dimensions that to get it upon the film at all demands a great distance between subject and camera.

When such a subject is stereographed under normal conditions, the distant subject lies beyond stereo infinity and becomes just as flat as in a planar photograph. To compensate for this, the usual procedure is to include some object in the immediate foreground. The classic foreground subject is a human figure looking toward the subject. Of course this figure, by its position and its relief, takes upon itself the major importance of the composition so that the true subject is not only flat, but sinks to the level of an accessory to the truly insignificant foreground.

The only solution is to use such a base that the true subject takes on realistic depth, and is then permitted to make up the pictorial composition without the use of the irrelevant foreground figure.

This is the practice which is condemned by classic stereo procedure, wholly upon unsupportable grounds, namely that the rules of orthostereo are violated and that the subject is presented as an insignificant miniature instead of in its original grandeur. Neither argument will stand searching inquiry.

In all fairness however it must be admitted that the normal stereogram exhibits all of the relief in such distant scenes that would be perceptible to the eye if the scene were actually viewed. Because we are accustomed to "read" into distant scenes the relief indicated by the extrinsic depth factors, the normal stereogram is about as satisfactory as direct vision. However, the purpose of the hyperstereogram is to reproduce the scene in a better manner than it could be seen by direct vision. Any such attempt to improve upon nature is condemned by many, but any such reasoning would rule out the extremely attractive field of photomicrography, so the objection is hardly tenable.

As for the laws of orthostereo, it is quite true that these are violated, but it is significant that those who are the most bitter antagonists of hyperstereo upon these grounds habitually violate the principles of orthostereo even when there is no reason for doing so. Although the necessity for having the focal lengths of the lenses of both camera and viewer identical is recognized, if orthostereo is to be achieved, this is rarely found in practice. Even when allowance is made for permissible variation, it will be found that practice violates the principle to an extent far beyond the permissible. Specifically, there is a widespread habit among stereographers, of using a 6 by 13cm camera with 3-inch lenses and then mounting contact prints from these negatives for viewing in the Brewster stereoscope which ordinarily has lenses whose focal length is between 6 and 8 inches. Fortunately, the widespread use of 35mm cameras and associated viewers is eliminating this abuse.

The fact is that, as shown by repeated experiment, violations of the ortho principle of considerable degree have no effect which is obvious when the stereogram is viewed. This is unfortunate as far as the law is concerned, but as it is true, the insistence upon orthostereoscopic conditions should be limited to those special instances where it is highly desirable, as in scientific record. Objection should be limited to those instances in which the violation has resulted in a space distortion which can be seen when the stereogram is viewed.

As for the second argument, that of the nearby miniature, or the giant's eye view, it, too, is far more important in theory than in practice. As has been stated, our perception of absolute size is as undependable as our perception of relative size is acute. The optics of stereo will prove conclusively that the subject made by hyperstereoscopic methods is shown as a miniature near at hand. However, when the stereogram is viewed, this aspect is not seen except by those stereo experts who know the stereogram is a hyperstereo, and who see what they have been taught to look for. This is a common occurrence in many activities other than stereo, so no more need be said about it.

When stereograms are shown to laymen who are familiar with the original, and when the subject is such that hyperstereo is warranted, the universal comment is that the hyperstereogram best displays the realistic, natural aspect of the original. This alone would warrant its use, even if the arguments against it were not so wholly invalid.

ESTIMATING BASE SEPARATION.—The reason for using hyperstereo is that the maximum distance at which we have stereoscopic perception is limited. Although the actual limits vary with individuals, it has been accepted that among those of highly developed stereopsis, the limit of stereo differentiation is that due to the parallax of 20 seconds of arc. Based upon the normal interpupillary, this means that objects beyond 670 meters are not seen in stereo relief. As a matter of fact, to most people stereo infinity lies at about half that distance. Thus for the normal interpupillary the maximum object distance is 670 meters, and as that is the distance at which a round object appears flat, it is not a useful distance. At half that distance, a cylinder has the appearance of having an oval section, one of whose diameters is half the length of the other, the side-to-side dimension being the greater.

On the contrary, it is not at all uncommon to find among outdoor people a definite stereopsis two or three times this value, occasionally more.

Thus, if an object is to be seen in readily appreciable stereo relief, it must have at least that parallax of an object seen by normal vision at a distance not exceeding 250 to 300 yards, and the parallax for an object at 100 yards is preferable.

Parallax is angular measurement, and a given amount of parallax is that corresponding to a certain angle. It can easily be understood that for some definite angle, let us say one minute of arc, the base at any given altitude (distance) must have a definite value. If we double the value of the base, we either double the value of the angle, or we double the value of the altitude.

This means that if we double the normal stereo base, the distance and relief of all objects in the field of view are given double value, objects appear to be only half as far away, and appear to have double their usual depth. It requires but a moment of consideration to see that when the apparent distance is halved and the apparent relief doubled, the specific relief of any object is exactly the normal degree of relief for the new apparent distance. That fact, so often overlooked, is the reason for the great success of hyperstereograms. There is no distortion of specific spatial values within the stereogram itself.

The practice of hyperstereoscopy is simple. Most stereo cameras are provided with a single lens cap for this purpose. The left lens is covered and an exposure is made. The right lens is then covered and the camera is moved to the left through the required base distance minus one base length, and the second exposure is made. Inasmuch as the motion is often a matter of some feet, the exposures are made freehand, aligning the camera as accurately as possible for the two shots. When the negative is developed, it should be cut apart and the bases aligned carefully. This is the one really difficult factor in hyperstereo technique. Naturally, as the two exposures are successive, the subject should be motionless, as it almost always is in hyper shots. If a single-lens camera is used, it is moved sidewise through the base length desired. When using 35mm cameras and color film, the camera must be carefully leveled and some key object placed in exactly the same position in the finder for each exposure. Cameras with positive interlocks are used by making the usual dual exposure, moving the camera and making the second. Later mount the two lefts together, then the two rights. This gives two complete hyperstereos.

This brings us to the critical point of the discussion, that of the determination of the degree of base increase to be used. Most stereographers who try hyperstereo use two or three times normal base even when the object is far away. The results are of course disappointing. Hyperstereo is without value unless used correctly.

One school of thought bases the increase upon stereo infinity. That is, assuming stereo infinity to be 670 meters, and given a subject whose distance is 6700 meters, a ten-times base would be used. The fallacy is apparent. If hyperstereo is to be useful the subject must be moved to some distance within the stereo limit. By moving it just to this limit the whole effort is rendered useless, for the subject continues to appear flat.

It is often said that a five times normal base is the absolute maximum permissible. It might be cited against this that a very successful stereogram has been made with a base of some 8000 miles, as was used in making stereograms of the moon where the successive shots were made at a considerable time interval so that the base was substantially the diameter of the earth.

At the same time you do not want a distant mountain to have the appearance of being only 10 feet away, for then indeed there would be an appearance of a nearby miniature. The base must always be selected by the consideration of the subject, and this cannot be limited by any rule-of-thumb regulation.

The first step is to determine the apparent position in space the subject is to occupy. But in all the computation it is necessary that approximate values be used so that the whole thing may be easily and quickly done mentally without recourse to involved calculations with pencil and paper.

Our hyperstereo computations are based upon the following assumptions which are not strictly accurate, but which have been found from experience to serve admirably. Because of the variability of individual stereopsis, accurate computation would be a loss of time, to say nothing of its inconvenience.

It is necessary to know the distance of the object to be photographed. It is necessary to know the distance at which this object is to appear. That is about all there is to it. The second factor of course may give trouble. You can assume stereo infinity to be 1000 yards, and half that the distance of best general relief. Therefore you will wish your distant object to appear at a distance of 500 yards more or less, or 1500 feet. As all of these distances are roughly approximate, you may consider 1500 feet to be 1/3 mile without seriously affecting the result.

Of course, if the object is a mountain, it would be wrong to show it only 1/3 mile distant, but still you must have it within 1/2 mile or it will be very flat. Therefore, the chosen apparent distance is controlled by the object to some extent.

Assume the mountain is five miles away, and you wish to bring it to within ½ mile. Parallax is a directly proportionate factor. Double the parallax and you halve the distance, treble it and the distance becomes 1/3. Therefore to make the distance 1/10 (1/2 mile from 5 miles), the required base will be 10 times normal or about two feet.

The only other factor is that of foreground. Keep the nearest foreground at least seven feet distant. As 7x10=70, the nearest permissible foreground would have to be 70 feet away when you use a 10x base.

Keep these two factors in mind and you can use hyperstereo freely and with excellent results. Remember that you can use a 3 foot foreground in normal stereo, so you could use a 30 foot foreground with 10x base, but the greater distance is advisable in hyperstereo.

In practice a reflecting camera, either stereo or mono-lens, will be found the most satisfactory, although excellent work has been done with the usual 35mm camera. The ground-glass is ruled in crosslines, if this has not been done by the maker. These lines serve to align the subject in the two successive exposures, and if key objects at the extreme limits of the screen are observed and exactly duplicated as to position, a continuous base perpendicular to the axes of the lenses may be maintained with surprising accuracy. Because of the great distance of the subject, there is practically no observable difference at the edges resulting from stereo parallax.

LONG-FOCUS LENSES.—It may be asked why a long-focus lens should be used if base alone determines apparent distance.

The original purpose of hyperstereo is to impart relief to some object whose size is such that a remote camera position is essential. As long as the subject has this characteristic, hyperstereo alone is the solution. In fact, to add long-focus lenses would defeat the purpose, as the large object would have its image spread beyond the limits of the negatives.

It must be remembered that the conventional telescope does not, as so commonly stated, bring objects nearer. It simply increases the perspective values, the angular value of the field of vision filled by the object. Therefore we shall make use of long-focus lenses only when the object is too small to be satisfactorily recorded from the nearest accessible camera position.

If we maintain a proportional increase between base and magnification, the type of reproduction closely approximates that of orthostereo. We reproduce the objects at their full natural *telescopic* size, and with that distance and degree of relief which is fully natural for that size. Thus if the lenses are doubled in focal length and the base is also doubled, objects are shown in the size and relief normal to a distance which is just half that of their true distance.

If the object is small and far away, the proportionate increase just described, that is, the use of parastereoscopic technique, will have much the same effect as that of using a telephoto lens upon a planar camera—except that we have stereo relief. That is to say, we are shown the object as it would appear from a point of view midway between the real camera position and the object. The same distortions appear as in the planar telescopic record, but like them, these distortions are extremely difficult to perceive even when they are pointed out in detail. Any distortion as subtle as this may be completely disregarded without detriment to the quality of the stereogram.

Therefore, in making stereograms of objects at a great distance, we first determine the base necessary to introduce the desired degree of relief. The next step is to select the lens which will cause the image to occupy the desired space upon the film, and if it is desirable that strictly normal proportions be preserved, the first two steps are compromised so that the two increases are of the same degree.

For example, suppose the scene you wish to photograph is a group of chimney rocks, tall pillars of stone as found in some of our great National parks. These are huge things, and when you are among them, the general effect is lost because your effective vision is held by the immense bases or the height of one or two pillars as you look upward. It is only when you go to some elevated position at a considerable distance that you can see the characteristics of the formation.

If this scene is photographed by hyperstereo, the result will be a stereogram including the whole of many of these pillars, and will thus give an impression of their true nature which is superior even to direct vision. Here we maintain the wide field of the normal lenses used at a distance, plus the exaggerated relief of the increased stereo base.

But if there is a man standing on top of one of these pillars, and you want to make a stereogram showing him, the original hyperstereo is of no value because the tiny figure is lost in the distance. This situation calls for parastereoscopy with the combination of telephoto lenses and telestereo base.

We cannot approach closely, because then we should have to shoot upward and the top of the rock would hide the man. The only point of view possible is the edge of a cliff 1000 yards from the man. In this instance, we wish to obtain at least a recognizable image, which means that we should use, at most, an apparent distance of 200 yards. Thus we should make use of a lens whose focal length is five times normal, and we should use a five-times normal base.

It will be seen that the choice of the base in hyperstereo, or the choice of the lens-base combination in parastereoscopy, is determined, not by the traditions of old time stereo, not by some complex mathematical computation, but solely by the exigencies of existing circumstances.

Increase the stereo base (hyperstereo) to bring the object *nearer*.
Increase the focal length of the lenses to make the object *larger*.
The two functions are not at all identical.

Let it be emphasized that there is no valid reason why the stereographer should not vary both base and focal length of his lenses if by so doing he is enabled to obtain a result which is visually superior to that which would have resulted otherwise. The freedom of choice extends beyond that limit. If the stereographer wishes to make a stereo caricature through the use of exaggerated relief, that is perfectly good stereography. In fact, if well done it constitutes expert stereography, because understood theory has been used to exert a wanted control.

If the stereographer can obtain more realistic effects through hyperstereo, as he most assuredly can, then that is fully satisfactory evidence of the very real value of hyperstereo as a recognized element of stereo technique.

Too much cannot be said against the stringent and wholly unreasonable limitations placed upon stereography by those whose sole interest is theory rather than the making of stereograms, and who condemn work for the method used rather than for the result achieved.

Any statement that so-and-so many times normal is the limit for hyperstereo, simply indicates that the speaker is not familiar with fundamental stereoscopic laws. The best results are obtained by those who experiment, and who find, not the limit in base units, but the apparent distance at which certain large objects appear to the best advantage.

It is one of the beauties of stereo that you can control it to an almost infinite extent. You can place objects at any desired distance and by careful work you can intermingle natural and fantastic distances in a single stereogram.

Finally the question arises, "Why not approach so near to the subject that natural stereo relief is seen?" The answer is that many of the most promising hyperstereo subjects are so huge that any such approach eliminates most of the subject and leaves only a restricted area, often of little beauty or interest.

Above all, avoid the common and regretable practice of using normal base for such shots with some bit of extraneous foreground, usually a wholly inappropriate human figure looking away into the scene, just to introduce enough stereo relief to show that it is truly a stereogram. If the stereogram is not self-evident in the principal part of the subject, then it had better not be made. If there is a genuine foreground subject of real interest, and the mountains are to form simply a theatrical backdrop, then the normal base may be used; but when the distance itself is the subject, then by all means make a stereogram of it, not a double flat photograph!

CHAPTER 19

STEREO MOVIES

THIS CHAPTER IS SO BRIEF and so uncomplex that a word is necessary in explanation. The chapter is brief because stereo movies are so extremely simple there is really nothing much to be said about them. You can assemble the beginner's outfit within ten minutes or so, and you can depend upon it that the results will astonish you. Movie projection, stereo or otherwise, is no more than a mechanical elaboration of still projection. Optically the two are identical. Therefore, everything which has been said about still stereo projection applies equally to movie projection.

The utter ease and simplicity and the thoroughly satisfactory results of even elementary stereo movies are so great that the hesitation of the amateur to try it is incredible. Everyone seems to be awaiting some very mysterious, very complex, very magical (and costly) method for doing this simple thing. I only wish I could think of some way to convince you that this hope is all nonsense. You already have available everything you need to make perfectly beautiful stereo movies with very little expenditure and with very good assurance of success in the first roll of film you expose.

The method outlined here is that used successfully in the Stereo Guild laboratory experiments, and the results were just as successful as those obtained from still stereo projection. This is one time when the expression "there is nothing to it" is true. It is so simple stereographers cannot believe it, but one trial will convince you.

It is perfectly easy for any movie amateur to make excellent stereo movies, although unfortunately he will have to provide his own equipment, as there is nothing really suitable on the market. It may be said, however, that for preliminary experimental work, the stereotach or the cine-stereo attachment of Mattey can be employed. At the same time it must be emphasized that wholly satisfactory results cannot be obtained from a fixed reflector.

You will need a stereo reflector, which fundamentally resembles the Stereotach, but which has two adjustments. (A) The angle of the outer mirrors must be adjustable and (B) The distance between the outer mirrors must be adjustable. Before World War I, about 1910, Burke and James sold a stereo reflector which had the first adjustment, and this is the reflector used in the preliminary experiments of the Guild. Many amateurs make their own, but if you have no skill with tools, you will surely have, among your acquaintances, an amateur metalworker who will be glad to make the attachment for you for a moderate sum.

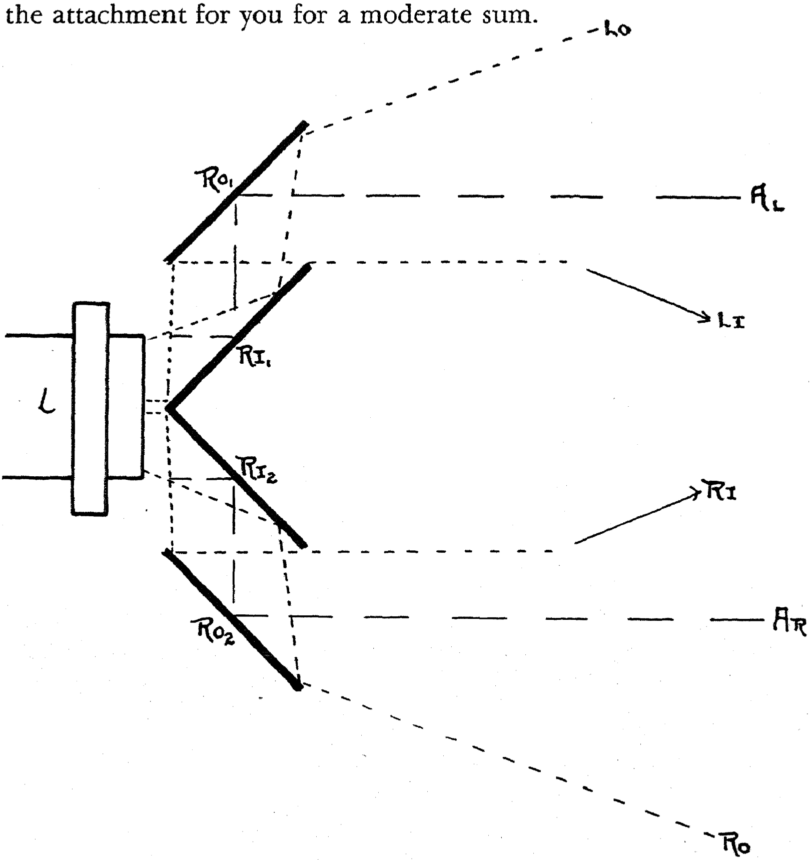


Fig. 19–1. The Stereo reflector. This diagrammatic plan view shows no mechanical supports, only optical elements. The two inner mirrors, RI_1 and RI_2 set at 90°, join opposite the vertical diameter of camera lens, L. At the right and left are the two outer mirrors, RO_1 and RO_2. Al and Ar indicate the axial rays for right and left, while LO, LI, RI and RO indicate the approximate field limits. LI and RI indicate the gradual convergence of these rays with distance.

We shall not give detailed working drawings, because there is a wide latitude of detail design permissible. The actual requirements are few and simple.

1. The outer mirrors must be adjustable through about ten degrees, swinging upon a vertical axis.

2. This movement must not affect the precision of the vertical plane (the reflecting plane) of the mirrors. In short, a sturdy pivot must be provided which is exactly perpendicular to the base of the framework.

3. The outer mirrors should move laterally so that the base may be varied between two and one-fifth and six inches or a movement of one and three-fourths inches for each mirror. This is to control parallax, especially when telephoto lenses of moderate focus are used. This motion must be along a rigid base so that the vertical planes of the mirrors will not lose parallelism.

The inner mirrors should have as sharp an apex as possible, but it is not at all necessary that it be an "invisible line" joint. One amateur made use of a right angle prism with the sides surface silvered (aluminum vaporized). This is a sensible solution and one not too expensive.

However, it is imperative that some means be provided by which the image as formed in the film plane can be subjected to visual examination. The equipment can be calibrated when once made, but the initial calibration demands visual inspection in the film aperture. There are "focusing prisms" and "focusing attachments" available which will provide this and which are applicable to most cameras.

In calibrating, remember that if the base of the reflector is not parallel with the base of the camera, one image will be higher than the other. If this happens do not conclude that your mirrors are out of parallel. Just raise or lower one end of the reflector base. That is, twist it with the lens axis as center of revolution.

Unless you are experienced in this kind of work, you should by all means make your first attempts with a Stereotach, which may be used without visual checking and calibrating, but you must use extreme care to get the reflector base parallel with the camera base.

FORMAT.—One serious objection to making stereo movies in this way is the fact that the image is duplicated in the normal frame which has proportions 3:4, and as a result the screen picture is a very narrow, very tall image with the horizontal to vertical ratio 2:3.

There is a solution to this problem also, one which is used in making Guild stereo movies, but which will involve some trouble in shopping. About 20 years ago, lenses were sold to movie amateurs which produced an imitation of the "wide screen" which was popular in theatres of that time. This was a corrected cylindrical lens, which compressed the image laterally, and in projection expanded it again so that the width of the picture was increased by some 50 percent without affecting the vertical dimension. When this lens is used for stereo movies, the screen format is practically square and wholly satisfactory.. However, it will be necessary for you to locate one of these lenses, because they are not now an article of regular commerce, this may be difficult. It is to be hoped they will be re-introduced.

MAKING THE STEREO MOVIE.—The camera is set up as usual. The compressor lens (if used) is placed before the camera lens and the stereo reflector mounted before the compressor. Thus the light strikes the reflector first, passes through the compressor, through the camera lens and to the film. The exposure factor is about 4x (in our test outfit it was about this, but the factor may vary somewhat).

Note that there is no polarization involved in the camera work.

Once the accessories are correctly adjusted and the diaphragm set for the exposure factor, the rest of the procedure is that of normal movie making. Objects within 30 feet of the camera, or so, will provide better results. The film is processed as usual.

PROJECTION.—The two images of the film must be projected in superposition, just as in regular stereo projection. When a fixed reflector is used, something is necessary to provide adjustable superimposition. This may be a pair of mirrors at slight angle, or a series of weak prisms which are placed over the lens base to base. However, the serious amateur will have an adjustable reflector made and when this is done, the same reflector used on the camera will be used with the projector and the mirrors adjusted to provide the superposition. This is by all odds the best method.

The whole accessory unit of compressor-reflector is removed from the camera and supported before the projector. In front of the reflector openings are placed the two polaroid filters with their axes at 45 degrees left and right so the standard 3-D viewing goggles may be used.

When superposition is obtained, no further adjustments are necessary and projection proceeds in a normal manner.

Filter position is easy to check. If the axes are reversed, distances will appear in reverse. When correct, relief will be normal. If a filter is "between" extinction positions, two images will be seen upon the screen when using the 3-D viewers. If you have the filters in rotating mounts, you can easily make the adjustment while the picture is on the screen.

Remember, the screen MUST have a surface which does depolarize light, the most convenient being the aluminum surface. Ordinary beaded screens will not work. You will see both images no matter whether you use the goggles or not.

SUMMARY OF ESSENTIALS

The most satisfactory stereo accessories for movie work must be home made. This is a condition we hope will soon be remedied.

The compressor lens, if one is found, is simply placed before the camera lens. Be sure to use the guide line so that the compression is accurately lateral, and be sure to focus the compressor using the engraved scale. Otherwise it is simply an accessory lens.

The reflector must be set for the lens in use, and so adjusted that the images are equally and symmetrically divided between the two halves of the aperture.

Use a wide base when using lenses of more than normal focal length. Use twice normal base for a two-inch lens and so on.

Use exposure compensation because of losses in both reflector and compressor. About three times to four times is advisable.

Use the whole unit, compressor and reflector upon the projector and add the polarizing filters.

Superimpose images upon the screen, preferably with the adjustable reflector.

Do not get too close to the screen.

Otherwise, use normal movie procedure.

Many amateurs who have expected some very difficult and very complex procedure may think this too easy, but like all stereo, it is as easy as normal photography once the necessary equipment is available. If you consider the general laws of stereo and the remarks concerning still stereo projection together with this chapter you will be fully prepared to embark in making stereo movies, and very often your first film will be fully successful. Starting from scratch some 14 years ago, we made one film which was slightly distorted as to depth-width relationship, but the second was good and no more trouble has been encountered.

PRACTICAL DETAILS

8MM STEREO.—We have not actually made 8mm stereo movies in the Guild laboratory, but there seems to be no reason why, within the usual size limitations, they should not be satisfactory. There is nothing to change in the general technique. Unfortunately, although we are now preparing to make such tests, they will not be completed in time for a report to appear in this volume.

OTHER METHODS.—There are several other methods of making stereo movies, but all of them demand more complex preparation.

First of all, there is the obvious method of using two cameras and making two complementary films. This, then, requires two projectors, but that is not the great objection.

Such a system demands exact synchronism in the projection, and it demands double film expense. It demands the greatest care in editing to keep both films identical, for even one frame mismatch would cause trouble. Each film break means the same painstaking care. All in all it is simply too much trouble for amateur use when the simple reflector method is available.

CONVERTED 8MM.—This is an excellent method, as it eliminates the need for the compressor. But it requires some very accurate camera conversion, and makes the camera unfit for planar use.

Any standard 8mm camera may be used as the basic equipment. The aperture plate is removed and widened so that it is full width (10mm) just as in a 16mm camera, BUT the height is not changed. This provides the full size of an 8mm frame for each of the stereo units, and when the reflector is used, the stereo pair is recorded in normal format.

The camera will work after a fashion with no more alteration than this, and it is simple. But for really good results it is necessary to shift the lens center 2.5mm toward the film center so that the lens is centered on the dividing line between the two images, and this is difficult. The lens must retain its distance from the film to maintain correct focus. The only practical solution is to dismount the lens, make a new eccentric base to replace the old one and substitute it. This requires the attention of an expert instrument maker or camera repair man. The projector requires a similar aperture plate conversion, but the lens shift is not as critical as in the camera. Nevertheless, for a first class job, the projector lens should also be shifted. When this is done, you will have a complete and highly satisfactory 8mm stereo movie outfit.

16MM CONVERSION.—The same thing can be done with a 16mm outfit with less trouble because the lenses do not have to be shifted.

The top or bottom half of the aperture is blocked off. For temporary use, you can do this by pasting a bit of black paper over it, *from the shutter side*. In most cameras, this can be done by removing the lens and revolving the shutter until it opens. Do not paste in the film side. The film will be scratched and will soon pull the paper from its position.

Finally, mask the finder to correspond, BUT if you mask the bottom of the aperture, mask the top of the finder. Then add side masks to the finder so that 1/4 of the field is cut off at each side. The area left is equal to 1/4 of the original.

The reflector is used with no compressor.

Only half the film will be exposed, and if you choose you can use the same roll for a second series of exposures, if you remember that sequences will be scrambled and editing will be impossible! The reflector is used with the projector too, of course. In this method, the actual film image has just the same size as in the converted 8mm outfit, but the 16mm involves either double film cost or the sacrifice of editing.

COMPROMISE.—There is one compromise which is perhaps the best of all solutions for the problem of format. The 16mm frame is approximately 7.5 x 10mm. If you wish to use a square aperture, it will be 5x10 because there must be two pictures side by side. Therefore instead of masking *half* the aperture you may mask only 1/3. For the best possible results, you will divide the 2.5mm mask into two parts. Mask off 1.25mm at the top and 1.25mm at the bottom. You will now have a centrally spaced aperture measuring 5mm high and 10mm wide. Your effective aperture is 5mm square or 25 sq. mm. area. With either of the former conversions, the effective frame measures 3.75x5 or about 18.75 sq. mm.

For the utmost gain commensurate with acceptable format, mask 1mm from top and bottom leaving the total aperture 5.5x10 or an effective aperture 5 wide by 5.5 high, a ratio of 10:11 or roughly the same proportions as the Realist frame. This gives an area gain of almost 1/3 over the 8mm conversions, and provides a highly satisfactory format. For rapid comparison of effective aperture areas we have:

8mm conversions, 3.75x5 = 18.75 sq. mm.
Compromise, 5.5x5 = 27.5 sq. mm.
16mm 7.5x5 = 37.5 sq. mm.
The area ratios are roughly 2—3—4.

For those who do not object to the slightly smaller picture, the compromise is the best format to use. It differs from the straight 8mm frame in being slightly higher than its width, while the normal 8mm is wider than high.

In all of these conversions the *width* of the frame is that of the normal 8mm frame. This can be increased ONLY by (A) using a 35mm camera to obtain masked 16mm screen size, (B) using a compressor to provide an effective frame width of about 7.5mm, or by using two separate cameras.

When using the compromise system, it is not necessary to mask the projector. When the camera aperture is masked, the unexposed film will be blackened in processing thus making an automatic mask for the film. This method together with simple prisms to deflect the projected images is the simplest of all stereo movie methods.

The two prisms are placed base to base and then placed over the projection lens so that the junction of the prism bases lies vertically. The strength of the prisms depends upon the screen distance and is best determined by trial. For example, obtain a

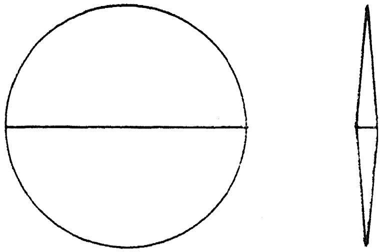


Fig. 19–2. A projector prism which has been cut to circular shape.

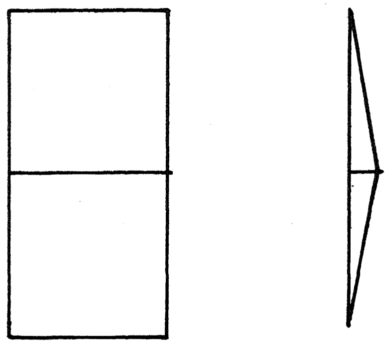


Fig. 19–3. A simple projector prism made by placing the thick edges of two prisms together.

pair of plane, 5 diopter prisms. Move the screen back and forth until the images superimpose. Measure the screen-to-projector distance. Also note the leeway that is the distance the screen may be moved without separating the images more than two inches right or left. Then try 3 diopter prisms and compare the results. This will enable you to determine the prism strength needed for your projection conditions.

Practical Conversion.—Of all the methods recommended, the compressor is best provided you can obtain the lens. (Original cost around $80.) If the lens cannot be found, the next best is the compromise masking which provides a square picture only about 25 percent smaller than normal 16mm. The compromise is of course by far the simplest of all methods and will probably prove most attractive when all factors are considered.

Only as a curiosity do we mention the alternate system. This provides full frame 16mm size, but it necessitates some kind of alternating reflector, reciprocating or rotary, which could be made only by an expert mechanic and would require connection to the camera drive which adds to the motor load. Similar provision is necessary for the projector. It is feasible but not entirely practical for the average amateur. Film speed is 32 or more, so the camera and projector mechanisms are subjected to excessive wear. Two successive frames are required for one picture, so film cost is doubled. It has been done and stereoscopically it is satisfactory, but it requires special equipment as mentioned.

The compromise method does not permanently disable the camera for planar work. If your camera has provision for aperture masks, such as the Cine Kodak Special, the changeover can be

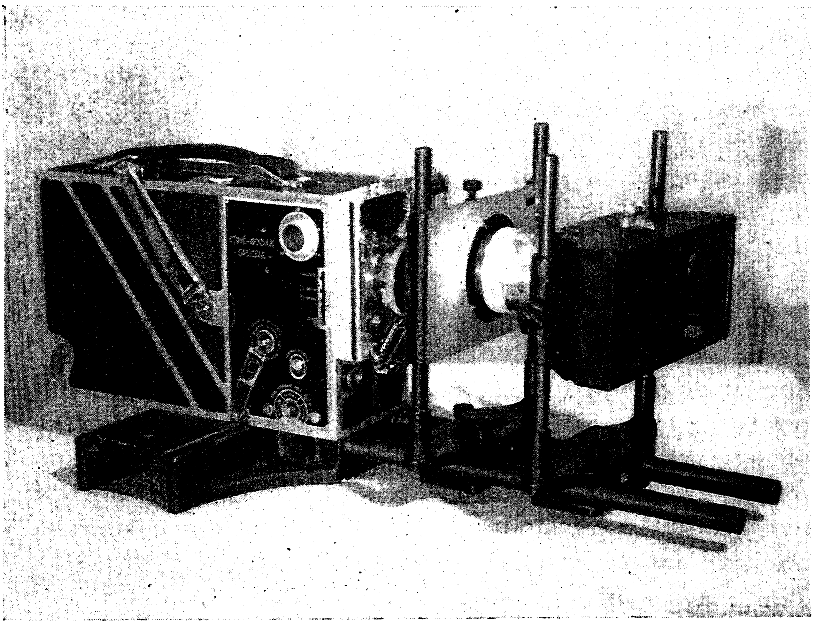


Fig. 19–4. Stereo-cine camera—Cine Kodak plus compression lens plus adjustable reflector—is the equipment used in the Stereo Guild experiments in stereo movie making.

made in a few seconds so that stereo and planar can be alternated in the same film. The only significant difference is that the camera must be moved back somewhat from the subject. A compromise film, in any modern projector will fill a 50x50 inch screen with a good quality image.

Thus, while methods are used which do not include the reflector, those systems which are most practical are based upon the use of the reflector.

Cost.—Reflector systems for the movie camera must be of precision quality. If you have the tools and are capable of fine machine work—as many stereographers are, the cost (without compressor), may be kept to less than $15 or $20. If you must have the reflector built by someone else, a competent amateur mechanic might do it for anything from the material cost up, but a professional will charge not less than $100 and from that up to perhaps five times that amount. I saw one camera which represented an outlay of $2500, but that included approximately $1000 for the Cine Kodak Special which was the basis of the outfit.

Stereo movies are perhaps even more attractive than motionless projected stereograms. That, of course, is a matter of personal opinion. Certainly, however, one thing can be said, which has often been said—and proven—regarding still stereo: Once you have the pleasure of seeing your color movies in the full realism of three dimensional space, you will not be content to return to the flat screen type.

In closing it may be said that anaglyphic movies, as well as still slides, have been offered in limited quantity. These are for use in normal projectors and require red-green viewers instead of the polarizing type. They are fairly satisfactory, although some people see a color bombardment when the red-green anaglyph is used. They do provide stereo projection for those who have no regular stereo equipment. Unfortunately they are limited to commercially available subjects which is a grave disadvantage.

It is rumored that similar slides and movies are to be made available using the Vectograph principle. This system uses polarization extinction and has no color bombardment effect. They are highly satisfactory, but again the "commercial subject" limitation is a disadvantage. It is said that when the Vectograph films do make their appearance they will be in color, whereas the red-green are perforce monochromatic.

In the absence of specific information, no more will be said about these stereo projection slides and films.

However, there are certain factors regarding the recent history of stereo motion pictures which will be of interest, so we shall give them passing attention. The first involves the often discussed "free vision" viewing, or the viewing of stereo motion pictures without the aid of any kind of viewing device, and the great publicity which has been given the subject, to say nothing of the multitude of spurious methods which have been proposed and which have actually been used.

Free-Vision Screen.—This is based upon the principle of a multitude of intersecting stereo beams, so disposed that the spectator will receive one left and one right beam in the corresponding eyes. It can readily be understood that as long as the essential conditions prevail, it will also be possible for a spectator in some position to receive alternate beams, thus producing a pseudoscopic relief rather than stereoscopic.

It will also be obvious that there will be certain positions of the spectator where neither the stereoscopic nor the pseudoscopic relief will be apparent.

Such a screen has been reported from Europe and has received a great deal of publicity. However, the technical report reveals a significant condition. The seats in the auditorium are specially positioned in groups, and the spectator must move his head about until he locates the correct position for relief viewing. These two facts reveal the nature of the screen to be that which was long ago developed in this country and later abandoned as impractical.

It must be kept in mind that stereo projection *per se* is an accomplished fact, but the practical objection lies in the fact that in

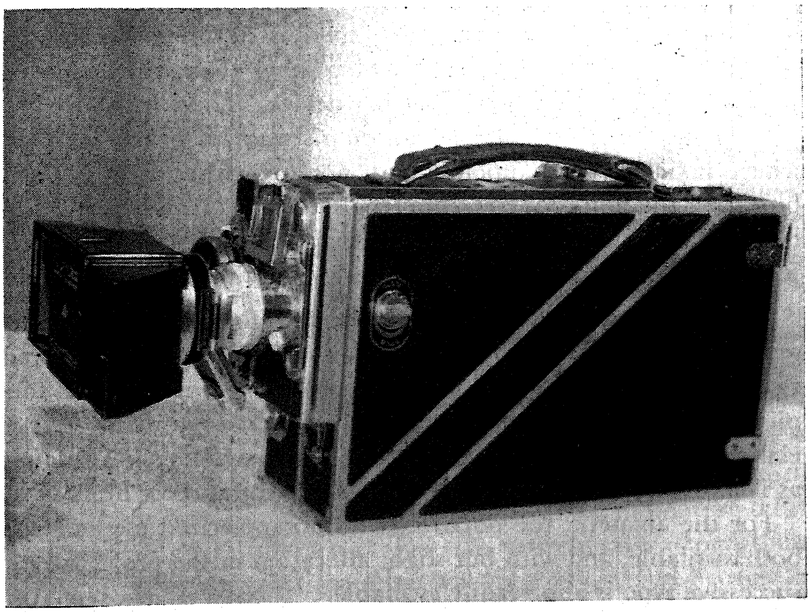


Fig. 19–5. The simplest stereo movie outfit. A Stereotach used in conjunction with a 16mm Cine Kodak.

America the system will never be considered commercially practical as long as the spectator has to do *anything* to aid in the reception of the stereo images. This means that individual viewers cannot be used, no matter what their nature. It means that special positions cannot be tolerated.

It seems strange that anyone should object to wearing a pair of light spectacles which are no more uncomfortable than any pair of lightweight spectacles or sunglasses, yet that is the only thing which stands in the way of the general adoption of wholly successful commercial stereo motion pictures!

One older system made use of a rotating shutter for each spectator, either fastened to the back of the seat in front of the spectator, or held in the hand. These shutters were synchronized with the projector shutter and gave an excellent stereo result, but were never used because the spectator would not cooperate by using the viewer. In fact, the list goes right back to the original red-green anaglyph, also a somewhat successful method, but one involving spectator cooperation.

Stereo movies, according to the producers, will never be commercially successful until some method is devised whereby the spectator cannot possibly see anything other than true stereo relief and without aid of any viewing device. Thus, when we discuss the failure of stereoscopic motion pictures, let us lay the blame where it belongs—not upon stereo, not upon the methods used, but upon the non-cooperation of the spectator. However it is our belief that the widespread and successful use of stereo still projection which we now enjoy may change the professional attitude.

Both the dual projection by polarized light and the Vectographic methods are available, although the latter is hardly practical for the amateur. The production of long lengths of motion-picture films in Vectographic relation would require the use of elaborate production machinery, but this machinery is available, as it has been used in printing two-color natural color films.

For the amateur, the polarized and non-polarized methods are both available, and with but slight alteration in the projector, the successive type is also readily available.

This alternate method was introduced in 1928 for amateur motion-picture use. Through a curious combination of circumstances, a most unusual result was achieved. This was partly due to the fact that the inventor was not at all familiar with stereoscopic principles.

The films were made by two cameras, spaced 65mm and operated in synchronism. Thus the right and left images had no

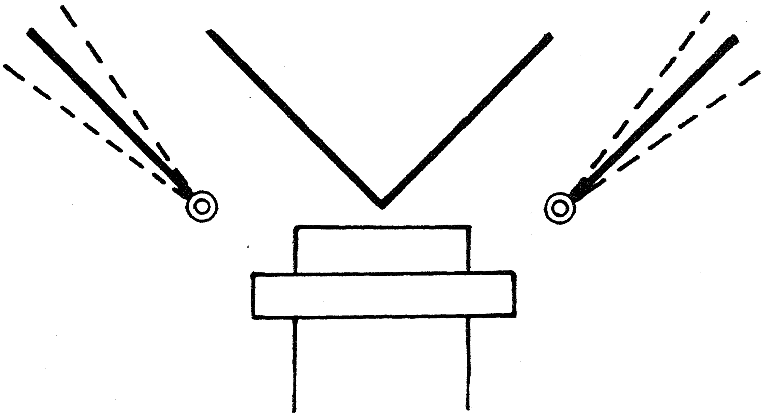


Fig. 19–6. Adjustable reflector. By pivoting, the rear edges of the outer mirrors may be swung as shown by the broken lines, thus making it possible to place the two stereo images in any desired relationship upon the film. Compare with Fig. 19–1.

difference due to motion, which produces much better quality than when the films are made in succession. The positives were designed for the color anaglyphic method, and the inventor, through confusion, assumed the cameras must be equipped with complementary filters. The result was a pair of negatives representing two-color separations.

The films were printed in skip printers, which advanced the positive two frames to each single frame of the negative. This left room for printing the other negative in the alternate spaces. The finished positives were dyed in the complementary red and green.

When the film was projected and viewed with the color spectacles, the images were not only seen in relief, but there were other and unexpected results. The relief was entirely satisfactory, there was more than a suggestion of natural color effect, and because of the alternation in time, the color bombardment effect common to still-color anaglyphs was missing. The films were surprisingly satisfactory, and, except that they were positive-negative and required elaborate equipment, the system could be regarded as highly successful.

In this chapter we have not emphasized the distinction between motion-picture and still projection, for one very good reason. Optical projection remains the same no matter whether the projected images are changed twenty times a second or twenty times an hour. A system which will work with one, will, with a few exceptions, work with the other.

The outstanding exception is the motion-picture system just described in which the right and left pictures are projected alternately upon the screen. This is done simply to preserve the original format of the picture. The stereoscopic control may be by means of the polarized anaglyph, in which case the polarizers are shifted in synchronism by an oscillating support, or a mechanical shutter and an auxiliary synchronized shutter is held before the eyes of each spectator so that each eye sees only its own picture. Inasmuch as each eye sees only half of the projected pictures, it is necessary to operate both camera and projector at double normal speed to prevent flicker. For that reason if for no other, the method may be considered obsolete as far as motion pictures are concerned.

FLICKER PROJECTION.—In the rotating shutter previously described, a left picture is projected to fill the whole screen and is

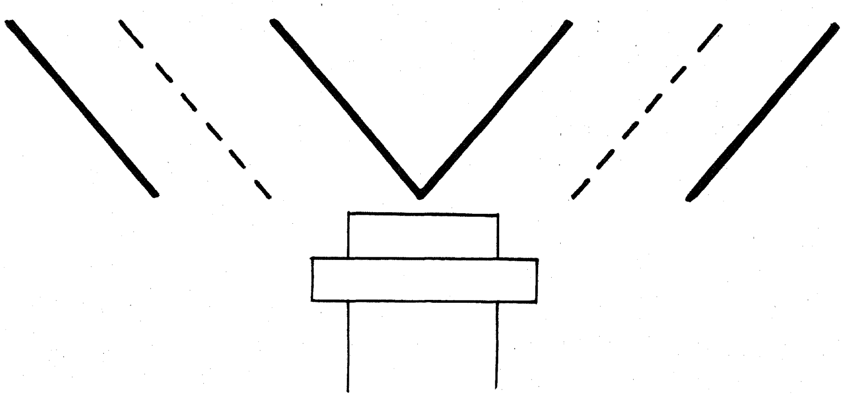


Fig. 19–7. The variable base reflector. The broken lines indicate the normal positions of the outer reflectors, while the solid lines indicate the "wide base" position.

seen only by the left eye. This is removed and a right picture fills the screen and is seen only by the right eye, and so on. The shutter which alternately blocks the vision is a rotary (occasionally oscillating) one so supported in front of the spectator, and synchronized with the projector, that the open sector comes before the eye with accurate timing. Thus the viewing shutter is synchronized with the projector film advance. Of course polarization is not necessary when synchronous shutters are used.

A similar device has been used, with far greater success, in still projection. The two stereo pictures are projected upon the screen in superimposition, just as when the anaglyphic method is used. A shutter is built into a dual lens projector so that during one-half revolution the left beam is passed, and at the next the right beam is passed. Thus upon the screen there is a rapid alternation of the two. However, because of the speed of the alternation, to the unaided eye the screen will present both images.

Each spectator is provided with a similar shutter which is synchronized with the shutter of the projector, and when the screen is viewed through it, the left eye sees only left pictures and the right eye sees only right pictures. In one commercial adaptation, that of Stereovision, Inc., the spectator shutter is enclosed in a small oblong case which is very easy to hold.

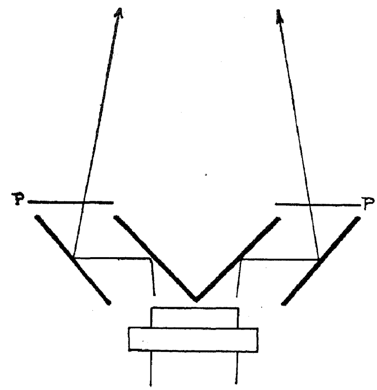
One is inclined to ask why such a system should be used when the polarization system is available with its light-weight goggles which may be worn without discomfort.

The reason most commonly advanced is that the absorption of light passing through two polarizing filters requires such a high light intensity that a special lamp must be used in the projector. This argument is quite valid from a theoretical point of view, and would of course give tremendous advantage to the flicker system which has no abnormal absorption losses. However, in actual practice we have found that 16mm polarized projection with a 750-watt lamp and a 40-inch screen is wholly satisfactory, while a still projector equipped with 500-watt bulbs will also give a good 50-inch picture, using polarizers.

On the contrary, the flicker system utilizes only 50 percent of the light and the screen is not uniformly illuminated. We prefer polarization.

SUMMARY.—1. The film is made normally, using a stereo reflector of the type used for still photography with a single-lens camera. The individual images are a half frame in width and hence the screen image will be abnormally high and narrow unless use is made of a system just devised whereby optical or masking means are utilized for overcoming this narrow format. The film is projected either through a prismatic lens or through the stereo reflector, each image being polarized at right angles to the other. Polaroid spectacles are used for viewing the images, which are projected upon an aluminum screen.

Fig. 19–8. The projector-reflector. The polaroid filters, P-P, have been added to the standard reflector and the outer mirrors set for sharp convergence. Compare with Fig. 19–1.



The amateur will find it to advantage to use the polarizing filters set at 45 degrees from the vertical so that the normal Polaroid 3-D spectacles may be used for these polarized images, and for Vectographs. This eliminates the necessity for two sets of spectacles.

2. The film is made with the reflector and projected normally. This also provides a narrow picture, and it, too, may be optically expanded or masked to proportion. The images are viewed by prismatic viewers which eliminate the unwanted image by angular displacement.

3. The camera is operated at double speed and the projector is speeded up to the same speed. The camera is equipped with a stereo reflector and a half-speed oscillating selector shutter which impresses the rights and lefts alternately upon the film. The projector has a similar oscillating shutter with polaroid films set at right angles in the two halves, thus the right and left images are

projected in succession at double speed. When viewed with the polarizing spectacles, the stereo relief is experienced.

4. The projector and each spectator is supplied with a flicker shutter which mechanically obscures the two stereo images alternately. The shutter may be rotary, rocking, or sliding, and may be actuated by rotary motors, magnetic motors, or solenoids. A shutter geared to the fan motor of the projector and actuating the individual viewers through solenoid control, is simple and effective.

Chapter 20

SPECIAL PHASES

Stereo is not limited to the making of personal pictures. In fact, it is rapidly moving into all industrial, commercial and scientific fields.

Advertising.—Advertising photography, which includes illustrations used for reproduction in the advertising space of various media, remains planar because we have not at this time accepted any adequate method for reproducing quality stereograms at a cost commensurate to that of the planar.

However, this is a temporary condition. The fundamental key to the whole thing has been overlooked because of a very human psychological quirk.

Everyone who reads has spent years in learning to read fluently, and it is assumed that one simply looks at a picture and grasps its meaning. This is not true. The youngster has to learn to see pictures just as he has to learn to walk and to speak. It has been demonstrated that a savage, seeing his first picture, helplessly turns it upside down, upon its side, right side up and then gives up. It is meaningless to him, even when the subject is his own village!

Some training, some experience is necessary before we can interpret anything at all. But when it is suggested that we spend just sixty minutes in learning to see three dimensional printed pictures, the suggestion is brushed aside with the typical comment, "Too much trouble!"

Anyone who has normal vision can learn within one hour to see a non-transposed stereo pair by the use of convergent vision, as explained elsewhere in this book.

All that is necessary to bring three dimensional printed pictures into reality is the sustained use, on the part of three or four publications, of untransposed pairs not exceeding a two inch base! And the small size is not detrimental, because the subjective size will be considerably larger than the printed area, making for economical use of paper space. It may be years, it may be only months, but eventually we shall recognize the utility of taking the short time necessary to teach people to "read" three dimensional pairs in books and periodicals.

It has been reported that one widely used physics text, using just this kind of free vision stereo, has been in print some years. Unfortunately it has been impossible to obtain details before going to press.*

Sales.—Makers of bulky and heavy products commonly equip their sales representatives with albums of planar photographs from which sales are made. This method is admittedly unsatisfactory, but a salesman can hardly carry a five ton truck with him. Manufacturers have recently experimented with stereo and have found new possibilities. Stereo proved instantly successful, because it enables the customer to see, not a worked-up photograph, but the real thing.

One manufacturer of dresses, whose saleswomen used to carry two huge trunks of samples, now send them out with a stereo set and a half dozen samples in a suitcase to demonstrate material quality and fine details of workmanship. This has resulted in a sharp upswing of sales because the buyer can actually see all of the real models.

Manufacturers of specialties for physicians have found stereo the first practical substitute for personal demonstration. Full techniques for using new products and instruments are shown in stereo.

A manufacturer of power shovels sent out a set of stereos showing various models, small and large, actually engaged in operation. Again stereo scored a huge success in a demonstration.

Throughout the sales field, from the smallest products to the largest, the use of stereo has proven successful, and is so rapidly advancing that already most large cities have stereo specialists at work.

Industrial Applications.—Stereo is rapidly gaining favor for making industrial and laboratory records. Mining and engineering firms make field records; scientists record laboratory experiments; factories have wiring and conduit circuits recorded. In planning, miniature scale models properly photographed show the space form of the ultimate full size structure. Whenever a visi-

* "From Gallileo to the Nuclear Age," Harvey Brace Lemon, University of Chicago Press.

ble record of concrete fact is desired, stereo has proven superior.

Education.—For teaching in schools as well as for adult education and specialized technical training, stereo has proven to be free from the disadvantages of planar photography. It is the only photographic process which can rival handmade drawings in such fields as surgery and pathology.

Educational stereo, however, lags. For some reason which cannot be understood, many educators are against visual aids in school work. They seem to have the same idea which rules medicine in primitive civilizations. The more unpalatable education is the greater its value. That this is false has been demonstrated time after time. Lasting knowledge comes only from study which is interesting. The forced cramming of ordinary book study fades from memory within weeks or months; while that which has been learned visually is a permanent acquisition.

Reading is a comparatively recent acquirement of man, but vision has come up with him from primeval time. It is easy to forget what we read and hear, but it is almost impossible ever to forget what we have *seen.* And as has been demonstrated time after time, the artificiality and convention of the planar photograph makes it akin to reading, but the stereogram is in every way equivalent to the sight of the real object. Those who have seen a stereogram remember it fully as long and as distinctly as do those who saw the original object.

It must be admitted, however, that in this discussion we speak of the stereogram as we have it today, the true replica of the original in gradation and color, coupled with the benefit of stereochromatism. The monochrome paper print is not nearly so effective and holds a position midway between the true stereo and the planar.

Even so, stereo is gaining in education, and it will be perhaps only a matter of a few years before it will have been fully accepted as a part of our educational program.

Forensic Stereo.—The acceptance of a photograph as evidence in a court of law is hedged about by many proper limitations. The photograph as we ordinarily know it is subject to too much alteration by skilled hands and to far too great a diversity of interpretation. True forensic photographs are made by trained operators and always in the presence of witnesses who can swear that the picture is truly representative of the original.

Since the stereo revival, stereograms have been received favorably by many courts, and the effect upon a jury is great because there is no room for interpretation. The original is seen as though it were present. Although, as far as we can learn, stereo started in the legal field with the presentation of evidence in a civil case, police photographers are now taking it up and using it to supplement or replace planar photography in the routine of criminal investigations.

One disadvantage at present is the delay in color film processing but with the steady improvement in "home" processed color film, this disadvantage is temporary.

Restricted Subjects.—Much of the subject matter of forensic, biological and medical work is such that it would not ordinarily be returned from the laboratory; but when it is fully understood that such films are of serious, professional nature this will not be the case.

On the contrary there is one class of subject matter which is inherently restricted—records of experiments and progress of secret developments. Ordinarily these would be safe enough, but there is always the slight chance that someone who is not authorized might see the pictures. At the same time, ordinary home processing involves the loss of color which is often of the first importance. Then there is only one course open. That is the use of home processed color such as Ansco color or Ektachrome. Both of these are widely used in stereo and have given highly satisfactory results. Of course, it is necessary to learn the routine, but that is true of any kind of photographic processing when it is first undertaken.

Stereo Radiography.—One of the first types of technical stereo was the stereo X-ray, first made before 1900 and used to some extent ever since that time. The manufacturers of X-ray equipment have produced special tube mounts and calibrated tables to facilitate the use of stereo in X-ray, but the technique has not been widely used for one reason. The radiographers do not take sufficient time to master the fundamental principles of stereo. In fact, from time to time articles have appeared in professional journals which were based upon fallacy. As a result, there are a few specialists who have done excellently well in stereo X-ray, some who obtain satisfactory results and the great majority who fail to obtain usable results.

The technique involved ordinarily makes use of two exposures from two tube positions. These tube positions are based upon the theory of convergence, but by the very nature of the X-ray emission they are fundamentally comparable to the parallel ray technique of the standard dual camera. This is because the emission of the tube is in all directions within the scope of the mask used; or, in other words, almost the exact reverse of the rays impinging upon the camera lens. However, there are no truly axial rays, so even with the actual tube converged the result is substantially that of parallel axes.

The result, of course, is a highly variable relief depending upon the tube distance versus spacing. It is a simple problem to one who knows stereo theory thoroughly, but the fact that operators believe the process to be extremely complex makes them commit errors.

Recently, a new technique has been introduced which promises to clear up a great deal of this confusion. This "new" technique is nothing more than the adaptation to X-ray of the long and favorably known rotary displacement, so common in stereo micro work.

The subject is placed upon a table which may be slightly rotated, or the exposed hand, foot or head is simply rotated between the exposures. This gives a full control of relief through angular displacement, and the distance factor has little significant effect.

If the films are to be viewed in the normal Wheatstone viewer with an eye-to-film distance of three feet, the angular value of the rotation will be normal to human vision at three feet. Nor does the rotation have to be exact. Twice the normal rotation will not produce too much exaggeration. For locating foreign bodies, of course, more precise control of angle is desirable.

Thus, while a great deal of space could be devoted to a discussion of the older technique, it is suggested that those who are interested in stereo X-ray work try this new technique, and for experimental purposes try rotating the subject through approximately two degrees each side of center, a total excursion of four degrees, which will place the image in space at a distance of approximately three feet. It is understood, of course, that the axis of rotation is perpendicular to the central ray of the tube.

By the use of a single fundamental technique, all object sizes and distances normal for any part of the human body can be used.

Vectograph.—The clinical X-ray is greatly increased in value through the use of the Vectograph. The Wheatstone stereoscope has never been really satisfactory as a stereo viewer. It is used simply because, until the advent of the Vectograph, it was the only form of stereoscope suitable for use with the large image sizes incident to X-ray work.

When Vectographic prints are made, it is possible to hang the X-ray film over the illuminator in the operating theatre. Then, by using polaroid 3D viewers with the bottom sectors cut away to provide unobstructed direct vision, a surgeon has the full three dimensional guide before him at all times, and it can be seen at any distance which would be practical with the conventional X-ray. It is a single film, as easily handled as the conventional type, and it may be used with the same illuminators and is in every physical way comparable to the single, conventional X-ray film.

One of the greatest of the advantages of the Vectograph is the fact that the three dimensional aspect is clearly seen at any distance at which the image itself may be seen; and it may be viewed at any angle without disturbing the full stereo relief.

As has been described elsewhere in this volume, the Vectograph process is easy, and does not require too much time. In emergencies, of course, the time factor might be important, but ordinarily the Vectograph should be available within one hour after the original film is dry.

Another value of the Vectograph is that by using a ruler of transparent material with one edge covered with Polaroid along one axis and the other covered with the opposed axis, the two component views are revealed. This makes it possible to make direct measurements between the two positions of any embedded object. This is very important in locating foreign bodies or even tumors. This simple device makes it possible to locate such inclusions in the most direct (and accurate) manner and with no loss of time or involved computations.

STEREO DRAWING

Because the characteristic stereo-subjective reaction has its stimulus in definite geometric relationships, it is possible to produce drawings based upon such relationships and to have these drawings appear in full three dimensions. Once no more than a novelty, it is now somewhat commonplace to construct true stereo elevations from floor-plans.

Geometric Drawing.—This should not be misunderstood. The geometric drawing itself is easily constructed by stereo methods, but many freehand artists make a "net" or "cage" in stereo by geometric methods and then use this net as a guide for the stereo-freehand drawing. This is similar to the use of cross-section paper for the purpose of reducing or enlarging a freehand sketch.

Stereo drawing is based upon the principles of geometric perspective. Inasmuch as full sized textbooks have been devoted to a discussion of this art, we do not have the space to develop the theory fully. However, it is possible to give a superficial explanation of the process.

Perspective.—Perspective drawing is based upon a horizon line; and somewhere along that line there are two vanishing points. Usually one vanishing point is nearer the working center of the line than the other, so that (assuming the object to be a cube), the perspective view will show more of one side of the cube than of the other. If the vanishing points are equally spaced, one edge of the cube will be directly before the eyes and an equal portion of both sides will be seen.

There are really two distinct steps in the drawing. The first step is one which starts with the undistorted plan and converts this into a plan in perspective.

The pivotal point is the station point or point-of-view. This is the assumed position of the spectator who is looking directly at the nearest point of the object.

If we wish to draw a cube in perspective, we start with the plan, which is a simple square. The first step is to convert this plan into the shape which it would have if we were above it and looking

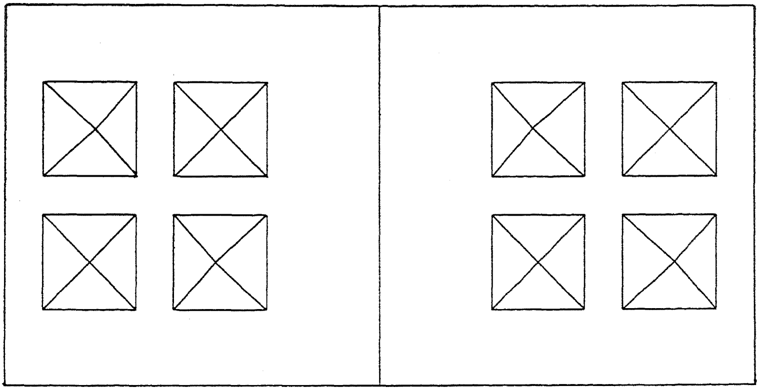


Fig. 20-1. Simple geometric figures illustrate principles of stereo drawing.

at it from an angle, downward and in front of us, with one corner of the plan nearest us. Lay a square sheet of paper upon the ground, five or six feet in front of you and with one corner pointing toward you. That is the visual shape the perspective plan will have. The nearest point of the plan (the corner) will lie in the horizon line.

The horizon line should be near the center of the drawing paper. Then, between that horizon and the bottom of the paper and somewhere near the center, place the station point. The selection of this point is wholly arbitrary and your skill, as you progress, will be reflected in the pleasing appearance of the objects, which is largely controlled by the selection of this point.

The details of drawing the plan are somewhat complex but are not at all difficult to learn. There are several textbooks available which treat the subject of perspective in a manner easily understood by everyone, even those unacquainted with either drawing or mathematics.*

In the second step, the perspective plan is substituted for the station point. Verticals are erected from each significant point of the plan. These verticals, which in the cube consist of one vertical from each corner of the plan, represent the actual verticals in the finished drawing. In our example these would comprise the four

* An excellent book for the beginner is "Perspective, An Elementary Textbook," by Ben J. Lubschez (Van Nostrand).

vertical edges of the cube, one of which is at the rear of the cube and so invisible, but its position must be known nevertheless.

Assuming that our eyes are level with the bottom of the cube, the point of intersection of the nearest edge vertical and the horizon is used as a starting point. The length of the edge is measured upward from the horizon. From the upper end of this line, other lines are drawn to the vanishing points. These form the two front-upper edges of the cube. The side edges are the projected verticals between these oblique edges and the horizon. This is the simplest aspect of the cube of two sides; just one horizontal base, three verticals and two oblique upper edges. With the eye above or below the cube, the upper or lower face would be seen, with edges running to the vanishing points.

Such is the very superficial description of the perspective drawing. It is to be hoped it is sufficient to identify the steps in relation to a more detailed treatise.

Stereo Drawing.—This brings us to the important phase of producing a drawing which will have three dimensions when properly viewed.

The plan is put into perspective exactly as if the conventional perspective drawing were to be made. Then the station point is moved to one side a sufficient distance to permit a second plan to

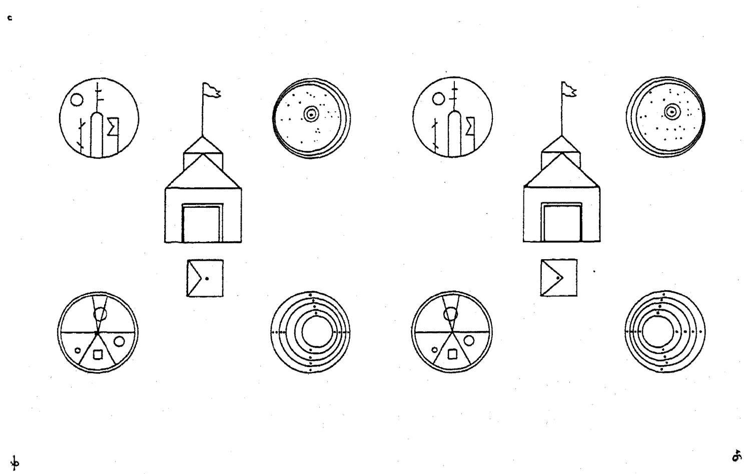


Fig. 20–2. Target figures as used for testing and inclusion in certain stereo-optical instruments.

be placed in perspective without overlapping the first. For a drawing to be viewed in the normal stereoscope, it is advisable that the first plan should be kept to a size of two inches or less and that the station point be moved 2¼ inches. In practice this usually means that the drawing will be made in a size sufficiently large to permit easy drawing and then the completed stereo pair reduced to correct size by photography.

When the dual plan is transferred to the second sheet and the two perspective drawings made, they will automatically be in stereo relief. It is understood that, although the station point is moved, the vanishing points must remain the same for both drawings.

Geometric Freehand Lattice.—For reproducing a freehand drawing it will be necessary to draw a geometric lattice (using the preceding technique). This lattice surrounds the drawing like a cage. Significant points in the drawing are given points in space within this cage. Then the second cage is drawn in stereo relationship and the corresponding (homologous) points are produced. These points permit the correct stereo orientation of the second freehand drawing.

Freehand Net.—The freehand net is a type of graph paper in which there occur vertical lines at intervals, usually of one centimeter. At a distance of one millimeter on each side of each line are drawn broken lines, and spaced 1.5mm from the outer sides of the broken lines there are dotted lines.

The solid lines represent mid-distance, the other lines represent varying distances from infinity to near foreground. One freehand drawing (on tracing paper) is placed over the net. A corresponding drawing is made over the other side of the net and the significant points moved to one side or the other according to the distance of the point. For example, the nose is placed upon a solid line, a similar nose outline is drawn upon a dotted line which is nearer the first drawing. The first drawing is moved so that a distant hilltop is coincident with a solid line. In the opposite drawing, for example the right one, the second hilltop is drawn coincident with the dotted line which is adjacent to and at the left of the homologous solid line. Thus the drawings are shifted back and forth to locate various parts of the drawing. It is necessary to work only with homologous guide lines, which are numbered to facilitate identification.

Freehand Drawing.—The best freehand drawings are actually made freehand. The first is drawn just like any freehand drawing. The second drawing is then made upon a piece of tracing paper placed over the first and during the tracing the lines are separated to right or left according to the spatial orientation of the detail being shown.

It has been reported that there are a few artists who can make the first drawing, and then, by using dissociated convergence, they can draw the second unit, being guided by the actual stereo relief developed by the drawing itself. If this report is true, such people must be very few, although there is no logical reason why the faculty should not be developed.

As far as we have been able to ascertain, no material covering this phase of stereoscopy has been published other than the Stereo Guild Manual of Stereoscopic Drawing.

Stereo Therapeutics.—A great many people refuse to engage in stereo for fear of injuring eyesight. Much of this fear can be traced to very definite injuries of the kind in the past, because stereo viewing can be injurious if the stereoscope used is of inferior design or badly out of alignment due to age or abuse.

Even though it does constitute repetition, we must say again that stereoscope quality is of vital importance and that there is no excuse for the existence of cheap viewers which are poorly made. If you use a 98-cent viewer you are making exactly the same error you would make if you were to buy your spectacles at the ten-cent store instead of having them made by a competent optician. The stereoscope is an accessory to your vision, and it should be of unquestionable optical quality. This does not mean that it has to be extremely costly. Good imported viewers still run around $50 and more, but we have domestic 35mm stereoscopes which sell as low as $10 and which are of satisfactory quality.

Provided the stereoscope used is good, there is no question about stereo being definitely beneficial. Ophthalmologists prescribe definite stereo exercises which are carried out by means of a standard type of stereoscope, and which make use of stereograms of the usual type. The subjects are selected, of course, and the slide originals carefully prepared for this purpose, but there is no significant factor involved which is not present in all stereo.

Visual Comfort.—Strangely enough, this is a factor almost universally disregarded. Unless one is vain to the point of foolishness, a pair of shoes must be comfortable, but a pair of spectacles as often as not are far from comfortable. This is not the fault of the ophthalmologist but results from our own failure to cooperate during the examination. A pair of spectacles should bring the same comfort to our eyes and to vision that a well fitted pair of shoes bring to our feet.

It is also true that physical comfort demands a certain amount of physical activity. Otherwise we become stiff and sore. The same is true of vision. Eyes which are used normally for looking at objects at a variety of distances are more comfortable than those which are strained by long periods of fixed distance vision. Many of us have only rare opportunities to exercise true distance vision, and as a result infinity vision becomes impossible to us without strain. That condition which should be the "rest" position becomes an abnormal one. Stereo viewing provides opportunity for true distance vision with resulting relaxation and the maintainance of more nearly normal visual conditions. This does not make close vision more difficult. On the contrary, the exercise itself makes close vision more comfortable through the occasional relaxation of the strain of constant near vision. Near vision necessitates a continued tension for both accommodation and convergence, and there is the same strain which would result if any muscle were kept under tension for hours at a time. If you want to know just what happens, hold your arm extended in front of you and in a fixed position for five minutes!

Prescription stereograms, if necessary, include some of positive divergence. Each patient has prescribed those slides which will provide the type of exercise he needs. Thus, by the simple act of looking at attractive stereograms for a certain period each day, visual comfort is tremendously increased and very often quite remarkable improvements are made in serious malfunctions of the visual apparatus.

Visual Skill.—This is even less familiar than visual comfort. Of course we know that some people are unfortunate enough to have defective vision. We know that even among "normal" visions some are better than others, usually with the comparison based upon resolving power. But the idea of one person being able to "do things" with vision which others cannot is wholly strange.

In fact, it is just as possible to have skill with the eyes as with the hands or body. Two people can look at a field of vision. One person will see much more than the other. If they match colors, one can do so far more accurately than another. If they look at a tree, one can estimate the distance and height much more accurately. And if both look at three posts in the distance set very closely together, one will be able to say which is the nearest and which the farthest, while the other may not be able even to guess at the relative positions.

These are a few examples of visual skill. It is more largely subjective than physical, in most instances. However, the point in which we are interested is that although stereo reproduces the conditions of direct vision, those who are accustomed to viewing stereograms develop such visual skills more rapidly than do those who see the same objects in reality. Just why the artificial stimulus should produce greater skill seems to be in doubt, but the fact itself has been too often demonstrated for there to be any doubt whatsoever.

Stereo Supremacy.—It is very easy to become highly enthusiastic about stereo. Therefore the writer would like to point out that his stereo experience is more than 30 years old, quite old enough for the sharp edge of enthusiasm to be worn off. He should also like to emphasize the point that the statements of stereo superiority which have been made are not expressions of personal opinions, but facts. They are facts which are subject to demonstration, facts which are matters of record.

CHAPTER 21

STEREO PROCESSING

COLOR IS DEFINITELY one of the factors of stereo relief. But at the same time stereo in monochrome has had a life of more than a century and it would be foolish to expect monochrome to disappear over night. In fact, there will be a demand for monochrome stereo for years to come, for reproduction, for record work, for experimental purposes and certainly among the old guard who have given years to the gold toned paper print and to the thiocarbamide toned transparency.

It is demonstrably true that no stereo paper print can equal the quality of the monochrome transparency; and it is equally true that the monochrome transparency can never equal the quality of the color transparency. Despite this, there will be hundreds, if not thousands, of paper stereo prints made in this country during the next 12 months and for years to come.

It is a fact that diminished parallax is deliberately used with only moderately close-up subjects to diminish the relief—we could never understand why. It is just as difficult to understand why anyone should still be content with the diminished relief, the silhouette form, which is common to the paper print because it lacks the gradation of the color transparency. But just as long as these things are done, there will necessarily be interest shown in stereo processing.

It may be added, however, that if monochrome is used, it is highly advisable to do the processing yourself because the technique is much different from that used in the average commercial processing laboratory.

In modern photography it is usually assumed that the emulsion sensitivity, as indicated by the ASA rating, the time and temperature of the developer are all unalterable factors. This is not true. Of course, the actual reaction of the emulsion to the impact of light is substantially stable, but the amount of such reaction necessary to produce a usable negative varies widely, according to the development used.

It is known that in the usual developer, all tones both light and dark appear at about the same time, and that the highlights grow more rapidly than the shadows. Thus, the normal negative progresses in both contrast and density as development proceeds. It is also known that the density grows more rapidly after an increased exposure. Thus it follows that if the exposure is increased, printable density will be reached coincident with a lower degree of contrast than would otherwise be the case. Thus, by increasing the exposure and decreasing the development, it is possible to decrease the overall contrast of the negative. This is the essence of control development, and stereo development is above all control development.

The possibilities of control development are not fully understood by the average amateur. Consider an emulsion normally rated at ASA 25. By the use of a high-energy developer, a printable negative may be obtained with 1/4 normal exposure. This in turn means an exposure based upon a sensitivity of ASA 100. But if a fine-grain, superficial developer is used, four times normal exposure is necessary, or an effective sensitivity of ASA 6.25. Yet only one film is under consideration, and while it does have a fixed primary sensitivity to light, its sensitivity in relation to the developed image actually ranges from ASA 6+ to ASA 100, or a range equivalent to that from a slow positive emulsion to a high-speed panchromatic!

Degree of Deviation.—The exposure is that required to record the deepest shadow detail of significant size . . . and that means anything larger than a pinhead in the negative. The deep shadow is read by holding the meter close to it. The highlight is read at its brightest exclusive of the rest of the scene. The normal photographic range from shadow to highlight is 1:100 (the "normal" negative has less than gamma 1.0, so such a recorded range is developed to about 1:60 to 1:80 and can be printed on paper). Suppose your shadow reads 4 and the highlight 800. The range is 1:200. You multiply the minimum reading by 50, the "latitude" factor, $4 \times 50 = 200$ and give an exposure indicated for 200 maximum highlight (meter = 50) regardless of the 800 highlight. This is only a rough rule but is usually near enough. But with 200 as the maximum, highlights over 400 will be blocked.

It requires a bit of experience to learn the exposure control, but the exposure indicated for a maximum highlight of 50 times the deepest shadow usually works out.

In development, the ratio of time to density will depend upon the composition of the developer and the temperature. Some developing agents have steeper progression curves than others. But as a rule of thumb, use normal development when the meter range lies within 1:100, and try ½ to ⅔ development time when the meter range is 1:200 or more. Your own experiments will soon indicate the correct factors. It is better to have the negative too soft than too hard. You can use a high contrast paper, but if the highlights are really blocked, you can do nothing short of chemical reduction.

But nothing systematic can be done unless both extremes of light intensity in the original scene are measured separately.

Most modern meters are good, but we have been using the G.E. because it has a triple sensitivity range which is convenient for deep shadows and because it fits the H&H color meter attachment, which has been discussed in the color chapter.

Control development is said to result in distorted tonal values. Of course it does. How else can you reproduce an original range of perhaps as much as 1:800 upon a medium which at best will give you 1:80? You either "distort" the gradation and represent every tone of the original in reduced form, or you obtain a print in which most of the highlights are pure white, most of the shadows are ink black and a small middle range is represented as a succession of harshly stepped tones. It may be said that every photograph made by sunlight either has such distorted tonal values or it is worthless as a picture! The distortion, of course, is but a matter of compression with some true but unnoticeable distortion of relative values in the extreme tones.

Developer.—Among the developers not commonly used by amateurs, both pyro and glycin are excellent, but both require experience. Old fashioned staining pyro is really superior to the non-staining types, but care must be used to avoid spots.

However, the mild alkali developers such as the borax types are good; fine grain developers are also good, although the surface types are not recommended. However, you will probably not care to try processing unless you are familiar with ordinary planar processing. You will, therefore, have some favorite developer, and if it is one which gives you good printing negatives you can use it.

All stereo manuals emphasize the necessity for very soft negatives, and this is misleading. In the old days of stereo, the normal printing method in photography was by contact, and contact printing requires a negative which is considerably more contrasty than one which enlarges well. Today we deal mostly with negatives for enlargement and they are just about right for stereo contact printing. Therefore, you may discount most of the remarks about general softness provided you have a negative from which you can make a print which does not show either a dense shadow without detail or a glaring highlight which also lacks detail. But the detail need not be strong. The most delicate hint is enough provided it is unmistakable. As a matter of fact, most modern negatives do have unblocked highlights so the pivotal factor becomes simple, but be sure the deep shadow has detail.

Formulae.—There is no good reason to give formulae here. Those used are standard; and occasionally a new formula is produced. There is no such thing as a specific stereo formula, particularly now that fine grain is a standard procedure. If you already do your own processing, use what you normally use. If you have had no experience, you require guidance in greater detail than can be given here.*

Fixing.—We do have a suggestion to make regarding fixing. There is a tendency for fixing solutions, particularly hypo, to attack the image. This action is not vigorous, but it is a mistake to develop negatives with very delicate shadow detail and then to permit them to soak in the fixer for an hour or so, or as we recently found one amateur doing, to soak them all night long in fixer! Use the solution fresh and use it according to directions.

Rapid fixers are available which have proven satisfactory. In the Guild laboratory we still use hypo, and make it according to the ancient 1:1:1 formula. This uses a hardener made up of 1 ounce each of sulfite, *glacial* acetic acid and potassium alum to each half gallon of 20 percent hypo. This is more acid than the usual formula, but we can develop normally at 85° and above,

* For the beginner we heartily recommend "How To Make Good Pictures" and the "Kodak Reference Handbook," both published by Eastman Kodak.

and do not have pinholes, reticulation, blisters and the like. It may also be said that repeated comparative tests have shown that this fixer does not degrade print quality as so often stated.

Washing.—Be sure to wash thoroughly. If your negatives have been properly hardened you can wash two or three hours without danger, but one-half to one hour in some device which thoroughly agitates the films or prints, or in a rack which keeps them positively separated, is sufficient. We have stereo negatives on hand which were made in 1918 and were fixed and washed this way. They are as printable as the day they were made.

Swab the negatives off after washing, squeegee to remove surplus water and dry in a place where drying occupies from one to three hours, neither too rapidly nor too slowly.

As soon as they are dry, cut the negatives apart, transpose them and place in individual protective envelopes. Negatives left lying around collect dust and dust makes scratches even upon a processed negative. If a negative is worth making it is worth protecting —and a scratched stereo negative might as well be destroyed.

THE STEREO POSITIVE

For almost a century, stereo negatives have been made principally upon glass, and printed upon either paper or glass. The recent revival of stereo is only a few years old, and is based upon the use of 35mm reversible color film. The physical differences have resulted in confusion and in the inevitable attempt to modify old processes by modern techniques.

Thus today we have adherents of glass for both phases, of film negatives and glass positives, of film negatives and positives, of glass negatives with paper positives and film negatives with paper positives. Only in the modern phase do we find a definitely standard procedure, that of 35mm color film.

It is difficult to obtain glass sensitive material, and only a few dealers carry it. The general trend is toward the use of film in the camera, paper for prints and film for transparencies. It has been our experience, however, that glass diapositive plates make possible a quality which we have not been able to duplicate with sheet film. However, that is a minor matter as the difference is slight.

One thing is important. There is nothing available in the 35mm field to compare with the automatic cabinet viewer or "classifier." The result is that many users have adapted the old cabinets to modern mounts. A viewer which makes use of side guides, such as the Taxiphot, presents quite a problem in rebuilding, while the Mattey, with its loading weight resting on top of the slide, and already adaptable to 6x13 or 45x107, requires only shortening of the trays. For glass mounted 35mm slides, color trays are used (12 slides to the tray) and for rigid cardboard the normal 25 slide trays are used. The semi flexible "folder" type of cardboard mount is not rigid enough for either projection or automatic viewer use.

The same thing is true of film positives made from the older negatives. The film is usually unmounted and is too flexible for anything but the hand viewer. If glass mounted, the slide is too thick for anything but color trays in the cabinet. There have been some successful experiments in the use of thin plastic for binding, but for projection it must be remembered that some plastics are optically active and produce rainbows over the screen. If slides are to be projected it will be necessary to use some plastic material which is inactive. The acrylics are satisfactory, but the cellulose plastics are, as a rule, very active.

We shall of course ignore the 35mm color positive as it is processed for you.

Paper Prints.—There is nothing out of the ordinary in making the paper print other than the problem of keeping the tonal range within the range of the paper with no burned out highlights or coal black shadow areas.

The short tonal range of paper prevents the full tonal reproduction of the original and hence tends to diminish the degree of stereo relief and produce stereograms in which round objects present a decidedly flattened appearance. Human figures resemble "gingerbread men." This defect is less noticeable when soft, full range prints are made and increases as the print becomes harsh in contrast.

Masking.—Prints may be masked as you choose, but the film negatives should be carefully spaced when transposing. The usual 3x6 stereogram has no space between the units, but it is suggested that the amateur slit adhesive tape to a 1/8″ width and leave this much space. The mask should be cut with a 3/16″ bar between opening so that any slight irregularities of the 1/8″ tape can be obliterated.

Prints 6x13 and larger appear best with rectangular masks having slightly rounded corners; 45x107 and smaller with sharp cornered, rectangular masks. If you choose you may follow the old convention of using a domed top with a sharp cornered bottom. This is almost universal in the 3x6 size, although no one has been able to cite a good reason for it. Perhaps the suggestion of an arched window seemed more "elegant" to the Victorian stereographer.

It is also known that commercial paper prints in 3x6 are mounted upon cards which have a decided curve. We have been unable to discover any reason for this practise which is certainly optically inferior to the flat mount.

Window trimming or masking is useful when open type viewers are used, but of less value in the better grade stereoscopes which have the field masked by the visual tunnels in the instrument.

Transparencies.—It is difficult to discuss this subject, because it is one photographic art which has relatively few adherents today. The stereo transparency, aside from the duality of image, is identical with the lantern slide. The stereographer can do nothing except get some materials and work at it until he has mastered the knack of doing it well. We know of no better guide for the beginner than the lantern slide brochure in the Kodak Reference Handbook.

The difficulty lies in the fact that in transparency making, the fixed exposure and development are abandoned, and the contrast of the positive controlled by a sliding scale relationship between exposure and development.

If the highlights have the correct delicate tone but the shadows are weak, decrease exposure and increase development.

If shadows are strong, but highlights fully clear, increase exposure, decrease development.

If the image is weak throughout with clear highlights, increase both exposure and development.

If highlights are gray and shadows black, decrease both exposure and development.

That is but a rough guide, and only experiment and experience will enable you to make a good transparency. It is not, however, difficult to learn if you really try.

The good transparency is almost black as it lies in the developer, far darker than a good paper print. The final judgment can only be made after the dry slide is examined in the viewer, but you can learn, by looking through the slide at the yellow-green safelight to judge very closely.

Because the transparency will reproduce many times the tonal range of the paper print, the negative should be made for transparency printing. You will find no negative which works at its best in both media. The negative for the transparency will be more vigorous than usual and will, in fact, be fully as vigorous as the hardest negative considered suitable for planar projection printing under modern methods; harder in fact than most amateurs ever use.

Projection.—Projection printing has already been mentioned. If the image is enlarged two diameters, the viewer should have lenses whose focal length is twice that of the camera lenses. This is the only significant factor in projection printing. Extreme care must be used, because the slightest softness of focus becomes visible in the stereoscope.

Toning.—Perhaps no division of amateur photography lays such stress upon toning as does the older stereo field.

Among the old guard a stereogram simply isn't ready for viewing until it has been gold toned. Again no one seems to know why. The technique apparently was born at the period when a commercial photographer couldn't sell a print unless it was "sepia." For some reason the richness of black did not appeal. Planar photography recovered from the fad, but it remained a stereo requirement. It is true that occasionally a gold toned print is really beautiful, usually it is a ghastly "half-baked" brown, not greatly different from the usual "sepia" tone.

If you grow to the point where you wish to make use of gold toning, you can purchase the necessary materials ready mixed at any photographic store. Just follow directions. It is a tricky process but eventually you can master it. I do not suggest you take the time to make up your own solutions.

The transparency makers also lay stress upon toning, but with better reason. The transparency does have an extended tone range, and often it is visually harsh when the gradation is good. The toner most favored is even more temperamental than gold toning, but yields a beautiful blue-gray range of tones which is the most realistic monochrome for outdoor scenes I have ever seen. This is the thiocarbamide toner, and is used as a part of the developer, not as a subsequent treatment.

SOLUTION A		
Metol	22 gr	2.5 g
Sodium sulfite	130 gr	15 g
Hydroquinone	90 gr	10 g
Sodium carbonate	130 gr	15 g
Water to make	20 oz	1000 ml.
SOLUTION B		
Ammonium carbonate	2 oz	100 g
Ammonium bromide	2 oz	100 g
Cold water to make	20 oz	1000 ml.
SOLUTION C		
Thiocarbamide	26 gr	3 g
Ammonium bromide	9 gr	1 g
Water to make	20 oz	1000 ml.

Color is controlled by varying the proportion of *A*, *B*, and *C*.

Color	*A*	*B*	*C*	*Relative Exposure*
Pure black	7	½	½	1
Blue black	6	1½	½	2
Blue	5½	2	½	4
Violet	5	2½	½	8

Finishing.—Glass positives should always be flowed with a good negative or print lacquer as soon as thoroughly dry. They should then be further protected by filing in individual envelopes or in a filing cabinet which is provided with slots or other means for keeping the slides separated. With the cabinet viewer, the slides are filed in the viewer "trays."

Those of you who wish to get into stereo processing seriously will not find it difficult, although it does demand careful technique. Carelessness and stereo do not mix. But with reasonable care there is no great difficulty, and most of the procedure is identical with that of planar photography.

Appendix A

THE PRISM DIOPTER

In stereo, we are vitally concerned with two visual axes which converge. Parallel visual axes do not give any stereo parallax, hence are useless in stereo. That is, objects at infinity lie beyond *stereo* infinity. For that reason we are concerned only with *convergent* axes and with light rays which have other corresponding angular relations.

It is commonplace to use the prism diopter as the unit of measurement, rather than the conventional degrees, minutes and seconds.

The prism diopter is a prismatic power which will cause a beam of light to deviate to the extent of one part in one hundred. Thus if you project a target upon a screen at a distance of 100 inches from the projector, and mark the position of the center of the target; and if you then place a prism over the lens of the projector which causes the center of the target to fall one inch at one side of the original position, you have a prismatic deviation of one diopter, and that prism is said to have a power of one prism diopter.

Of course, if the prism causes a deviation of 1 inch in 100, it will produce a deviation of 1 centimeter at a distance of 100 centimeters or a deviation of 1 foot at a distance of 100 feet.

It is customary to give the deviation as applied to one ray only, that is, if each eye deviates one prism diopter, we have actually a total convergence of two prism diopters, but we speak of the condition as a deviation of one prism diopter. Note that "deviation" is the movement of one eye, "convergence" is double the deviation and applies to both eyes. This is not a fixed rule and often in optical literature you will find the terms used interchangeably, with considerable resulting confusion.

THE HALF ANGLE

This is similar and refers to the monocular deviation. The base is the distance from the pupil to the center of the nose, or one-half the interpupillary distance. Conventionally the base has a value of 32.5mm, which is equal to 3.25cm. As one meter contains 100 centimeters, the deviation normal for a distance of one meter is 3.25 prism diopters, or a total convergence of 6.5 prism diopters.

There is no fixed angular value for the prism diopter. One prism diopter has an angular value of about 0°34′23″, so we should expect 100 prism diopters to have 100 times this value or 57°18′20″. However, by definition the distance through which the beam is deviated is compared with the distance of the surface upon which the deviation is measured, so at a distance of 100 units we should find a lateral deviation of 100 units giving us two equal legs of a right angled triangle, so the angular deviation must be 45° for 100 prism diopters. The reason for this is that each additional degree intersects the measuring plane at a greater distance than the preceding one, so that each succeeding prism diopter has a smaller angular value than its predecessor.

This method of angular measurement is considerably more convenient in our work than the conventional angular measurement.

PRISM BASE

Another term often encountered in reference to steroscopic vision is "base-in" and "base-out," with certain prism diopter values. Thus we might encounter "base-in 13 diopters." This is actually the normal convergence for looking at an object at a distance of 50cm. That is, if two parallel rays are deviated toward each other by the use of a pair of prisms, each of 6.5 power, the two beams would be deviated toward each other 6.5 prism diopters and would have a total convergence of 13 prism diopters. If these parallel rays are separated by 65mm, this 13 diopter convergence will cause the rays to meet 50cm in front of the prism.

On the contrary, if you have a standard therapeutic stereoscope with 200mm lenses and 90mm base, one prism diopter will have a lateral value of 2mm. If you prepare a stereogram for this instrument in which the maximum homologous separation is 96mm, you have the condition of 3 prism diopters, base-out.

Thus "base-in" indicates convergence while "base-out" represents divergence, both related to the parallel vision of the normal condition of rest.

Most people can converge 32.5mm in 200, that is, look at an object 8 inches in front of the nose. This is a deviation of 16.25 prism diopters and a convergence of 32.50 prism diopters for both eyes. On the contrary, most people find difficulty in fusing with as little as 2.5 prism diopters divergence from the parallel.

DEVIATION IN STEREOGRAPHY

Deviation is important in stereography, because of the variations in convergence necessary for fusing images of close-up objects and also variation at a distance.

For example, when slides are to be projected, there should be a maximum of 3 prism diopters variation between the nearest and farthest images, and 2.5 prism diopter is even more advisable. But it is important to note that this is a differential value, not an absolute one. For example, assume that the camera lenses are spaced 70mm, with a 35mm half base. Then a deviation of 1 prism diopter occurs at an object distance of 3½ meters, although to average vision (65mm) it would be 3¼ meters. A deviation of 3 prism diopters would therefore be encountered at a distance of $3.5/3 = 1.166+$ meters.

Under the 3 prism diopter rule, objects which lie between 1.166 meters and infinity can be fused comfortably. If the 2.5 deviation is used, the minimum distance will be $3.5/2.5 = 1.4 \times 1.166$ or 1.63 meters, about 5½ feet.

However, if we compute the deviation for 6 diopters, we find it to be 0.585 (58.3 centimeters) and 81 centimeters for the 5 diopter distance (2½x2).

Therefore, if we stereograph an object at a distance of 58.3cm (23 inches in round figures), and have objects at infinity in the same picture, the range of fusion is excessive and the stereogram will not be comfortable to view. However, if the object at 58.3cm is placed before a wall whose distance is 1.166 meters (46 inches more or less), the *range* of deviation will be from +3 to +6, and the stereogram will be just as comfortable to view as the one whose range is from 0 to +3.

Using the 2.5 maximum the near distance would be 32 inches with the background at 64 inches, giving a range from +2.5 to +5 diopters.

The adverse criticism levelled against the very close close-up in stereo may be justified in those instances where there is a distant background, but the criticism is not warranted when the total included range lies within limits. Most of the criticism against the close-up originates in the fact that many stereo technicians have inherited a tradition but are unfamiliar with its technical nature. A close-up is, to them, inherently poor regardless of any and all other circumstances.

DEVIATION IN PROJECTION

When projecting a series of slides, it is advisable to have them pre-adjusted, because if the lateral separation is set for distance subjects, the projector will maintain the infinity separation and close-up subjects will require compensating adjustment.

Slides for projection should be arranged so that the separation of the *farthest* images should be uniform. For example, in the usual 35mm slide, assuming it has been made with lenses of 35mm focal length, we may assume one prism diopter to have a lateral value of 35/100mm, which is roughly one-third millimeter. Let us also assume that in standard mounting, the infinity-homologous distance is 65mm. Slides which include infinity, have images of objects at infinity separated by 65mm. But such slides should have no images separated by less than the limiting deviation of 3 prism diopters or a total of 6 prism diopters for the two units. Therefore the images of the nearest objects should be not less than 65 — 2.1 or 62.9mm apart.

If, however, the widest separation (image of most distant object) is 62.9, then the nearest may be as little as 60.8 in separation. In that instance, the films themselves are moved apart 2.1mm. This slide which represents an original field with a depth extending from 23 to 46 inches, will project just like the one which represents an original range of 46 inches to infinity.

The whole technique lies in keeping the images of the most distant object at the nominal homologous separation for infinity. This applies to slides made at a range of 11½ to 23 inches, as well as to the other two examples cited.

SPECIFIC DEVIATION

If you will divide the focal length of the camera lens by 100, you will have the nominal lateral value of one prism diopter under taking conditions (variation in value caused by extension of lens in focusing is ignored). Dividing the focal length of the viewer lenses by 100 will give you the nominal value for the visual prism diopter. The ratio of these two will give you a numerical evaluation of the inherent distortion. For example, if the camera has a prism diopter value of 0.35mm, and the viewer has one of 0.50 diopter, the inherent stereo distortion amounts to 35:50 or 70:100, which may be interpreted as a 30% distortion.

It is significant that only when the distortion exceeds 50% (that is with the viewer twice the focal length of the camera), or when the viewer has less than two-thirds the focal length of the camera, does the distortion start to become visible.

PRACTICAL APPLICATIONS

A little experiment will soon show you the tolerance which you have and the range through which you can deviate images without detriment insofar as your specific audiences are concerned. Once this knowledge is available, you can compute the characteristics of your slides and mount them with accurate compensation for deviation. This produces an excellent slide for direct viewing and for projection.

Appendix B

STEREO GLOSSARY

There is nothing very difficult or different about stereo, but it is a distinct branch of photography and has its own terminology. These specific words and phrases are not intended to confuse, they simply make it possible to say some specific thing in a few words and without which it would require many more words to make the same statement, and in less satisfactory manner.

Although you will soon become familiar with these terms, it is convenient to have a glossary available while you are still unfamiliar with the subject. This glossary is offered for reference. It is far from complete, but it does include the most useful words common to stereo but less familiar outside the field.

As you progress you will meet many terms not included here, but for the most part they will be terms dealing with more advanced phases of the subject.

American stereoscope.—The common parlor or Holmes version of the Brewster stereoscope. Also Mexican stereoscope.

Anaglyph.—A stereogram of two superimposed images in which the images are blocked to their respective eyes, so each eye sees only its own proper image. The original form was the bichrome in which the images are printed in two complementary colors and viewed through correspondingly colored filters. A half century ago the process of using polarized light instead of color was patented, and today is favored over the color type for projection. In motion picture work, alternate frames are dyed in complementary color and the film run at double speed to produce the alternate anaglyph. Both bichrome and polarized types are now in use. Books and magazines, for practical reasons, are usually illustrated in bichrome anaglyphs.

Anaglyphic restoration.—Reconverting an anaglyph to its original form of two separate photographs to be viewed in a conventional stereoscope.

Autostereo plate.—An obsolete plate with a parallax grid on the back, used for making direct parallax stereograms. Reversal processing.

Autotransposer.—Either a printing frame or machine in which provision is made for transposition by simply pulling two levers.

Auxiliaries, stereo visual.—Factors in stereo vision which enhance the stereo relief but which are not essential to stereo vision. The two most important are the effects of perspective and overlapping of distant objects by those nearer.

Base.—The stereo base is the distance between homologous optical points, usually the optical axes of the camera, but also applied to the separation of viewer lenses and at times to human interpupillary.

Box stereoscope.—A stereoscope in the form of an enclosed box as contrasted with the skeleton form of Holmes. Standard in Europe.

Brewster, Sir David.—Probably the true inventor of stereoscopic reproduction, although the claims of Wheatstone are also favored by some. Brewster was the first to point out the overwhelming importance of the subjective in stereo. He also invented the prismatic stereoscope (semi-lenticular) which is properly known by his name, but often called Holmes, Mexican, American and the like. These are only one type of Brewster construction.

C. T. meter.—Color temperature meter. See Color meter.

Chain stereoscope.—A cabinet stereoscope with the views hung in chains which pass over twin sprockets thus bringing into view one stereogram after another. More familiar in Europe than here.

Chromatic perspective.—See Stereo-chromatism.

Chromatic relief.—See Stereo-chromatism.

Color correction.—The use of faintly tinted filters with color film to compensate for off standard color of incident light. More important in stereo than planar photography as normal color is an important factor in panortho stereo. Also used to adapt color film to a type of light for which it is not designed as the conversion filter to use Type A kodachrome with daylight. Also color control.

C. C. Filter.—One type of filter used in color control. Also L. C. filters.

Color meter.—A special meter which indicates the spectral balance of any existing light of photographic level, and by doing so indirectly indicates the proper correcting filter which should be used. Among the most popular are the H&H attachment which converts the G.E. exposure meter into a color meter and the Rebikoff precision color temperature meter, made in Switzerland.

Color perspective.—See Stereo-chromatism.

Complementary stereoscope.—A stereoscope matched to the camera as is essential in orthostereoscopy.

Compressor, image.—A cylindrical lens used in making stereo motion pictures to permit a rectangular screen image instead of the narrow vertical format of a half frame.

Contour reversal.—A type of space control in which certain elements of the scene are shown in pseudoscopic relief while others are shown in proper stereoscopic relief, although both elements are combined in a single stereogram.

Convergence.—The meeting of visual (or other optical) axes when produced from two separate stations to a common object. Absolute convergence is the actual angle between the convergent axes and is identical with the parallactic angle. Relative convergence is the convergence upon one object within a scene compared with that upon another object. Relative convergence is the more important in stereo photography. Convergence is often said to be the primary stereo stimulus, but this has been disproved.

Convergence camera.—A method of making stereograms by altering the direction of the camera between exposures so the object is centered in both films. Impractical for any subject except one limited largely to one plane. Otherwise more or less serious distortion is introduced.

Conversion filter.—A specific type of color control filter designed to permit the use of artificial light film by daylight or vice versa.

Coronet (Trade name).—An inexpensive stereo camera and viewer using 828 or equivalent size film. Comparable to a deluxe box camera.

Deviation calculator.—Dial calculator for determination of the range of deviation in any scene before photographing.

Diagnostic stereo.—The use of stereograms to aid in the diagnosis of visual disorders.

Diopter.—Ophthalmic lenses (and viewer lenses) are designated by power rather than focal length. The power in diopters is equal to 100 divided by the focal length in cm. Thus a 20cm lens is 5 diopter, a 10cm is 10 diopter, a 5cm is 20 diopter and so on.

Diplopia (Double vision).—Ordinarily an abnormal visual condition, but normal to all stereo vision outside the macular area.

Drawing, stereo.—A drawing made in duplicate but with stereo differentiation so that when viewed stereoscopically it will have stereo relief.

Equivalent distance.—In stereomicrography, a photograph made at a very short distance is viewed as if it were at some greater arbitrary distance, usually "reading" distance. This apparent distance is the equivalent distance. Also applied to other distortions, deliberate and accidental, of stereo relief.

False stereogram.—(See Spreader, Twister, Infusible.) A true stereo pair so mounted that viewing is uncomfortable or impossible.

Flicker projection.—Stereo projection in which the two images are projected upon a screen in rapid alternation, and viewed through a shutter which alternately obscures the right and left eyes in synchronism with the projector.

Frame masking.—Masking the top and bottom of the aperture in a motion picture camera (less commonly in the projector), to produce the desired square stereo screen format.

Free vision.—Any system which permits a true stereoscopic effect to be seen without the use of any kind of viewer.

Fusion.—The visual registration of the two images in the eyes. This is distinct from the phenomenon of subjective synthesis to which the term is often applied.

Purely a physioneurological factor.

Ghost image.—Any visual or photographic image which permits objects behind it to be seen; a transparent image. The condition common to images of objects not the subject of direct vision.

Glyphoscope (Trade name).—A simple device now obsolete, used as both camera and viewer.

Graflex (Trade name).—The stereo-graflex uses 5x7 sensitive material to make stereo pairs 3½x5. Has stereo viewer lenses in focusing hood.

Grid stereo.—Narrow strip elements from two images alternate. Viewed through a grid spaced before the print, the two eyes see different images due to angular vision through the grid. The least satisfactory of the general integrated type of free vision stereogram.

Guildmount.—A special, rigid, cardboard stereo mount made for the Stereo Guild.

Homologue.—That which exactly corresponds in position, proportion or structure. In stereo applied to corresponding points or parts in the two images.

Homologous distance.—The distance between two homologous points. Identical with base or separation when the homologous points lie at infinity.

Homologous points.—The two point images in the stereo pair which exactly correspond. The two images of the same nailhead in a board, for example, are practically homologous points.

Hyperstereo.—Stereo with an extended base. Results in theoretical error which is practically imperceptible. Reduces apparent distance of objects, which appear as scale models of the larger object.

Hypostereo.—Stereo with diminished base. Used for close-up and stereomicrography.

Iloca.—Stereo version of the 35mm Iloca camera.

Infusible stereogram.—A stereogram so made or so mounted that it cannot be fused.

Integrated stereogram.—A free vision stereogram of the basic grid type but operating upon different optical principles to provide stereo vision from integrated elements of the two images. A lenticular (spherical or cylindrical) screen replaces the grid. Peristereoscopy.

Interocular.—Basically the distance between the two eyes; also applied to the separation of camera or viewer lenses. May be variable.

Inversion.—The complete reversal of position exhibited in the stereo negative as compared with the true positions. The optical phenomenon which makes necessary the transposition of stereo prints.

Kelvin meter.—Color temperature meter. See Color meter.

Lens, stereo-prismatic. — Supplementary lenses for stereo close-ups which combine both the positive refraction of the conventional close-up lens and a prismatic deviation which permits the image of the close-up object to be centered in the film area.

Light control.—See Color control.

Macular vision.—That part of vision which is characterized by maximum definition and resolution. Also known as "sharp" vision. The object of macular vision is that object upon which the visual attention is fixed.

Magnification of viewer.—In orthostereo the magnification is unity, as the taking and viewing lenses compensate. A viewer with lenses of less than the camera focal length results in undesirable magnification of the image. Magnification as a primary function of the viewer may be ignored when the viewer is a complementary one.

Metastereoscopy.—Reproduction of original in normal proportions but in abnormal size. Common in stereomicrography.

Mexican stereoscope.—Holmes stereoscope.

Mirror stereoscope.—A stereoscope which involves reflection from a mirror. The Wheatstone stereoscope largely used in X-ray work is one type. See Reflecting stereoscope.

Monocular viewer.—This is not a stereoscope. It is a single lens which is used to give to a single photograph a three-dimensional but not stereoscopic appearance. Pantoscope.

Normal stereoscope. — Any stereoscope which uses stereograms whose infinity-homologous distance is substantially equal to the average interpupillary separation, i.e. 65mm. Contrasted with the Brewster in which the I-H points are much farther apart than the normal human eyes.

Orthostereoscopy.—That type of stereoscopy in which the image is reproduced in full natural size as seen at full natural distance and in full normal degree of relief. Not possible with projection nor free vision; only when an individual viewer is used, and this must be complementary to the camera.

Panortho-stereoscopy. — The nearest approach to perfection in stereo. This is an orthostereogram in which full advantage has been taken of the auxiliaries (q.v.), and which is in full, corrected, natural color. By all means the most perfect type of photograph yet produced.

Parallactic distortion.—A degree of parallax too small or too great for the object size. Objects appear as thin (i.e., silhouettes) or elongated in the direction of the optic axes.

Parallax.—A difference. Specifically the difference of the visual images which result from the two eyes having different points of view. The fundamental external stimulus of stereoscopic vision.

Absolute P.—The parallax of a given point as determined by the angle between the visual axes meeting at that point.

Circular P.—Stereo relief produced by rotating the object rather than by having two separate points of view.

Differential P.—The variation between the parallax of two points upon the surface of an object. The fundamental external stimulus which enables us to see roundness or spatial difference.

Dynamic P.—The ever changing parallax involved when the eyes shift from object to object. The specific external stimulus of stereoscopic vision.

Illumination P.—In stereomicrography the production of parallax by opposed light beams rather than by physical difference.

Relative P.—The parallax of one object or point as compared with that of another. Closely similar to differential parallax but used as a basis of measurement.

Rotary P.—See Circular parallax.

Stereo P.—Parallax as specifically related to stereo vision and in contrast to strictly geometric parallax.

Parallax stereogram.—Commonly but incorrectly used to designate an integrated stereogram. Because parallax is the vital factor in stereoscopy, any stereogram of any type might properly be called a "parallax" stereogram. A free vision stereogram, see Grid stereo.

Parallel vision.—The normal condition of vision at complete rest. In stereo the ability to fuse a stereogram of conventional type without the use of a viewer. Accomplished by separating the habitual co-action of convergence and accommodation.

Parastereo.—A stereogram which is apparently ortho in quality but which can be demonstrated to possess the anomalous spatial relationship of the stereo telescopic field. To all intents and purposes an orthostereogram of telephotographic type.

PePax.—Coined term to indicate the relationship between the apparent size and the apparent relief of any object. Normal PePax is characteristic of the orthostereogram. Abnormal PePax indicates parallactic distortion.

Personal.—A miniature stereo camera using standard 35mm film but making 70 stereo pairs of substantially 16mm size upon a standard 36 exposure film. Also applied to camera and mounting accessories made by Sawyer's, Inc.

Perspective.—The disposition of lines to represent a solid object upon a plane surface. In stereo regarded as the complement of parallax. Perspective has to do with "size-in-width" while parallax has to do with "size-in-depth."

Planar.—Restricted to a single plane. Ordinary photography in contrast to stereography.

Polarized light.—Light which vibrates substantially in a single plane. Used in stereo largely because of its property of extinguishing an image when planes of polarization are crossed.

Polaroid (Trade name).—A synthetic material which has the property of polarizing light. Used in stereo projection of polar anaglyphs.

Prismatic stereoscope.—A stereoscope in which the lenses are really half lenses, thus forming spherical prisms. The Brewster type of stereoscope. Also a reflecting stereoscope using prisms. Often an autotransposing viewer.

Prism diopter.—The unit used in measuring the amount by which a beam of light is deviated by passing through a prism. One prism diopter deviates one unit in 100.

Projection gage.—A film gage to facilitate mounting stereo films with the correct separation to compensate for various ranges of deviation.

Pseudoscopic.—The effect of untransposed stereo images. Depth values are reversed with far objects seen nearby and vice versa.

Pseudostereoscopic.—A "stereogram" made up of two identical images. As there is no parallax, no stereo relief is seen. Such pseudostereograms have actually been marketed as stereograms.

Realist (Trade name).—A widely popular 35mm stereo camera. Also generic name for a projector, viewer and other 35mm stereo accessories made by David White Company.

Separation.—Stereo parallax results from the existence of two optical (visual) stations. The distance between these is the separation. Normal ocular separation is assumed to be 65mm, but in fact varies widely through several millimeters upon each side.

Slide.—Common name for the stereogram.

S. commercial.—Stereograms made for sale to the general public rather than for private use.

Sliding base.—A camera base, usually tripod head, which enables a conventional camera to be moved laterally 65mm so that stereo negatives may be obtained by successive exposure.

Space control.—A method of stereography in which objects can be given an apparent position in space which is not the natural one. A miniature human figure for example can be posed upon a tabletop with every appearance of realism.

Spreader.—A stereogram with unit images too far apart necessitating divergence of the optic axes, painful at best and impossible for most.

Stereo.—Abbreviation for stereoscopic, also as prefix for many compound words.

S. book.—A book illustrated by stereograms.

S. calisthenics.—Exercises for the eye muscles obtained through viewing special stereograms. Intended to produce visual comfort and skill rather than to relieve definite visual malfunctions.

S. chromatism. — The extrinsic depth factor provided by the alteration of chroma and saturation of color with distance. Of vital importance in reproducing stereo depth.

S. copier. — A special support for the stereo camera in making copies of other stereograms and in photography of small objects.

S. diplopia.—The diplopia or double image vision normal to all objects outside the macular field, in stereoscopic vision.

S. drawing.—See Drawing.

Stereogram.—The "picture" used in stereoscopy. Two images either separate, side-by-side, superimposed or integrated.

Stereogrammetry.—A specialized form of stereoscopy used for making stereograms which are used as a basis for measurement rather than for visual examination.

S. Guild.—An international association of stereographers which circulates collections of 35mm stereograms among members.

S. infinity.—That distance beyond which stereo relief can no longer be distinguished. Highly variable. As little as 50 yards for some individuals and as much as 1½ miles for others. Normal average 670 meters or roughly three-eighths mile.

S. macro bench.—See S. copier.

S. macrography.—The stereoscopic photography of small objects at magnifications of -5 to $+10$ magnification.

S. micrography.—The stereoscopic photography of small objects at magnifications in excess of ten diameters.

S. microscope.—A compound microscope, usually of the Greenough type which gives a stereoscopic field.

S. mount.—A physical support for the stereo pair. Usually cardboard in the case of paper prints. Of cardboard, plastic, metal or glass or combinations of these materials for the 35mm films.

S. prism—(A). The free vision stereoprism is a stereo novelty in the form of a cubical solid in which a stereo image is seen. Improved by HCM through introduction of distributed critical angle. (B). A stereo reflector or element thereof, using prisms instead of mirrors.

S. projector.—A projector used for projecting stereograms upon a screen in such a manner that they may be viewed in relief.

S. radiogram.—An X-ray stereogram.

S. relief.—The appearance of solidity, roundness and space seen in the stereogram.

S. Society.—An international (British) organization of amateur stereographers which circulates collections of stereograms among members, primarily of the 3x6-inch paper type.

S. synthesis.—The subjective process by which the stereo image is built up from the two dissimilar planar images transmitted to the visual centers from the two eyes.

S. Tach. (Trade name).—A device to produce stereograms with an ordinary camera.

S. telephotography.—Telephoto stereoscopic photography. Applied loosely to any stereogram made with long focus lenses, but can be correctly applied only to parastereograms.

S. telescope.—An instrument invented by Helmholtz which provides a magnification of relief rather than the magnification of size common to the conventional telescope. The Battery Commander's binocular (scissors type) combines the double telescope and the stereo telescope.

S. therapeutics.—The treatment of visual disorders by stereoscopic methods. In wider sense it includes stereo calisthenics and diagnostic stereoscopy.

S. typogram.—An artificial stereogram produced by differential spacing of printer's type, notably ornaments.

Stereography.—In this field, identical with stereoscopic photography.

Stereomatics.—The art of planning and exposing a series of stereograms in such a way that they will tell a coherent story. The planning of a series of stereograms of definitely related interest and in definite sequence.

Stereopsis.—Stereoscopic vision. The ability to perceive depth visually, and specifically the degree to which such perception is possessed.

Stereopticon.—This word is included to point out the fact that it has absolutely no relationship of any kind with any phase of stereoscopy although it is commonly used when "stereoscope" is meant. Actually, a stereopticon is a dissolving lantern slide projector as used for projecting song slides in the old nickelodeon days.

Stereoscope.—A device or instrument used for viewing stereograms. Not ordinarily applied to the colored or polarizing filters used with anaglyphic stereograms.

American S.—The Holmes (or Mexican) open type of viewer.

Bates S.—Bates took over the very crude Holmes skeleton viewer and produced what was substantially the same parlor viewer which we know today.

Box S.—The enclosed type of viewer. European type.

Brewster S.—A viewer incorporating two half lenses which thus form spherical prisms, mounted base out.

Brumberger S.—Plastic, self illuminated viewer for 35mm stereograms.

Busch S.—Plastic, self illuminated viewer for 35mm stereograms, specifically those made in the Verascope F-40.

Cabinet S.—A stereoscope built as a piece of furniture; a finished cabinet enclosing the automatic or semi-automatic mechanism.

Holmes S.—Open type Brewster viewer, also American or Mexican.

Mattey S.—The firm of Mattey of Paris is one of the few which makes viewers exclusively in all grades from folding cardboard viewers to the finest inlaid wood models of automatic classifiers.

Mirror S.—Usually the Wheatstone or Pulfrich type of viewer.

Pedestal S.—An automatic cabinet viewer placed upon a cabinet pillar or pedestal which forms a cabinet for the slide collection. Either one or two piece.

Pocket S.—Folding stereoscope for carrying in the pocket. Usually of inferior quality.

Pulfrich S.—A small viewer of the Wheatstone type for tabletop use. See Ryker.

Realist S.—Plastic, 35mm viewer self illuminated. Companion to the Stereo Realist camera.

Reflecting S.—A viewer of (A) the general Wheatstone type or (B) an auto-transposing viewer.

Richard S.—Companion viewers to the Verascope cameras, usually self transposing type in 35mm sizes.

Ryker S.—A tabletop stereoscope of the general Wheatstone-Pulfrich type but equipped with magnifiers for the study of detail. Military-aerial instrument. One of the best examples of the Wheatstone type.

Stereo-Vivid S.—Self-illuminated plastic viewer, companion to the Stereo-Vivid camera. 35mm.

Transposing S.—A viewer which by an arrangement of reflectors or a refracting system makes it possible to view stereo images which have not been transposed. Used with film-strip stereo views.

3D S.—This is actually a "viewer" rather than a "stereoscope" inasmuch as it consists of a pair of goggles equipped with polarizing lenses. Used to view stereo projected pictures, Vectographs and the like.

Universal S.— (A) A viewer which may be used either as a normal or as a Brewster instrument. (B) A viewer, such as a classifier, which will take a variety of sizes of stereogram.

Wheatstone S.—A viewer which uses separate stereo units, usually facing each other, which are viewed as reflected images. Largely used for stereo X-ray and large print stereo.

Stereoscopic.—Having to do with stereoscopy.

S. balance.—A term used in stereo composition in differentiation from the pictorial balance of a plane surface.

S. camera.—A camera used for making stereoscopic negatives or images, specifically a dual chamber camera.

S. vision—Normal, binocular human vision is stereoscopic. Many beginners seem to think that "stereoscopic" applies only to stereo reproduction. Stereoscopic vision is normal, everyday vision enjoyed by most of us.

Stereo-Vivid.— (Trade name, also T.D.C.) Generic name for a polarizing stereo projector, a 35mm stereo camera and a companion 35mm stereoscope, made by the Three Dimension Company.

Subjective.—In stereo, the final step of stereo perception, the consciousness of the image, the actual step of "seeing" as opposed to the purely physical, physiological and neurological steps.

S. anomaly.—The failure of subjective interpretation to conform to stereo theory. Two identical prints (pseudostereoscopic) mounted as a stereogram when viewed in the stereoscope should appear as images of gigantic size located at infinity. In fact there is no such appearance at all. There is no depth of any kind or degree visible. There are many such effects which can be predicted but which rarely are experienced as a part of the subjective interpretation.

S. stereo.—That part of stereoscopy which has to do with the interpretation of stereo synthesis; the actual "seeing" as contrasted with geometric and physiological stereoscopy.

Televiewer. (Trade name).—Stereoscope of Brewster type in metal construction.

3-D.—Popular abbreviation for Three Dimensional. Also polarizing goggles made for viewing projected stereograms and Vectographs.

Three dimensional.—Having an appearance of depth or solidity, but not necessarily of stereoscopic quality. Monocular viewers give a three dimensional but not a stereoscopic appearance.

Telestereoscope.—This is a viewer which resembles a pair of opera glasses and is used for the examination of large size stereo pairs, (aerial, X-ray and the like) or stereo pairs projected side by side. Fusion is accomplished through the use of rocking prisms.

Twister.—A stereogram so mounted that the eyes are strained in trying to view it.

Unit magnification.—The principle which states that any photograph should be viewed from a distance equal to the focal length of the taking lens. When extended to stereo this principle becomes that of orthostereoscopy.

Vectograph.—A stereogram made by placing polarizing images upon both sides of an optically active base. Viewed with polarizing goggles.

Verascope (Trade name).—Generic name for cameras made by Jules Richard of Paris, also extended to the 35mm model.

Verascope F-40.—An improved 35mm Verascope camera distributed by Busch Camera Corporation.

Videon.—A 35mm stereo camera.

Viewer.—See Stereoscope.

Anaglyphic V.— (A) A mask or goggles containing two differently colored lenses or filters for viewing bichrome anaglyphs. (B) A similar device containing polarizing filters set at 90 degrees to each other for viewing polar anaglyphs.

Flicker V.—A hand held shutter for viewing flicker projected images.

Viewmaster (Trade name).—Small stereoscope for viewing specially mounted 16mm stereograms. Including those made with the Sawyer Personal camera.

Window.—In a stereoscope the stereogram appears as if seen through a window. The "window" which may be a mask or simply the way the unit prints are trimmed, may be placed in any desired plane; but it is usually placed nearer the observer than any other unit of the picture.

Appendix C

FREE VISION FOR ILLUSTRATION

Although the subject of free vision has been explained in this volume, we wish to present, at the risk of repetition, a resumé of practical free vision as it can be learned by anyone interested in acquiring a new and fascinating visual skill.

The illustration of books and periodicals by three dimensional photographs and drawings would enormously enhance the value of all illustrative material. Now that color reproduction is commonplace, the use of color stereograms would approach the ideal. In fact, the desirability of the process has been recognized for years. The only fact which has been ignored is that a fully practical process has been available for years. One which demands no more than three or four periods of 10 to 15 minutes for its complete mastery.

It is not necessary at this time to review the theory and methods which already have been presented in this book. It will be recalled that the process involves:

(1) Printing the normal stereogram by any of the conventional processes of reproduction.

(a). Transposed stereograms

(b). Untransposed stereograms

Either (a) or (b) to have a homologous separation not exceeding 60mm.

The transposed stereograms are more difficult to see without benefit of viewer. It would be more accurate to say that this method is the more difficult to learn. Once mastered it is as easy and natural as reading.

The use of untransposed stereograms (b) offers the easy method so far as learning is concerned, but whereas (a) leads to a visual relaxation which is restful, method (b) demands a greater-than-normal degree of convergence and tends toward increasing a presently unpleasant national condition, namely, a tendency toward "squint" (cross-eyes) which is already aggravated by our habits of continued close vision.

It would be far easier to initiate method (b), but if criticism and future trouble are to be avoided, it is definitely advisable to standardize upon method (a).

Introduction.—For some time, perhaps as much as a year or more, it would be necessary to carry a small "box" in each issue of a publication which would briefly explain how the ability to see the three dimensions may be acquired. But if two or three national publications were to make a practise of running a single page of stereos in each issue, public demand would not permit them to be abandoned after a year.

Learning.—General training would present difficulties. Elderly people would have more difficulty than young ones. Because ophthalmologists still differ as to the value of stereo, there would be professional opinions, pro and con. Many people, feeling the strain which accompanies the initial divorce between accommodation and convergence, would be convinced that their eyes were being injured. As a matter of interest, I had to change ophthalmologists not long ago because the one I had insisted that my "lack" of normal co-action between accommodation and convergence was pathological and insisted upon treatment to restore it. I patiently told of the trouble I had taken to achieve it, and was then told I had probably ruined my eyes! I went to another, and considerably better qualified man and he laughed at the idea. He told me that a number of his colleagues were bitterly opposed to any form of stereo and even refused to use the professional instruments based upon stereo principles. He agreed with modern stereo researchers that stereo skill is valuable and well repays any slight difficulty incident to acquiring it. He then pointed out that my range of vergence was considerably greater than would be expected in a patient less than half my age, with presbyopia considerably delayed.

Method.—There is perhaps no better method than that of using the mask to start with. If the two eyes cannot converge upon a common point, they will try to fuse the two similar images even under unusual conditions of convergence. I have found the greatest success in teaching stereo viewing by starting with small pictures with 20mm separation, and gradually substituting others of increasing separation until 60mm was reached. This is the end point, because there are many people who have less than 65mm interpupillary. The individual with widely spaced eyes can view the narrow stereogram comfortably; but the one with closely set eyes cannot see the wide stereogram except by painful divergence.

The worst obstacle is the seeming impossibility of the thing at first. Try as one will, the fused image is out-of-focus, or the sharp image is seen double. It is best to let the focus (accommodation) go and learn to hold fusion. With fusion locked, accommodation is tried. The images fly apart, and one starts over again. Repetition and more repetition slowly brings results. When the 20mm picture can be held and focused the battle is over. Spreading the ability to wider and wider separations is a matter of a little practise. The big difficulty comes in holding the first 20mm picture.

Just how practical is it?

My wife was mildly irritated because I would glance at stereograms without a viewer and comment upon them. She wanted to see "if it were possible." You will find this skepticism quite common. Although at that time she was not particularly interested in stereography, I undertook to teach her. It required five periods of five minutes each, with five minute rest periods between. At the end of that time she was fusing and focusing a normal 6x13 stereogram. (No graded series was available at the time.) Since that time there are intervals of six or eight weeks during which she has no occasion to use the ability, but when it arises she views the stereogram as easily as a page is read. Not only that, but she fuses a standard 3x6 paper print with homologous separation up to 80mm! The latter I find difficult, but she does it easily. And her vision is excellent.

Similar results have occurred in teaching a number of students the same skill. The time varies, but once the first free fusion has been accomplished the rest follows easily; the acquired skill is permanent and general visual comfort is usually increased in that headaches from visual fatigue and the like are less common, "tired eyes" almost unknown and the ability to consciously relax convergence gives the physical comfort incident to relaxation of any muscles.

Problem.—The single problem is to persuade any publisher that the thing is feasible. He is sold on the stereo idea, he can learn it himself but he cannot be persuaded that his readers share his own ability to acquire the skill.

When the time comes that one or two courageous publishers make a serious attempt to introduce this natural type of free vision stereo, publishing will experience the greatest revolution it has known since the invention of the typesetting machines.

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