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Introduction

The world around us is three-dimensional. The human eye depicts a picture on the retina (this picture is laterally and vertically reversed) and thus compresses all subjects into one plane although they are actually echeloned in depth. Drawings, paintings and photographs are two dimensional representations of the same type. Experience has shown that this type of picture of our surroundings is sufficient in most cases to give us an idea not only of dimensions in one plane but also of the impression of depth. This is particularly so, since painters and photographers, etc., have at their disposal various factors (such as perspective, illumination, colour, etc.) which, properly used in suitable cases, enhance the illusion of spatial recession.

The illusion of depth, as perceived also by one-eyed people in the open, unless they move their head or eyes is not, however, always sufficient for the recognition and evaluation of the spatial shape, arrangement and situation of objects. It may be misleading (optical deception), especially if the brain is unable to make comparisons with other values experienced previously. There are, for instance, many photographs of surgical operations, the uncertain perspective of which frequently causes insurmountable difficulties. Such experience, repeatedly mentioned in the relevant literature, will sometimes be made by our readers in their own photographic work.

However, man has *two* eyes, each one of which gives a slightly different view of a scene due to the interpupillary separation. Despite this fact, the brain, to which these different images are conveyed, will produce the impression of a single, but three-dimensional image. The two images on the retinas are unconsciously fused in the brain to produce this "stereo-scopic" impression. If, in binocular viewing double pictures are seen, there will be a visual disturbance, usually called "fusing disturbance".

The interpupillary distance of the human eyes is called the base. It differs, according to race, sex or age, between 55 mm and 75 mm. On the average it is 65 mm.

The *perception* of depth with *two* eyes, in contrast to the *conception* of depth with *one* eye – as long as excessive distances are not involved – is extremely impressive and remarkably acute in the discrimination of differences in depth. Even under most critical conditions the perception will always give accurate results.

Sir Charles *Wheatstone*[1] established the fact that the brain can, in the same way, fuse to a three-dimensional impression perspectively different two dimensional representations of bodies if such dissimilar representations, the so-called stereoscopic pairs (or the two half-images) are presented separately to each eye. This knowledge made him the promoter of stereo-photography.

Unfortunately, stereo-photography is not used nowadays in research and education to that degree that might be expected from its extraordinary efficiency in this field. The reason for this negligence, however, may not lie in ignorance of its usefulness, but rather in a most remarkable timidity in employing it on account of its ostensibly difficult operation.

Once this reluctance was certainly justified, but it is rather obsolete nowadays, since the ZEISS IKON stereo-systems have been introduced and rendered stereo-photography as simple as normal flat-photography, as will be shown in the following articles.

Stereo-photography is also most attractive for the amateur, a fact which is obviously not so well-known in Europe as in the U.S.A., where stereo-photography has become immensely popular during recent years.

The Meaning and Importance of a Stereo-System

Stereo-photography has its own laws and principles which exceed by far those of "single-eyed" photography. Adherence to these principles is the basic prerequisite for success in stereo-photography and is indispensable from the moment the picture is taken until it can be examined in the viewer or on the screen.

A satisfactory impression of space, when viewing stereoscopic pairs, can be conveyed to the brain only under the following conditions:

The half-images should be taken so that they convey a different perspective to the viewing eyes as with the normal vision. The actual or apparent distance between the two lenses of a stereo-camera is called the "taking base" (fig. 3 and 4). Normally it is equal to the average interpupillary distance. In special cases, however, it can be altered. Increasing the taking base will exaggerate the impression of depth, decreasing it will prevent exaggerations of close subjects.

The half-images should be conveyed to the eyes "correctly", that is to say, the left half-image only to the left eye, the right half-image only to the right eye.

The half-images should be conveyed to the eyes laterally and vertically correct.

The half-images should be conveyed to the eyes at the correct interpupillary distance.

The half-images should be free from errors in vertical alignment.

The difference in depth between the nearest and the farthest object point in the stereo-picture should be limited.

The framing of the picture should be adapted geometrically to the content of the picture, so as to produce the effect of looking at the subject through a window (imaginary window).

There are two possible ways to fulfil these indispensable demands, which are dictated by

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[1] 1802—1875, Professor of Natural Philosophy at King's College, London.

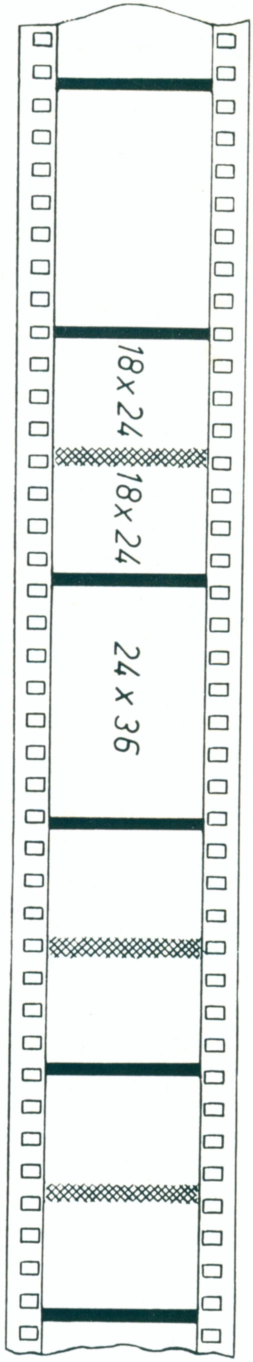
the laws of Nature. Either it is left to the care, the skill and the patience of the photographer to make his stereo-pictures in such a way as to correspond to these principles, or the whole task is entrusted to the devices and accessories available for the taking, processing and reproduction of stereo-pictures. All components serving this purpose must, of course, match; be it a complex camera, an attachment or only a tiny mask, they all must be carefully mated and combined in a "system".

(According to "Meyers Lexikon", 1929)
SYSTEM *(Greek "set of connected things"), organised body of components or several things arranged according to a definite viewpoint, in order to work together.*

It is possible, and permissible, that one or other of the components can be used in two or more stereo-systems. Designing such simplifications of a system is one of the many problems the skilful designer has to solve in order to lower the price of the single component and of the whole system. The idea of a "stereo-system" was used for the first time in connection with a range of stereo accessories for the CONTAX and a few devices belonging to the same range, and has also been defined in this journal[2]. A stereo-system such as this is, according to Vierling, a series of "suitably matched devices for stereo-photography, which automatically meet the fundamental demands of stereoscopy, particularly as far as mounting and evaluating the pictures are concerned, without the photographer's own efforts".

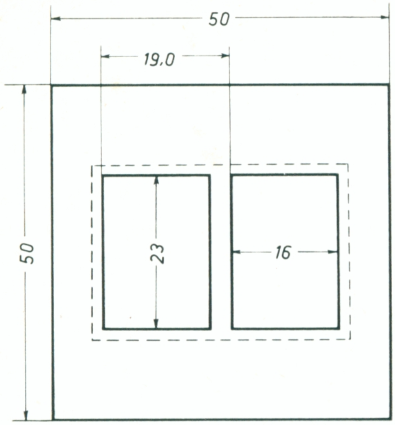
A "stereo-system" is, therefore, principally designed to replace the often difficult technical operations of binding stereo-pictures by suitable devices which simplify stereo-photography to such an extent that it is almost as easy to perform as normal photography and leads to an almost complete automation of the proceedings.

Fig. 1



Film strip with alternating normal miniature 24 × 36 mm exposures and miniature stereo 2 × (18 × 24 mm) exposures.

Fig. 2



Arrangement of the 24 × 36 mm miniature format for the purpose of taking stereo-pictures, according to standard specification DIN 4531, Sheet 2.

Fig. 3

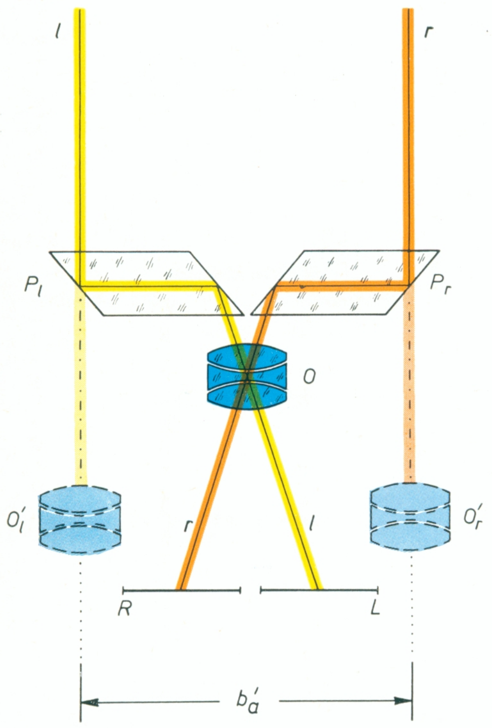


Diagram of a mono-lens stereo attachment. The base prisms P_l and P_r produce two images O'_l and O'_r of the lens O at the apparent and effective horizontal distance (= taking base) b'_a.
By the crossing of the paths of rays l and r within the lens O transposed half-images are created, the right-hand half-image lying to the left of the left-hand one.

This series of matched groups of devices for stereo-photography is presented in the CONTAX stereo-system, the CONTAFLEX stereo-system and the CONTINA stereo-system. These systems are, however, more or less intermeshed and the same elements can be used for various purposes, such as masks, viewers and stereo-attachments for projectors.

The CONTAX stereo-system, as the most advanced with regard to its possible applications, is particularly suitable for scientific and technical use, but can also be employed by amateurs, of course, whilst the other stereo-systems are designed primarily for amateur photography.

The Arrangement of the Half-Images: One-ring (O) and Two-ring (OO) Stereo-Pictures

Cameras for taking pairs of stereoscopic pictures may be special designs and used exclusively for this purpose. However, stereo-taking devices can be made also as supplementary attachments to normal cameras, as, for obvious reasons, is the case with the devices of the ZEISS IKON stereo-systems. The stereoscopic half-images then simply occupy the space of the standard miniature format, being 18 × 24 mm² in size within the nominal 24 × 36 mm² format. With the ZEISS IKON stereo-systems the two vertical-format half-images are placed directly adjacent to each other and *remain always connected to one another when mounted*. This is, without doubt, a great advantage and makes the automation of picture production much easier. Stereo pictures can alternate immediately with flat pictures, so that there is absolute freedom in using the camera for stereo or flat pictures (fig. 1). The division of the 24 × 36 mm² format has, in the meantime, been determined by standard specification DIN 4531, sheet 2 (fig. 2) so that no departure from these measurements by individual makers is possible.

According to the design of the basic camera (CONTAX, CONTAFLEX, CONTINA) and their stereo-attachments, every half-image is produced either by its own lens or both half-images are photographed with one common lens. The reproduction by two lenses of identical design is, of course, much more accurate and versatile, but also considerably more expensive. Furthermore, it is possible only with cameras with interchangeable lenses (CONTAX). With a camera with a fixed lens (CONTAFLEX, CONTINA), the standard lens is also used to produce both the stereo-half-images. This makes the additional attachment less expensive, but does not allow the standard focal length to be adapted to a stereo-format which is only half the size of the standard format, as is possible with the two lenses built into a special twin-lens stereo-attachment.

The essential difference between the stereo-half-images taken with one *common* lens only in comparison with those taken with two *special* lenses, however, is their position relative to each other. According to fig. 3, showing the design and the path of rays in a single-lens stereo-attachment, the paths of rays are crossed and the half-images "transposed", that is to say, the image taken with the left half of the common lens is to the right of the other half-image and vice versa. The half-images are interchanged.

With a device similar to that shown in fig. 4, illustrating the design and the path of rays in a bi-lens stereo-attachment, this crossing of the rays does not occur; the picture taken with the left-hand lens is also on the left-hand side of its companion on the film and vice versa. The half-images are "untranspos-

Fig. 4

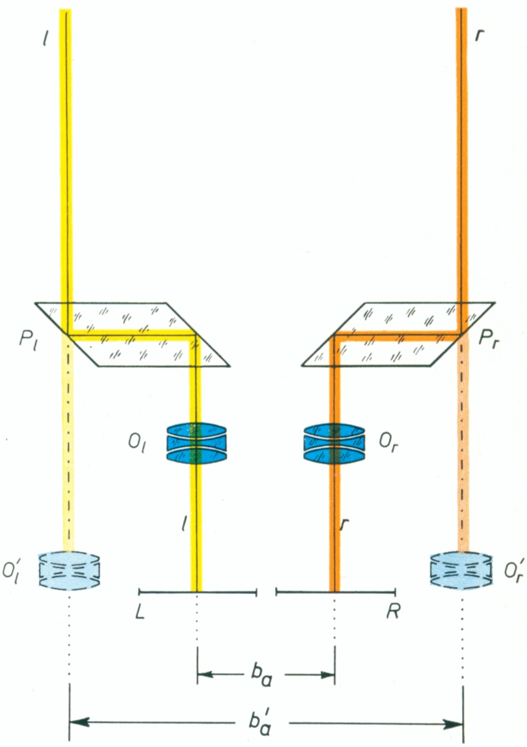


Diagram of a bi-lens stereo attachment. The base prisms P_l and P_r produce one image O'_l and O'_r of each of the lenses O_l and O_r, the actual horizontal distance between which is b_a, whilst the apparent and effective horizontal distance is b'_a. Since the paths of rays l and r do not cross the half-images are not transposed, the left-hand half-picture lying to the left of the right one.

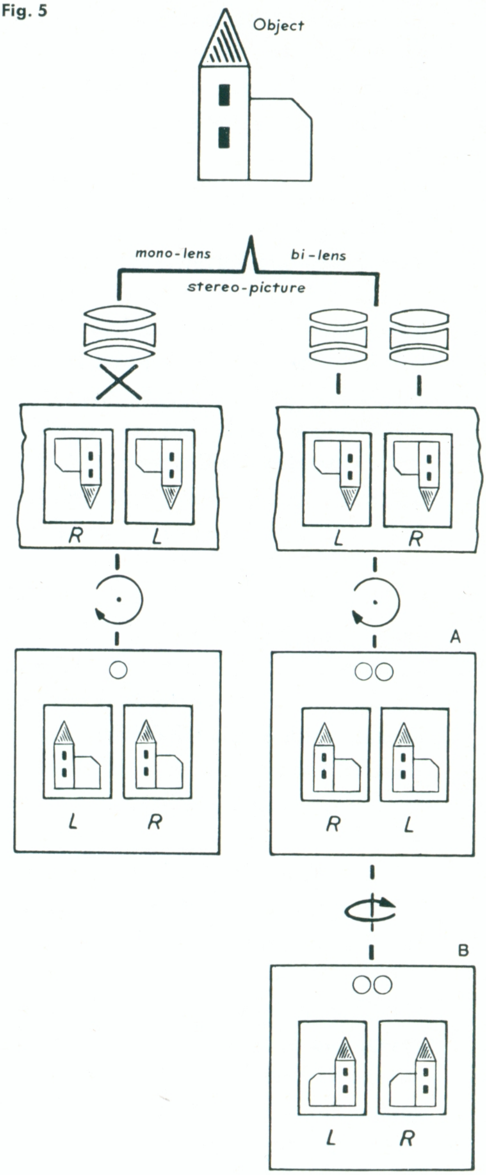
ed". Now, these pictures on the film are, like any other photograph, laterally and vertically reversed. According to the rules they should, however, be presented to the eyes so that the half-image seized by the left pupil, that is the left-hand half-image, should be seen only by the left eye and the right half-image only by the right eye; furthermore, the pictures should both be laterally and vertically correct. The diagram fig. 5 shows how the two types of pictures meet these demands. It is naturally assumed that the two half-images are arranged side by side on a common film base and must not be separated for viewing purposes.

From fig. 5 it is obvious that the pair of half-images taken with a single-lens stereo-attachment can be brought to a correct position by merely turning it within its plane. The left-hand half-image is in front of the left eye, the right-hand one in front of the right eye (correct position with regard to the eyes) and both images are vertically and laterally correct.

However, this is not so with the stereo-picture taken with two lenses. Whatever kind of rotation or twisting may be employed, there are only two different positions possible either A or B, although the half-images are vertically correct. In position A the half-images are laterally correct but the left-hand image is in front of the right eye, the right one in front of the left eye. The position B, however, is the correct position with regard to the eyes, but the half-images are laterally reversed.

This proves that in stereo-photography we have to do with two fundamentally different types of picture. This fact has to be taken into account when viewers and projectors are being designed. On the other hand, the pictures themselves must be marked so that they are used only with apparatus that bears the same markings and are not interchanged.

Fig. 5



The position of the half-images in mono-lens and bi-lens stereo pictures. Mono-lens stereo-pictures (left) can be brought to a laterally and vertically correct position and correctly related to the eyes by merely rotating them in their own plane. Bi-lens stereo pictures (right) are either in a laterally and vertically correct position, but correlated to the wrong eye (case A) or the correlation to the eyes is correct, but they are laterally reversed (case B).

The Marking of Stereo-Pictures and Stereo-Accessories

The markings for the easy distinction of the two types of stereo-pictures are logical and impress themselves easily on one's mind, since they are merely the obvious symbols for the manner of taking the pictures.
We have suggested the use of small circles as symbols, such as:

- O *one* circle to denote the pictures taken with one common lens (mono-lens), which were hitherto known as "transposed" stereo-pairs, and

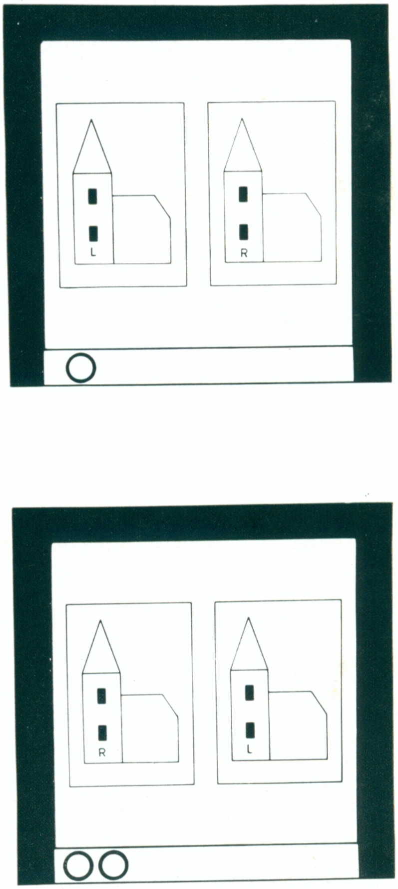
- OO *two* circles denoting stereo-pictures taken with two lenses (bi-lens), hitherto known as "un-transposed" stereo pairs.

This method of marking stereo-transparencies has been published[3] as a standard (DIN 4531, sheet 3) and is shown in illustration 6. However, not only are the stereo-pictures provided with these markings, but also all apparatus belonging to one of the ZEISS IKON stereo-systems. Every stereo-attachment, for instance, shows immediately which type of pictures it will produce and every viewer is marked so as to show for what type of stereo-slides it is suitable.

Lateral Distance of the Half-Images / Standard Gauge

One of the conditions of stereoscopic viewing is to present the two half-images to the eye at their correct lateral distance. In an automatically effective stereo-system this demand can be met only when half-images of all stereo-pairs to be evaluated correspond to one finite distance, the *standard gauge*, and that the measurements of all elements of the

Fig. 6



Suggestion for DIN standard 4531, Sheet 3, for introducing ring symbols on 2″ × 2″ stereo slides to distinguish mono-lens stereo pictures from bi-lens ones. Mono-lens stereo slides should have o n e circle O, *bi-lens ones t w o circles* OO *attached to the spot visible in this diagram.*

stereo-system are based on this gauge and must be guided by it. The most appropriate standard gauge for stereo-pictures of the miniature format has been found (in the development of the CONTAX stereo-system) to be 19.0 mm, which has also been acknowledged as a DIN-standard[4]. The near points of all half-images of every taking range must, therefore, be separated by 19.0 mm. The taking attachments of the ZEISS IKON stereo-systems ensure this automatically by means of a special control of the path of rays, as long as they are not used below the shortest taking distance recommended.

The Condition of Depth

According to the rule, the human eyes can only survey at the same time a range of depth which, in angular measurement, does not exceed very much an angle of 70 minutes[5]. If this is not the case stereoscopic viewing is impossible on account of fusing disturbance.

This applies also to the viewing of stereo-pictures. The standpoint of the viewer or the position of his eyes with regard to the stereoscopic half-pictures and to their depth, must be arranged correspondingly. It is quite obvious that the range of depth embraced by a stereo-photograph will increase when the taking base is shortened and decrease the closer the camera approaches the object. Thus we are able to increase the range of depth embraced by the human eye by shortening the taking base in the close-up range.

The Stereo Window

The stereo-photograph as well as the flat photograph has a sharp boundary line, a frame. For the flat photograph this frame has the simple purpose of providing an aesthetic termination; in the stereo-photograph, however, it appears to stand out in space bodily, preferably in the shape of an "imaginary window". It is advisable, therefore, to make this frame so that, in a normal stereo-photograph, all objects appear as if seen through a window and *behind* it. With a few exceptions any different presentation of a stereo-photograph will convey an unnatural effect. With the ZEISS IKON stereo-systems, this effect is obtained by the employment of the special stereo mask (fig. 20) into which the piece of film with the inter-related pairs of half-images are simply inserted. This mask is calculated so that the corresponding lateral edges are accurately spaced apart by the standard gauge = 19.0 mm (see also fig. 2). The corresponding portions of the frame and the images of the near points of every taking range thus have the same lateral distance between them, that of the standard gauge of 19.0 mm. Since the lateral distance of related image points determines the spatial position of the stereoscopic image point, the near points of every taking range appear *automatically* in the plane of the imaginary window. All other image points in the taking range thus appear also automatically behind the imaginary window.

Reproduction

Miniature stereo transparencies can be reproduced by projection and thus convey the three-dimensional impression to many viewers at the same time; the pictures can also be viewed individually by using a stereo-viewer (stereoscope).

In order to convey to the observer a correct impression by means of a stereo-picture the conditions listed on page 3 have to be adhered to strictly. Strictly speaking, the half-images should be arranged so that every object in them is seen from the same angle, as it is seen with the unaided eye in real life.

The position in space of an object point in a composite image (fig. 7) – for instance – the point "M" is determined by the lateral distance between its disparate points M_l within the left and M_r within the right half-image. The left eye A_l, when viewing a stereo-picture, is directed to the point M_l in the left half-image, the right eye A_r simultaneously being directed to the corresponding point M_r in the right half-image. The lines of vision A_l M_l and A_r M_r are apparently extended until they intersect in point M. This is the position assigned to the point in space M by the visual perception. In the same way, every other point which forms the stereo-picture is assigned to apparent positions. The closer any pair of adjacent image points of the half-images (N_l N_r) are to each other, the closer (N) they appear to the viewer and vice versa. The greatest possible distance between any two half-image points (F_l F_r) is equal to the interpupillary distance, that is about 65 mm. At the interpupillary distance the lines of vision of the two eyes become parallel and make the point in space (F) concerned, appear at infinity. The position of the nearest point (N) is determined by the conditions of depth and is automatically fixed in the ZEISS IKON systems by the corresponding rating of the taking ranges.

These interrelations are also fundamental to the *individual* viewing of a stereo photograph by one observer as well as to the viewing of a projected stereo picture by *several* observers, although a "correct" three-dimensional impression, strictly speaking, can be conveyed only to one individual observer. All the other observers, according to their standpoints, see what is actually a more or less distorted 3-D picture. These distortions, however, with the exception of extreme cases, are seldom disturbing.

Fig. 7

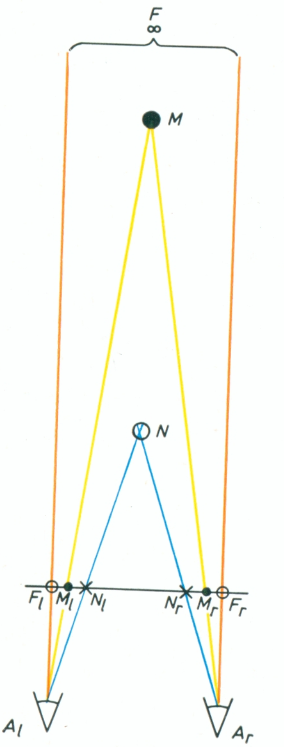


Diagram of the three-dimensional representation obtained by viewing stereoscopic pictures.
The brain "places" the apparent pictures where the lines of vision of the left and right eyes cross.

One-circle (O) stereo-pictures taken with standard cameras and stereo-attachments result in an unavoidable, trapezoidal distortion of the half-images, which may sometimes be a little disturbing. This distortion is due to the required controlled path of rays. In projection this could theoretically be corrected fundamentally and quite easily by a reversal of the taking-path of rays; but this cannot be realised in actual practice on account of the severe difficulties in the projection technique connected with it.

For the IKOLUX models 150, 300 and S 300 a new mirror stereo-attachment for all existing focal lengths will be available soon, the distortion-correcting effect of which will be better the closer the focal length of the projection lens approaches 50 mm (see Chapter IV, A. C.).

Another possibility of distortion has been found for O-stereo viewers, which gives practically total correction in all cases. It is described in Chapter VI. B on page 218 ff under "Stereo-Viewers".

Stereo-Projection

The chief problem of stereo-projection is to reproduce the half-images in a way that they are viewed separately and correctly by each eye, as, for various reasons, they have to be superimposed upon each other on the screen.

There is an excellent method of achieving this which has been well-known so long ago as 1891 but practised not before the mid-thirties and which makes use of lineary polarized light[6].

(The employment of right and left circulating polarized light would result in a slight improvement in comparison with lineary polarization, but would be considerably more expensive on account of the need for more costly devices and spectacles.)

Up to a short time ago the polarizing method could no be employed. It was uneconomical and too expensive. A fundamental change was brought about by the invention of the now widely known artificial surface polarizers (polarizing screens). The projection beams which produce the right and the left half-image on the screen are polarized differently so that the directions of vibration of the two polarized beams are rectangular to each other. Every observer has to use spectacles or similar devices with two polarizers of the corresponding settings. In the meantime, it has become usual that the directions of vibration of the spectacle-polarizers are being inclined through about 45 ° in relation to the horizontal so that they form a V (V setting) with each other. This setting also determines the settings of the polarizers in the projectors. This differs by 180 ° in the O and OO stereo pictures.

On account of the interaction of the two polarizers, each of parallel and crossed directions of vibration, which may be regarded as generally known, the spectacles (in conjunction with the correctly set polarizers in the projector) act as a light dividing filter, guiding the right-hand half-image to the right eye only and the left-hand half-image to the left eye.

Screens

Stereo projection with polarized light is, however, possible only if the screen, an important element between the spectacles and the projector, has the properties to maintain the polarizing effect. This is the case only with screens with metallic surfaces (for surface projection) and some ground-glass screen and matted foils (for back-projection). Standard white or beaded screens are unsuitable, since they alter the polarizing effect on light or destroy it. The "silver screens" as well as the translucent matt surfaces have a distinctive "directional effect" on the reflected light. For this reason centrally-viewing observers will see very bright pictures, whilst the brightness is considerably reduced at the sides. When arranging seats for observers of stereo-projection this fact should be taken into account.

The screen is an important element in stereo projection and should be chosen with the greatest possible care.

Viewing through a Stereoscope

If the viewer used is in accordance with the above-mentioned rules (Chapter IV. B), special instructions for viewing stereo-pictures are unnecessary.

The Various Devices of the ZEISS IKON Stereo-Systems

By Dr. Otto Vierling, Stuttgart

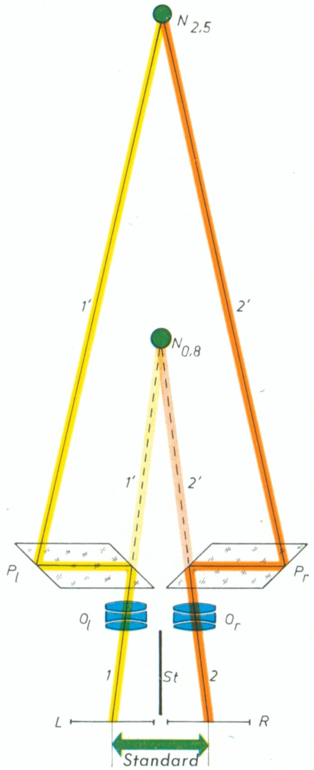
I. Taking Attachments

Taking Attachments, producing OO-Stereo-Pictures

The STEREOTAR-C for the CONTAX

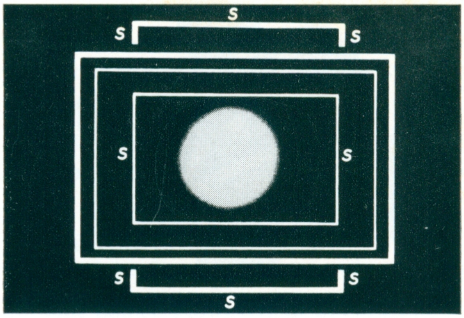
The optical design of the stereo-attachment for the CONTAX is shown in Diagram 8. The half-images L and R lie on the film separated from each other by the "standard gauge" = 19.0 mm. The half-images are produced by the two lenses O_l and O_r, which are two 35 mm, f/3.5 STEREOTARS. Their paths of rays are separated from each other by means of a built-in separator plate St. The actual distance between the lenses is 18 mm. In order to obtain a taking base corresponding to the interpupillary distance, two rhomboid prisms P_l and P_r are used in front of the lenses for "normal" exposures. The prisms deflect the paths of rays laterally and make the lenses appear to be at a distance of 62 mm from each other. Thus the apparent and consequently effective taking base (see fig. 4) is 62 mm. The permissible range of depth (according to the principle of depth) will then extend from infinity to approx. 8 ft (2.5 m). The "base prisms", which are assembled in a common casing, can be removed from the lenses, however. This makes effective a taking base of 18 mm for the double-lens alone. This is of the greatest advantage in the "portrait-range", since all exaggerations in depth are avoided, and also in the "close-up range" where the exaggerations in depth are reduced considerably. This reduction of the taking base has also

Fig. 8



STEREOTAR attachment for the CONTAX. Diagram of the optical design and the path of the light-rays. The near points N of each taking range ($N_{0.8}$ for portrait range, $N_{2.5}$ for the normal range) are depicted on the film at the standard gauge of 19.0 mm.

Fig. 10



The image framing in the CONTAMETER *optical near focusing device. The image field S indicates the stereo format.*

Fig. 9

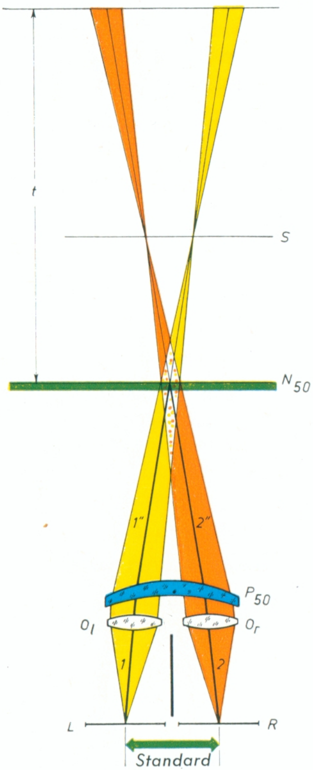


Diagram of the path of rays in the STEREOTAR *attachment in conjunction with an ancillary lens. The convergent connecting lines 1, 2 from the centres of the half-images to the lens centres are deflected by the ancillary lens P_{50} in such a way that their extensions 1″ and 2″ converge in the plane N_{50}. All image points lying in the convergence plane N_{50} thus are depicted on the film in accordance with the standard 19.0 mm gauge. Five more ancillary lenses $P_{30, 20, 13, 9, 6}$ of different refractive powers result in five more focusing planes $N_{30, 20, 13, 9, 6,}$ in the same way. The plane of sharp definition is at S.*

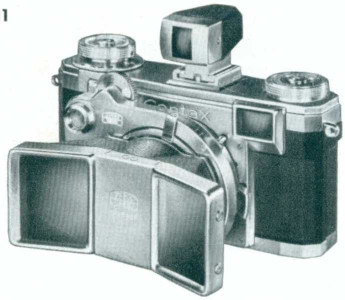
another advantage in so far as the "allowed" range of depth is now extended from infinity to approx. 31½ in. (80 cm).

The diagram (Fig. 8) shows, furthermore, that the beams (1 and 2) which connect the centres of the half-images with those of the lenses converge, when extended (1′ and 2′) in the points of convergence $N_{2.5}$ or $N_{0.8}$. In which of the two points they converge depends on whether the STEREOTAR-C is used either with or without the prism attachment. These "convergence points" $N_{2.5}$ and $N_{0.8}$ are, however, the actual starting points of the two taking ranges, which, according to the 70 minutes principle, apply to both the two taking bases of 62 mm (with prisms) and 18 mm (double lenses only), when "infinity" is taken as the starting point. In other words, the near points of each range are automatically depicted on the film with the standard gauge distance of 19.0 mm between the image points in each of the two half-pictures. All objects at a greater distance, however, will be depicted with a *shorter* lateral distance between their two half-images.

Additional Accessories for the STEREOTAR-C for Stereo-Close-ups

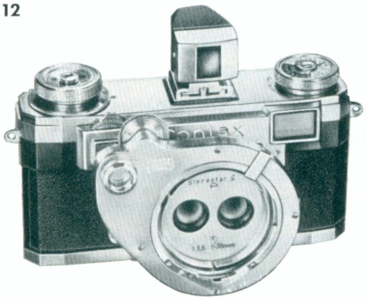
By adding special supplementary lenses, the "Stereo-Proxars", to the STEREOTAR-C it can also be used for close-ups within the range

Fig. 11



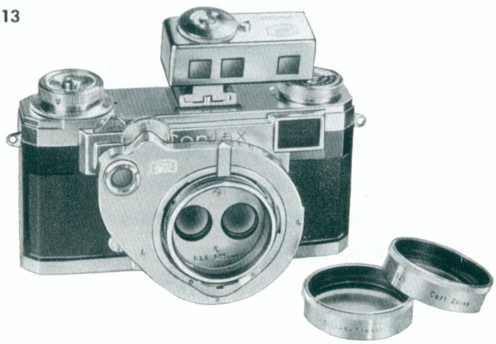
STEREOTAR C, *stereo-attachment for the* CONTAX *and special slip-on viewfinder for exposures within the normal range (8 ft. to infinity).*

Fig. 12



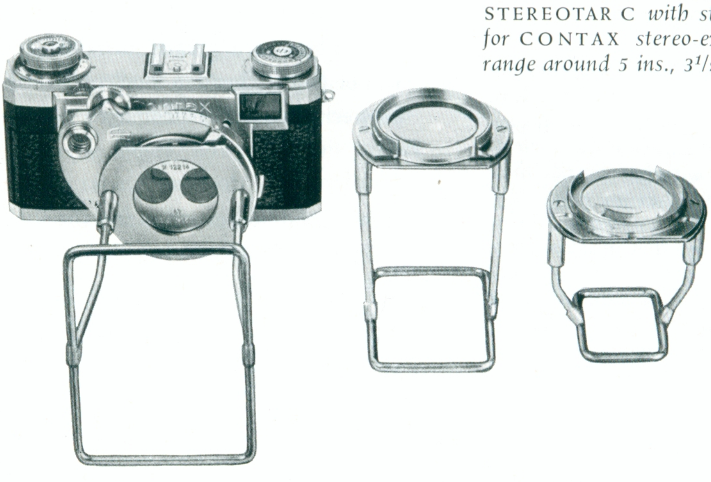
STEREOTAR C *without prism-attachment for stereo-exposures with the* CONTAX *within the portrait range from* $31^{1}/_{2}$ *ins. (80 cm) to 8 ft. (2.5 m) and more.*

Fig. 13



STEREOTAR C *with stereo-Proxar lenses and* CONTAMETER *view/rangefinder for* CONTAX *stereo-exposures within the close-up range around 20 ins.,* $11^{3}/_{4}$ *ins., 8 ins. (50, 30, 20 cm).*

Fig. 14



STEREOTAR C *with stereo-close-up attachments for* CONTAX *stereo-exposures in the close-up range around 5 ins.,* $3^{1}/_{2}$ *ins.,* $2^{3}/_{6}$ *ins. (13, 9, 6 cm).*

of the CONTAMETER (optical near-focussing unit for the CONTAX), that is, at distances of about 19³/₄", 12" and 7³/₄" (50, 30 and 20 cm) and by adding further "close-up attachments", at distances of about 5", 3¹/₂" and 2³/₈" (13, 9 and 6 cm). These three distances are also automatically included in the system. How this has been achieved is shown in the Diagram 9.

The supplementary lens P_{50} jointly covers both the STEREOTAR lenses O_l and O_r. It is, therefore, effective chiefly in the marginal zones for each stereo-lens. This means that the tendency of a lens to displace the definition is, for both paths of light rays, combined with the effect of a wedge, that of deflecting the rays. As a positive lens it draws the focusing plane nearer. At the same time it deflects the paths of the rays (1 and 2) which connect the centres of the half-images with those of the lenses in such a way that, when extended (1" and 2") they no longer converge at a convergence point $N_{0.8}$ (Fig. 8), but at the nearer convergence point N_{50} (Fig. 9). This new convergence point N_{50}, now, is once again the starting point (near point) of a new stereo-taking range, automatically remaining in accordance with the standard gauge of the system (19.0 mm) obviating any further operations by the user. The same applies to the supplementary lenses 30, 20, 13, 9 and 6.

In the cases of the Stereo-Proxars 50, 30 and 20, the power of refraction of each individual lens has been computed so that the near points $N_{50, 30, 20}$ coincide with the three distance settings of the CONTAMETER. This makes possible convenient optical focusing. With the close-up attachments 13, 9 and 6 distance setting is fixed automatically by mechanical devices (focusing frames), which proved more economical.

The new Contameters can all be used directly for stereo-photography, since they indicate the accurate framing obtainable for all three stereo-close-up ranges (Fig. 10). Older Contameters of post-war manufacture can be converted to give these framings.

The focusing plane does *not* lie in the near points $N_{50, 30, 20, 13, 9, 6}$, but further away in the plane S (Fig. 9).

This ensures a more uniform distribution of the sharp definition between the near and distant points. However, to achieve this object the STEREOTAR lenses must be set to finite distance settings (see Tables 2 and 3).

The stereoscopically-embraced depth, once again, conforms in each case to the principle of depth. The useful depth of close-ups is determined in practice by the depth of field.

A survey of the various taking ranges possible with the STEREOTAR-C and its accessories is given in the Tables 1-3.

The exterior of the STEREOTAR-C and its various methods of application are shown in figs. 11 to 14. For the "normal-range" and the "portrait-range" the STEREOTAR-C is fitted with a coupled rangefinder, which is not effective, however, with the old CONTAX Models II and III.

The lenses have iris-diaphragms coupled to each other with settings from f/3.5 to f/22. The STEREOTAR is attached to the CONTAX by means of the outer bayonet and the prism-attachment fixed by means of a special bayonet to the lens casing. This makes all necessary changes simple, rapid and reliable. Correct framing of normal pictures and portraits is achieved by means of a special stereo-viewfinder with parallax compensation; the CONTAMETER ranges of 50, 30 and 20 are indicated by the CONTAMETER itself. The near-focusing attachments 13, 9 and 6 consist of the appropriate supplementary lens in a bayonet mount and a focusing frame, which can be plugged-in and indicates the correct distance for the nearest point and also the framing. The frames can be detach-

Table 1

Range	Distance setting (object distance) in relation to focal plane	Depths of field at stop 3.5	5.6	8	11	16	22	Width and height of object within the set distance	Image scale within the set distance
Normal range	∞	—	—	—	12′ – ∞	8′6″– ∞	6′2″– ∞	—	—
	28′	—	13′ – ∞	10′6″ – ∞	8′6″ – ∞	6′6″– ∞	5′ – ∞	13′1″ x 18′	1:250
	·	11′7″ –29′	9′10″ –55′	8′3″ – ∞	7′ – ∞	5′8″– ∞	4′7″– ∞	7′1″ x 10′	1:135
	13′	9′9″ –20′	8′6″ –28′	7′4″ –58′	6′4″ – ∞	5′2″– ∞	4′3″– ∞	6′3/4″ x 8′6 3/4″	1:116
	8′	6′8″ –10′	6′ –12′	5′5″ –15′	4′10″ –23′	4′2″–143′	3′6″– ∞	3′8″ x 5′2 1/4″	1:70
Portrait range	6′	5′3″ –7′	4′10″ –7′11″	4′6″ –9′	4′1″ –12′	3′7″ –20′	3′1″ –170′	2′9″ x 3′10 3/4″	1:53
	5′	4′6″ –5′8″	4′2″ –6′3″	3′11″ –7′	3′8″ –8′3″	3′3″ –11′9″	2′10″ –24′	2′3″ x 3′2″	1:43
	4′	3′8″ –4′5″	3′6″ –4′8″	3′3½″–5′2″	3′1″ –5′10″	2′10″ –7′3″	2′6″ –10′6″	1′9 1/4″ x 2′6″	1:34
	:	3′3″ –3′9″	3′1″ –4′	2′11½″–4′4″	2′9½″–4′9″	2′7″ –5′8″	2′3½″–7′6″	1′4 3/4″ x 2′	1:27
	3′	2′10″ –3′2½″	2′8½″–3′5″	2′7″ –3′7″	2′5½″–3′11″	2′3½″–4′5½″	2′1½″–5′6″	1′1 1/2″ x 1′10″	1:25
	2′8″	2′6½″–2′10″	2′5½″–2′10½″	2′4″ –3′1″	2′3″ –3′4″	2′1″ –3′9″	1′11″ –4′5″	1′1/2″ x 1′6 1/4″	1:20

Depth-of-field ranges, object sizes and image scales for the various distance settings of the Stereotar C, in both the normal and the portrait range.

Table 2

Stop	Stereo-Proxar 50: Distance setting in feet	Depth of field from the Contameter distance setting*	Stereo-Proxar 30: Distance setting in feet	Depth of field from the Contameter distance setting*	Stereo-Proxar 20: Distance setting in feet	Depth of field from the Contameter distance setting*
3.5	2′8″	1′9 1/4″	2′8″	1′2 1/4″	3′	8 3/4″
5.6	2′10″	1′11 1/4″	2′8″	1′2 3/4″		
8			2′10″	1′3 1/2″	3′/:	9″
11	3′	2′2″	3′	1′4 1/2″	:	9 1/2″
16	3′/:	2′6 1/2″	3′/:	1′6 1/4″	4′	10 1/3″
22	:	3′1″	:	1′8 1/2″	5′	11 1/2″
Contameter distance setting**	1′8 1/4″		1′1 3/4″		8 1/2″	
Object size***	8 3/4″ x 1′1/4″		5 7/8″ x 8 1/4″		3 3/4″ x 5 1/4″	
Image scale***	1:13.8		1:9.4		1:5.9	

* Measured from the front rim of Stereo-Proxar lens mount

**) Distance between front rim of Stereo-Proxar lens mount and object near point

***) In relation to the Contameter distance setting and projection format 16 × 22.5 mm^2

Most favourable values of distance setting for the various stops with regard to the best possible utilisation of the corresponding depth-of-field range, depths-of-field, object sizes and image scales with the Stereotar C in conjunction with the Stereo-Proxar lenses 50, 30 and 20. When the maximum range of definition is not required, matters can be simplified greatly for all three taking ranges by setting the lens to 2′8″. In this case the rear boundaries of the depth-of-field ranges move towards the front.

Table 3

Stop	Stereo close-up attachment 13: Focusing in feet	Depth of field from the focusing frame up to[1]	Stereo close-up attachment 9: Focusing in feet	Depth of field from the focusing frame up to[1]	Stereo close-up attachment 6: Focusing in feet	Depth of field from the focusing frame up to[1]
5.6	3′	5 3/8″	—	—	—	—
8	3′/:*	5 1/2″	4′	3 49/64″	—	—
11	:	5 21/32″	5′	3 27/32″	5′	2 7/16″
16	4′	5 59/64″	6′	3 31/32″	8′	2 33/64″
22	6′	6 11/32″	13′	4 11/64″	·	2 19/32″
Distance[2] between the focusing frame and the mount of the close-up lens	5 1/8″		3 9/16″		2 21/64″	
Object size[3]	2 21/64″ x 3 17/64″		1 21/32″ x 2 21/64″		1 7/64″ x 1 17/32″	
Image scale[3]	1:3.6		1:2.6		1:1.7	

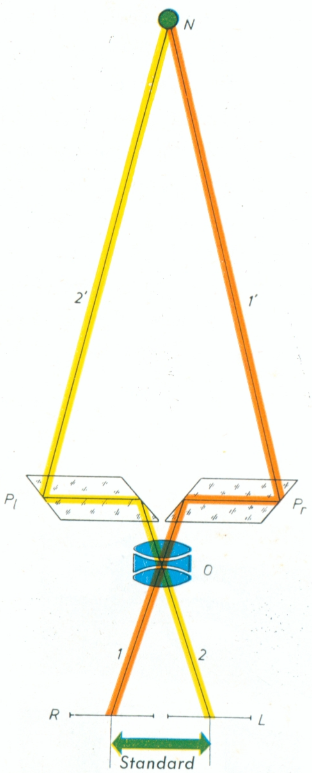
1 Measured from the engraved area of the close-up lens mount, in inches
2 Measured between the engraved area of the close-up lens mount and the area of the focusing frame towards the object, in inches
3 In relation to the distance of the focusing frame
*) between 3′ and:

Most favourable values of distance setting for the various stops with regard to the best possible utilisation of the corresponding depth-of-field ranges, depths-of-field, object sizes and image scales with the Stereotar C in conjunction with the stereo close-up attachments 13,9 and 6. When the maximum range of definition is not required, matters can be simplified greatly especially for flashlight pictures by selecting f/22 and setting the lens to ∞. In this case the depth-of-field ranges move towards the rear.

ed easily from the mounts and can be sterilised when used for medical work.
All combinations can be used with the same S 40.5 filters as used for the CONTAX standard lenses.

Taking Attachments, producing O-Stereo-Pictures

Fig. 15



STERITAR *attachment for all* CONTAFLEX *models and the* CONTINA III. *Diagram of the optical design and the paths of rays. The near point N of the taking range is depicted on the film at the standard gauge of 19.0 mm.*

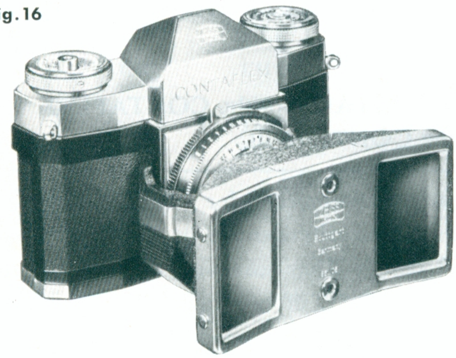
The STERITARS for the CONTAFLEX and the CONTINA III

The stereo-attachments for these camera models are virtually identical in their fundamental design. They essentially consist, as shown in fig. 15, of two rhomboid prisms P_l and P_r, which are fixed in front of the individual O camera lens. These prisms have a purpose similar to those in the STEREOTAR that is to say, they have to deflect the paths of rays laterally so that each prism produces a laterally displaced image of the O lens (fig. 3). These prisms are designed so that the two images of the lens have a lateral distance between them giving an effective base of approx. 65 mm. The half-images R and L on the film are once again separated by the standard gauge of 19.0 mm. With this stereo-attachment, too, the extensions (1′ and 2′) of the rays (1 and 2), the latter connecting the centres of the half-images with the centre of the lens, once again converge in the point N. This means that the STERITAR is also classified in the present stereo-system with the standard gauge of 19.0 mm. This convergence point N is once again the near point of the taking range, being at a distance of approx. 8 ft. (2.5 m) in front of the camera. The more distant subject points are depicted at a lateral distance *greater* than 19.0 mm between their two half-images.

With the STERITARS the base-prisms have yet another purpose. With the employment of only one lens, the standard camera lens, to produce *both* half-images, separating the two half-images is no longer as simple as with two lenses. The built-in separator plate, used with the STEREOTAR, cannot be employed. By using the critical angle of the total reflection, the separation is now achieved by the base-prisms themselves. Under critical conditions this separation is sometimes not sufficient when the stops from f/2.8 to f/4 are used. If a greater stop than f/5.6 must be used it is advisable to ensure sufficient separation by using the separator, which can be inserted into two bushings of the prism attachment. The separator is supplied with each STERITAR.

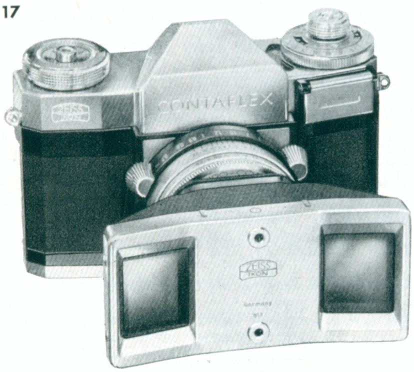
The STERITAR attachments, although basically the same for the various camera models, differ in details of mechanical and optical equipment. For instance, the connecting links to the various cameras are different in order to fit the different lens mounts and front

Fig. 16



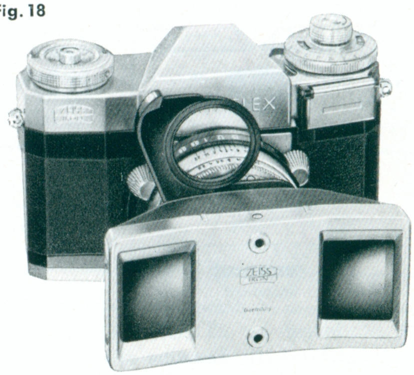
STERITAR A *on the* CONTAFLEX I. *It is fixed by means of the attachment bracket and can also be used on the* CONTAFLEX II.

Fig. 17



STERITAR B *on the* CONTAFLEX IV. *It is attached by means of the front-element bayonet and can also be used on the* CONTAFLEX III.

Fig. 18

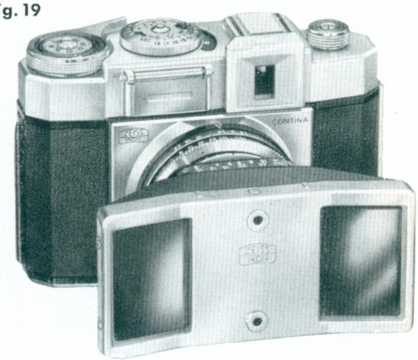


STERITAR B *with swung-out filter holder which accepts normal S 27 filters.*

panels. The sizes of the prisms and the optical values may also differ to suit different focal lengths of the standard lenses.

The STERITAR-A for the CONTAFLEX Models I and II with the 45 mm, f/2.8 Tessar lens, therefore, cannot be used for the CONTAFLEX III an IV, which have a 50 mm Tessar. For these models the STERITAR-B has been designed, which has differently shaped prisms and a different attaching device. Another important difference is that, in contrast to STERITAR-A, the front-element of the f/2.8, 50 mm Tessar must be removed and replaced by the STERITAR-B. The STERITAR-D should be operated in the same way together with the CONTINA III. In this case the front-element of the convertible Pantar f/2.8, 45 mm lens must be removed and replaced by the STERITAR-D the coupling bayonet of which fits that of the Pantar. In its optical design the STERITAR-D corresponds to the STERITAR-A The exterior shapes of the O-stereo-attachments STERITAR-A, STERITAR-B and STERITAR-D can be seen in figs. 16 to 19.

Fig. 19

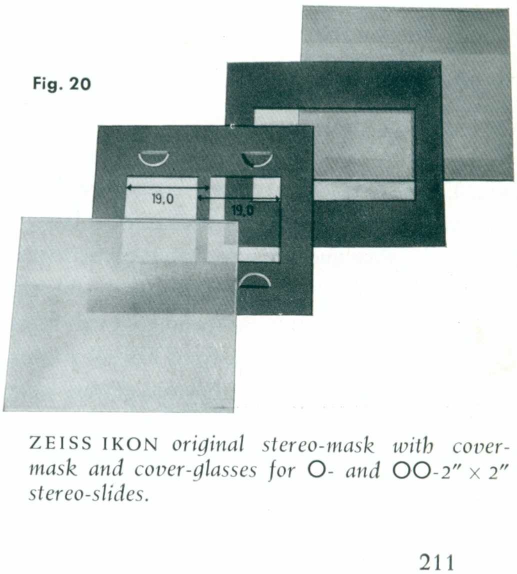


STERITAR D *on the* CONTINA III. *It is also attached by means of the front-element bayonet. Normal S 27 filters can be used as with the* STERITAR B *by employing the filter holder.*

II. Auxiliary Tools and Auxiliary Means

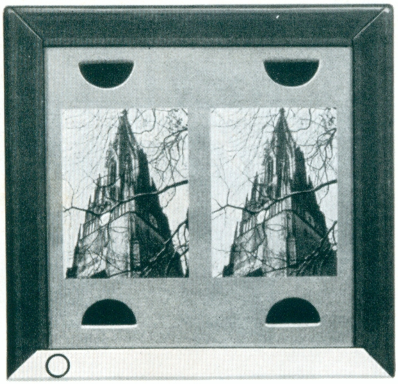
Since stereo-pictures taken with apparatus of the ZEISS IKON stereo-systems consist of two half-images, positioned side by side on *one* single frame of the film, which are automatically correctly positioned in relation to one another and remain *uncut* on the original film for examination (for projection or viewing in a viewer or even for copying), all those awkward and difficult operations of individual mounting or binding become unnecessary. This also makes superfluous special mounting and binding jigs, which otherwise would be required for that purpose.

Fig. 20



ZEISS IKON *original stereo-mask with cover-mask and cover-glasses for* O- *and* OO-2″ × 2″ *stereo-slides.*

Fig. 21



O-2″ × 2″ *Stereo-slide with original* ZEISS IKON *stereo-mask and marked by ring symbol.*

The small strip of film containing the two half-images is simply positioned within the four tongues of the ZEISS IKON stereo-mask (fig. 20) and bound together with the cover mask supplied, between two commercial 2″ × 2″ cover glasses. Using the original ZEISS IKON stereo-masks ensures the correct spatial position of the frame with regard to the image, since these masks are made with the greatest possible precision (accurate to some hundredth of a millimetre). Fig. 21 shows a finished miniature 2″ × 2″ stereo slide with O-symbol.

III. Negative Material, Printing

Fundamentally, any film material which is suitable for normal miniature photography can be used for stereo-photography. When selecting a film it should be borne in mind, however, that *stereo*-photographs are always viewed or projected with high magnification. The use of reversal film, black-and-white or colour, is preferable, therefore, since this material ensures the highest possible image quality. If negative material is used it is of the greatest importance to avoid any change in scale between the negative and the positive, that is to say, printing should be strictly 1:1. This can be performed easily in contact printing but the highest accuracy is necessary with optical printing, since some optical printing machines, for certain reasons, are set to a 1 : 1,1 scale.

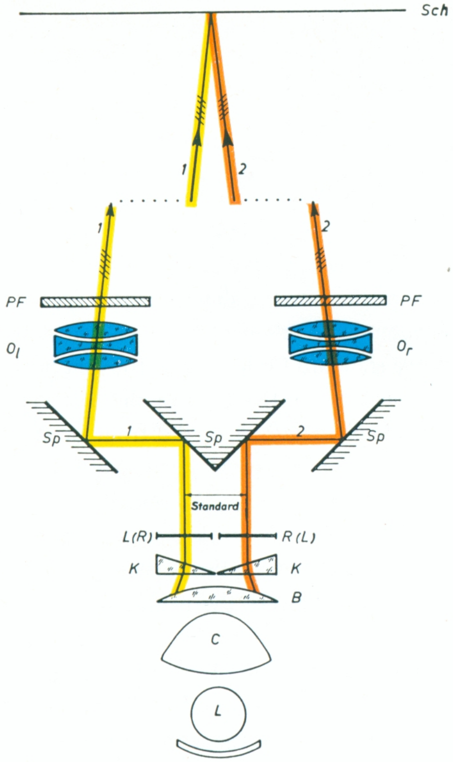
IV. Projecting- and Viewing-Apparatus

Due to the fact that all half-images are already automatically correctly positioned relative to each other and are also framed precisely by the boundaries of the stereo-mask, the conditions governing three-dimensional reproduction are definitely fixed for all pictures taken with the taking devices of the ZEISS IKON stereo-systems. The depths of field are also determined by the boundaries of the various taking ranges. However, the photographer himself should endeavour to hold the camera on a horizontal level in order to avoid vertical distortions.

Stereo Projectors

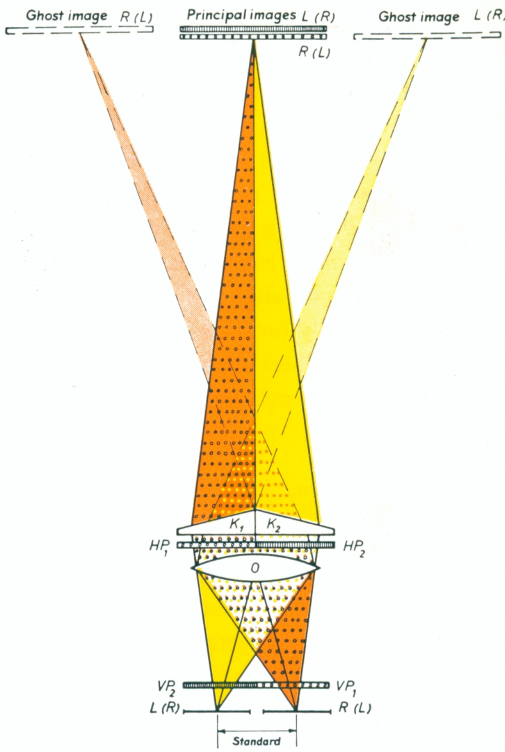
On the basis of this careful preparation of the stereo-pictures themselves, the sole remaining task of the projectors, or rather the stereo-attachments for the projectors – is to

Fig. 22



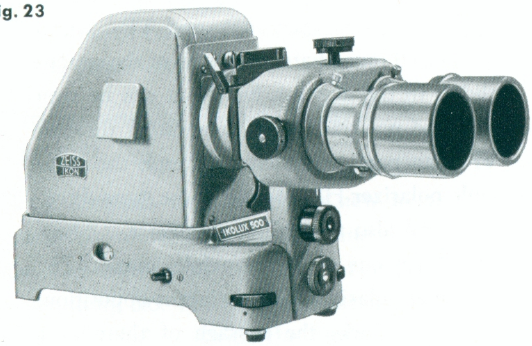
Stereo-head for the IKOLUX 500. *Diagram of the optical design and the path of the light-rays. By means of the system of illumination, consisting of the lamp L, the aspherical condenser C, the image-field lens B and double-prism K, the half-images L and R are trans-illuminated. The combination of mirrors Sp separates the paths of rays of the left-hand and the right-hand image and the portions pass through the lenses O_l and O_r to the polarizers PF from where they finally coincide on the screen Sch.*

Fig. 24



STERIKON 10 *with pre-polarizer, a stereo-projection attachment for the* IKOLUX 250, 500 *and* AVISO II. *Diagram of the optical design and the path of rays. The beams of rays coming from the half-images L and R and filling completely the lens O are divided by the deflecting prisms K_1 and K_2 and deflected in the opposite directions so that one left half-image L and one right half-image R are brought to coincidence on the screen Sch. A pair of pre-polarizers VP_1 and VP_2 near the transparency and a pair of principal polarizers HP_1 and HP_2 near the deflecting prisms polarize differently the rays from the left and the right half-image and at the same time remove the disturbing ghost images.*

Fig. 23



IKOLUX 500 *with stereo-head (fig. 23).*

bring suitably the half-images to coincidence on a screen and to polarize the light rays which produce them.
In the following section three types of stereo-units are described, which can be attached to the normal ZEISS IKON miniature still projectors and differ in their fundamental design, their efficiency, their prices and their potentialities of application. All three units can be used optionally for O- or OO-stereo-pictures (DIN 4531, Sheet 2), according to the adjustment of the polarizer setting.

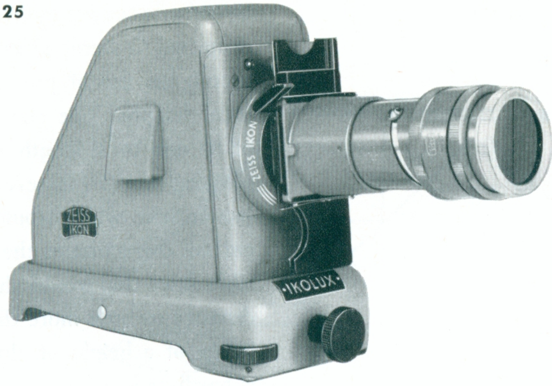
The Stereo-head for the IKOLUX 500

Diagram 22 shows the schematic design of this unit. The light coming from the projection lamp L is used to illuminate both the half-images L and R together by means of the aspherical condenser C in conjunction with the image-field lens B and the double-wedge K. The path of rays is then split into two (1 and 2) by the mirror system Sp and these two beams are passed through the two separate lenses O_l and O_r. This makes it possible to utilise the total light output passing through each half-image most effectively on the screen Sch. Both lenses can be adjusted both laterally and vertically. By using the lateral adjustment the coincidence of the edge-covering of the half-images can be adjusted for practically any projection distance required, whilst the vertical adjustment serves to compensate for slight irregularities in the vertical position of the half-images.
The polarizing filters PF in front of the lenses produce the correct degree of polarisation for both the left and right half-images. The condenser C and the lamp L shown in the diagram are basic elements of the still projector, all the other components being elements of the stereo-head. The projector can be equipped with Orikar f/2.5, 100 mm or Orikar f/3.2, 150 mm lenses. It has no distortional effect on O-pictures. Fig. 23 shows the IKOLUX 500 combination with the stereo-head.

The STERIKON *10 for* IKOLUX *250, 500 and* AVISO II

The STERIKON 10 makes possible the projection of the stereo-slides without a special projection lens. It operates in conjunction with the standard Orikar f/2.5, 100 mm projection lens of the IKOLUX or the AVISO II and is simply attached to the front of this lens. As shown in fig. 24 it consists chiefly of two deflecting wedges K_1 and K_2, which halve the pupil of the projection lens. These are achromatic wedges, the deflecting values of which must be very thoroughly observed. To each wedge is assigned a polarizer HP_1 and HP_2, the directions of vibration of which are perpendicular to each other. Each half of the lens, produces on the screen an enlargement of the relevant half-image, L or R, each of which is only half as bright as that produced by the undivided lens. The wedges K_1 and K_2, which deflect the light rays in opposite directions, are computed so that of the four half-images produced, two, one right and one left, coincide (overlap accurately). These overlapping images are called the principal images in contrast to the ghost images which lie beside them. These ghost-images would impair the observation of the principle images and for this reason they are masked by the pre-polarizers VP_1 and VP_2, which are placed immediately in front of the stereo-slide[7]. In the diagram fig. 24, it can be seen how the polarized rays penetrating through VP_1 can pass unhindered through the principle polarizer HP_1, acting in the same direction, and also through the wedge K_1. These rays form one of the principle images. The principle polarizer HP_2, being in opposition, however, blocks the passage of these rays

Fig. 25



IKOLUX *250 with f/2.5 100 mm Orikar lens and* STERIKON *10.*

and prevents them passing through into the prism K_2. This prevents the formation of the ghost image to the left of the principle image. The same applies to the light rays passing through VP_2.

The STERIKON 10 has the effect of partial distortion on O-stereo-slides. In fig. 25 it is shown in conjunction with the IKOLUX 250.

The Stereo-Attachment for the IKOLUX *150, 300 and S 300*

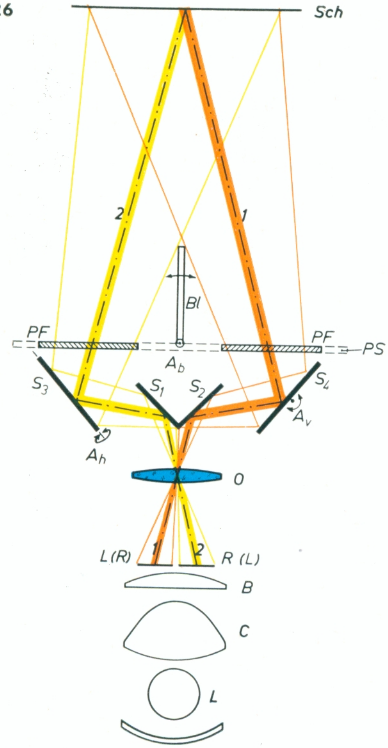
This attachment is still in preparation. It is being designed to satisfy the following requirements:

1. If possible, the attachment should work in conjunction with all lenses of the new IKOLUX models.
2. The attachment should be designed with the intention of correcting trapezoid-distortion of O-stereo-pictures.
3. Its construction should be as simple as possible.

These demands were met by a new mono-lens *mirror* attachment, the fundamental design and method of operation of which is shown in fig. 26. The two stationary internal mirrors S_1 and S_2 divide the beams of rays passing through the projection lens O and the two half-images L and R into equal portions, which are supplied to the two outer mirrors S_3 and S_4. Here they are deflected so that the projection images produced on the screen Sch can be brought to coincidence.

Owing to the various projection distances and the different focal lengths of the projection lenses, the outer mirror S_4 is rotatable round a vertical spindle A_v. The adjustability of this mirror is chosen so as to give a good frame covering of standard 2″ × 2″ stereo-slides for practically all projection focal lengths and a wide range of projection distances. The vertical adjustment of one of the projected half-images is made possible by making the other outer mirror S_3 rotatable round a horizontal spindle A_h. The variable polarisation of the partial beams is performed by the polarizing filters PF, which are mounted together in the polarizer slide PS. By reversing this slide the variable adjustment of the polarizing filters for O- and OO-stereo slides can be achieved. The limitation of the partial beams is done mechanically by a separator shield B_1 which is rotatable round a vertical spindle A_b. The mirror attachment can be fixed to the lens panel of the IKOLUX by means of a special support. Fig. 27 shows this stereo-attachment mounted on the IKOLUX 300.

Fig. 26



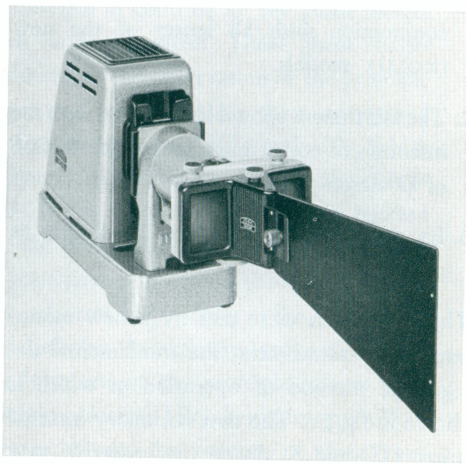
Mirror stereo-projection-attachment for IKOLUX *150, 300 and S 300. Diagram of the optical design and the path of rays.*
The half-images L and R transilluminated by the lighting system consisting of the lamp L, the aspherical condenser C and the image field lens B are projected by means of the lens O on to the screen Sch. The beams of rays are divided by the internal mirrors S_1 and S_2 and brought to coincidence on the screen Sch via the outer mirrors S_3 and S_4. They are differently polarized by the polarizers PF and separated from each other by the separator Bl.

In order to reduce the trapezoid-distortion of projected O-stereo slides, the new projectors permit the use of projection lenses of short focal lengths. The standard projection lens of 85 mm focal length gives, in this respect, pleasing results. However, using a 50 mm projection lens, which would result in an almost perfect correction of the distortion, is impossible since this would shorten the projection distance to little more than 6 ft for a screen image of a height of almost 40 inches. This is hardly advisable.

Stereo Viewers (stereoscopes)

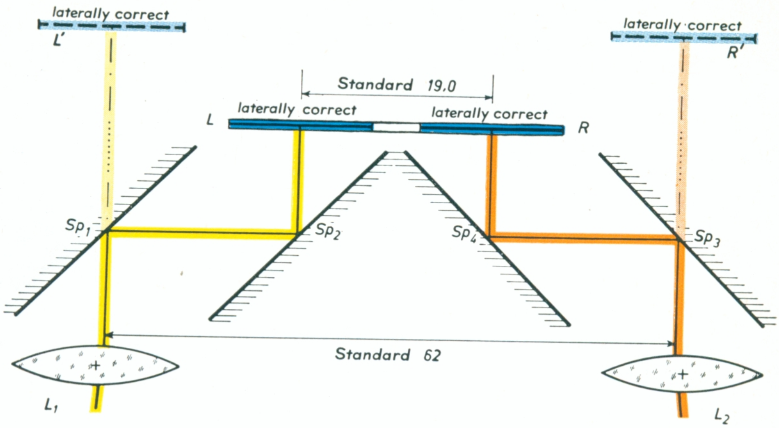
According to the principles mentioned at the beginning of this chapter, the chief function of viewers or stereoscopes is to bring the half-images sufficiently close to the eyes and convey one to each eye individually at such an apparent and effective lateral distance that the objects depicted appear vertically and laterally correct and can be viewed at almost the same angles as they would appear to the eyes in natural vision.

Fig. 27



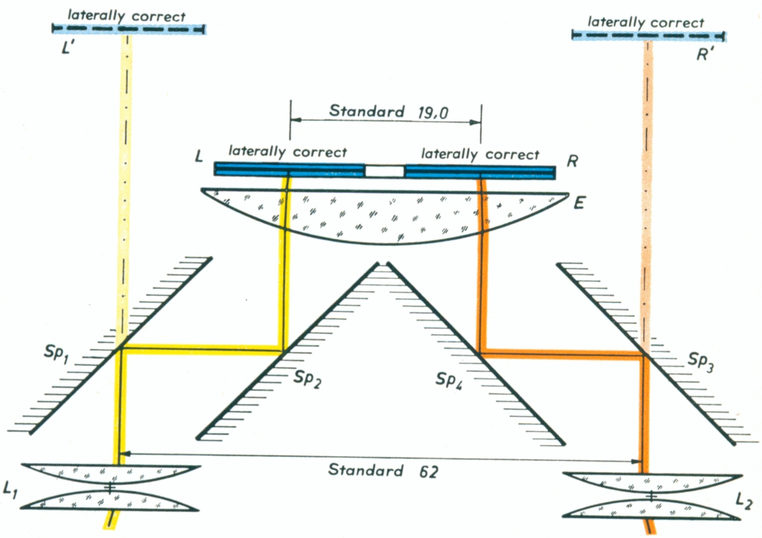
IKOLUX *300 with mirror stereo-projection attachment (fig. 27).*

Fig. 28



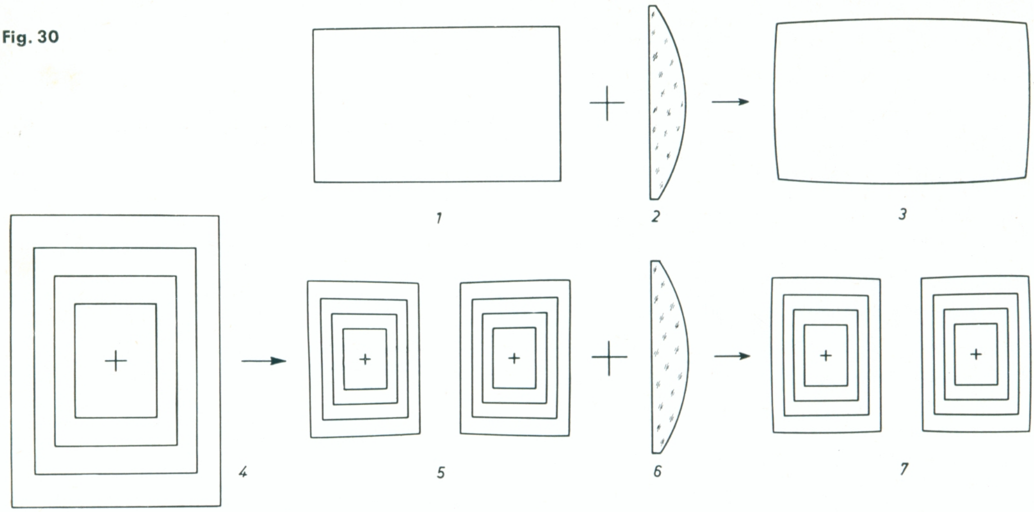
A simple O-stereo viewer. Diagram of the optical design and the path of rays. The half-images L and R which are laterally and vertically correct and also correctly correlated to the eyes are transferred by means of the pairs of mirrors SP_1, SP_2, and SP_3, SP_4, into the apparent positions L' and R' and so viewed through the magnifiers L_1 and L_2.

Fig. 29



ZEISS IKON *O-stereo viewer with double-magnifiers and image-field lens. Diagram of the optical design and the path of rays.*
Fundamentally, the conditions are the same as with the simple O-stereo viewer in fig. 28.
Spherically corrected double magnifiers L_1 and L_2 permit unhindered viewing even for observers with unusually large or small interpupillary distances. The image-field lens E reduces the trapezoid distortion of the O-stereo slides, according to fig. 30.

Fig. 30



Method of operation of the image-field lens $\mathcal{E}$ in the O-stereo viewer shown in fig. 29. A rectangle 1, seen from the convex side of a plano-convex lens 2 appears as a barrel-shaped figure 3. The rectangles of the test figure 4 are depicted as oppositely directed trapezoid half-images 5 when taken with a mono-lens stereo attachment. The plano-convex lens 6 converts them to almost accurate rectangles 7.

Fig. 31

ZEISS IKON O-*stereo viewer.*

Since the half-images are positioned differently in both the O- and OO-stereo pairs various ways and means are required to achieve this aim. With regard not only to the technical but also the economical point of view, it appears almost impossible to design a viewer which meets the requirements of both types of pictures.

For this reason a special viewer has been made for each of the two ZEISS IKON 2″× 2″ O- and OO-stereo-slides.

The O-Stereo Viewer for 2″ × 2″ Stereo-Slides

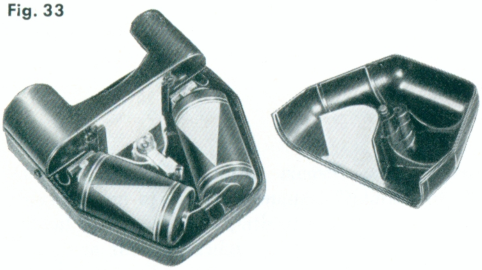
This viewer is relatively simple in its basic design. As can be seen in fig. 28 the simplest viewer consists essentially of four mirrors, Sp_1, Sp_2, Sp_3 and Sp_4, two bi-convex lenses L_1 and L_2 acting as magnifiers and a support for the slide with the half-images L and R. This simple optical design is possible because of the favourable position of the half-images (laterally and vertically correct with the left half-image to the left of the right one).

The two pairs of mirrors Sp_1 and Sp_2 or Sp_3 and Sp_4 have only to cause such a deflection

Fig. 32

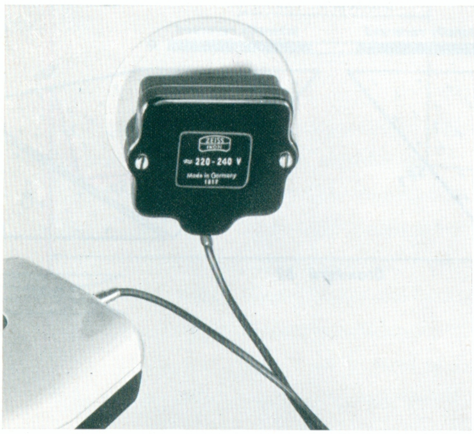
ZEISS IKON O-*stereo viewer with illumination attachment.*

Fig. 33



Illumination attachment for the ZEISS IKON O-*stereo viewer, open.*

Fig. 34



Transformer for the illumination attachment of the ZEISS IKON O- *and* OO-*stereo viewers, which can be connected to A.C. mains of 110-130 volts or 220-240 volts.*

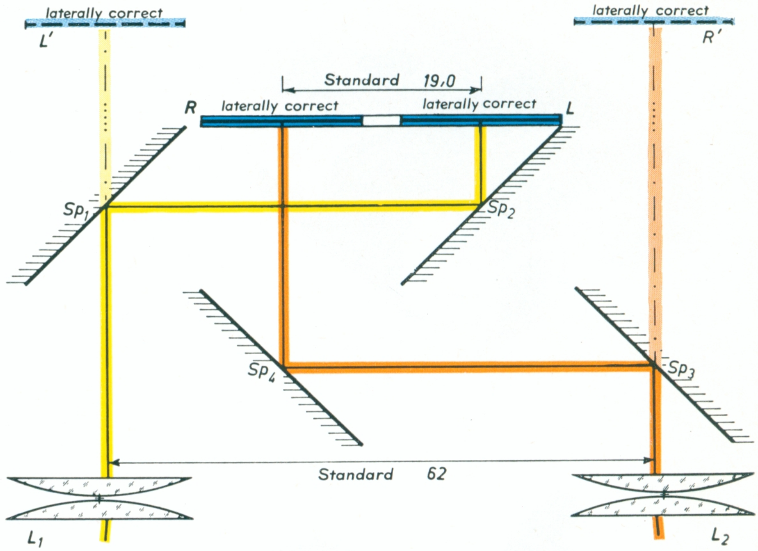
of the beams of rays that the half-images L and R appear to the eyes to be in the positions L′ and R′. The two magnifiers L_1 and L_2 permit the pictures to be viewed sharply at less than the normal viewing distance.

ZEISS IKON have not chosen this most simple design for an O-stereo viewer, for two reasons:

1. The lateral distance between the magnifiers depends on the apparent distance between the half-images and must be of a fixed magnitude. The interpupillary distance of the eyes, however, differs with various observers. A lateral adjustment of the magnifiers to accommodate them to the interpupillary distance of the individual viewer would be fundamentally wrong. For this reason the viewing area of the magnifiers is made large in our O-stereo viewer and the distance of them is fixed. Depending upon the distance of the eyes, either the centre or the edges may be used. In order to make stereo-viewing possible for people with an extremely great interpupillary distance as well as for those with an extremely short one, two times two suitably arranged plano-convex lenses have replaced the simple bi-convex lenses (fig. 29) and in this combination form spherically corrected double magnifiers giving pictures of high quality right up to the edges. The lenses are of the fix-focus type and are adjusted for observers with normal vision. People with defective eyesight have to use their spectacles. This is a limitation, of course, but nevertheless a considerable simplification of the basic design and its satisfactory operation has been achieved.

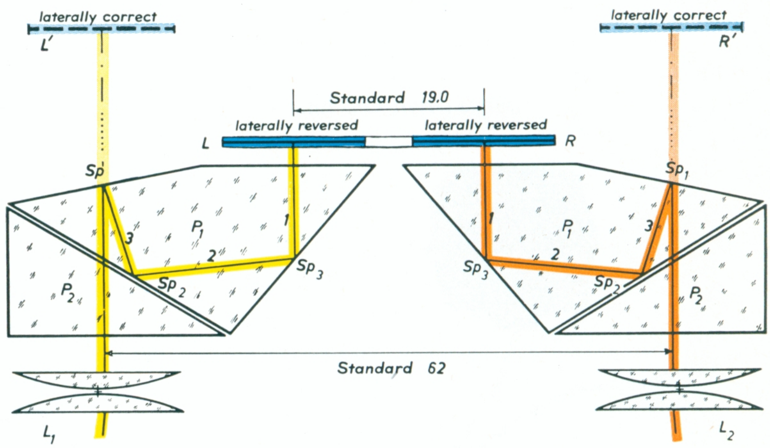
2. The unavoidable trapezoid distortion of the half-images taken with an O-stereo attachment caused us to use an additional element, which might be called a distortion correcting element. It is the plano-convex lens E (fig. 29) which covers both the half-images L and R and is built into the viewer

Fig. 35



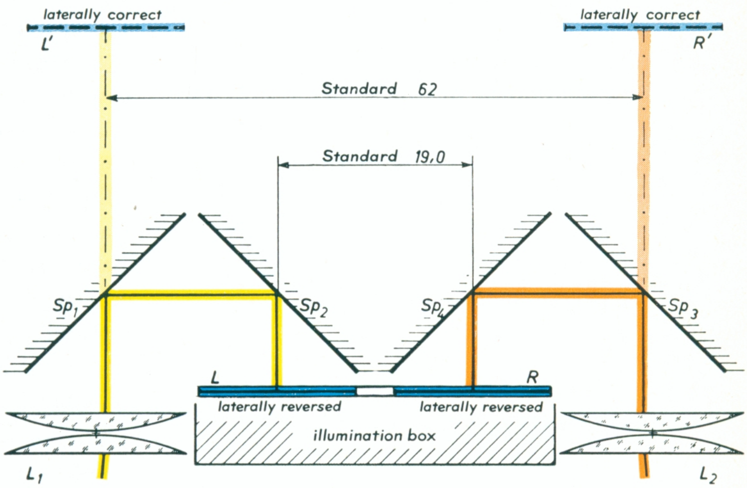
OO-stereo viewer with transposition of the half-images. Diagram of the optical design and path of rays. The laterally and vertically correct but, in relation to the eyes, incorrectly correlated half-images L and R are viewed via the pairs of mirrors SP_1, SP_2 or SP_3, SP_4. The crossing of rays make the half-images appear in the apparent positions L' and R', where they appear laterally correct and also correlated correctly to the eyes.

Fig. 36



OO-stereo viewer with lateral transposition of the half-images. Diagram of the optical design and the path of rays.
The half-images L and R are correctly correlated to the eyes but laterally reversed. By reflecting them three times via the surfaces SP_3, SP_2, SP_1, they are viewed in the apparent positions L' and R' and are then laterally correct and correctly correlated to the eyes.

Fig. 37



ZEISS IKON OO-*stereo viewer with lateral transposition of the half-images. Diagram of the optical design and the path of rays.*
Owing to the particular position of the pairs of mirrors Sp_1, Sp_2 and Sp_3, Sp_4, the half-images, which are correctly correlated to the eyes but laterally reversed are viewed from the back, which causes a lateral transposition. They appear laterally correct in the apparent positions L' and R' and are viewed through the magnifiers L_1 and L_2. The pictures are illuminated from the illumination box.

in addition to the other absolutely essential optical components. The method of operation of this image-field lens is shown in the diagram fig. 30.

As is well known, looking through a plano-convex lens (2) from the convex side will make a rectangle (1) appear as a barrel-shaped figure (3). A test figure (4) consisting of rectangles lying concentrically, one inside another, will be depicted when taken with a mono-lens stereo-attachment, as half-images (5) of a trapezoid figure, facing in opposite directions. If these are now viewed through a plano-convex lens (6) a figure (7) will be seen in which the half-images are once again almost correctly rectangular. This is sufficient to correct the trapezoid distortion in O-stereo pictures.

The ZEISS IKON O-stereo viewer also possesses the following important features:

It can be operated without special adjustment, has spherically corrected large double magnifiers with large eyepieces and in conjunction with a corrective image-field lens permits correct stereo-viewing to practically all observers no matter what their interpupillary distance or whether they are wearing glasses or not. The viewer can be supplied with an illumination attachment for battery operation or a transformer for connection to 110–130 volts or 220–240 volts A. C. mains. Figures 31 and 32 show the O-stereo viewer with and without the illumination attachment, whilst fig. 33 gives an idea of the interior of the illumination attachment and fig. 34 of the plug-in transformer for mains supply.

The OO-Stereo Viewer for 2" × 2" Stereo Slides

Viewing OO-stereo pictures is fundamentally different from viewing O-stereo pictures and for this reason OO-stereo viewers cannot be as simple as the other ones.

OO-stereo pictures have *either*

their half-images in a laterally correct position but in the wrong order relative to the eyes (left half-image to the right, right half-image to the left) – see pages 196 ff;

or the half-images are correctly correlated to the eyes (left half-image to the left, right half-image to the right) but laterally reversed.

For these problems, there are two distinct solutions and two fundamentally different types of stereo-viewers.

1. Starting with the laterally correct half-images which are incorrectly correlated to the eyes, it is obvious that the viewers must be designed so that the two half-images are optically transposed in such a way that the left eye sees the left half-image and the right eye sees the right half-image, without reversing them laterally. At the same time the viewers must be so constructed, like the O-stereo viewer, as to convert optically the actual distance of the half-images L and R to the apparent interpupillary distance, that is to say, to the positions L′ and R′. Fig. 35 shows how the pairs of mirrors Sp_1 and Sp_2 and Sp_3 and Sp_4 solve both this problems by making the paths of rays cross each other. The magnifiers L_1 and L_2 are once again designed so that the eyes, when sufficiently close to the magnifiers, can see both half-images sharply defined. The various sets of mirrors can be replaced by prisms, which, with regard to the optical length of the paths of rays, are more favourable in practice.

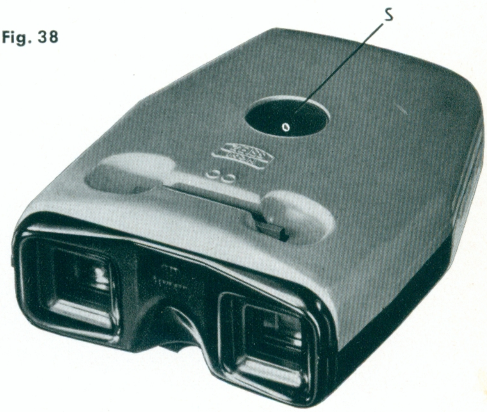
2. When starting with half-images which are correctly positioned in relation to the eyes but laterally reversed, the optical equipment of the viewer must be designed so that its various elements not only effect an apparently correct separation of the half-images but also produce a lateral reversal[8]. An OO-stereo viewer of this type is shown in fig. 36. The combination of prisms P_1, P_2 has three reflecting surfaces Sp_1, Sp_2 and Sp_3, one of which (Sp_2) is formed by an air-gap between the partial prisms P_1, P_2. The rays coming from the sections 1, 2 and 3 of the half-images L and R are deflected by the reflecting surfaces Sp_3, Sp_2 and Sp_1 so that they reach the eyes after passing the prisms P_2 and the magnifiers L_1 or L_2. They transfer the half-images L and R to the apparent image positions L′ and R′. Due to the odd number of reflections (three times) the half-images which are originally laterally reversed now appear laterally correct in the apparent positions L′ and R′.
Both these types of viewer, however, need a considerable amount of optical elements and are rather uneconomical to manufacture. For this reason they are not produced by ZEISS IKON and have been described only to show all the possible ways of solving this problem.

Fig. 37 shows how this problem can be solved by using only a few optical elements, although in a somewhat unusual manner, by starting with correctly positioned but laterally reversed half-images. This design of a particularly inexpensive OO-stereo viewer is principally composed of two pairs of mirrors Sp_1, Sp_2 and Sp_3, Sp_4 and two magnifiers L_1 and L_2. The position of stereo-slide and the setting of the mirrors may seem peculiar. The lateral reversal of the half-images here is not achieved by an odd number of reflections of the paths of rays, but by viewing the stereo-slide from the back – as seen from the observer. This is rather difficult, as it is necessary to place the slide L, R as near as possible to the observer and to transilluminate it at the same time. It has been possible, however, to place an ingeniously designed "illumination box" between the magnifiers L_1 and L_2. From this box the half-images L and R are transilluminated and the rays coming from them are collected by the mirrors Sp_2 or Sp_4, deflected and transferred to the mirrors Sp_1 or Sp_3 and led to the eyes by passing through the magnifiers L_1 or L_2. The dimensions and the arrangement of the mirrors are designed so that the half-images appear laterally correct in the positions L′ and R′.

The magnifiers L_1 and L_2 are spherically corrected double magnifiers, for the same reason as mentioned with the O-stereo viewer. On the other hand, there is no necessity for using a distortion corrector, since OO-stereo pairs do not suffer from the trapezoid distortion of the O-stereo slides.

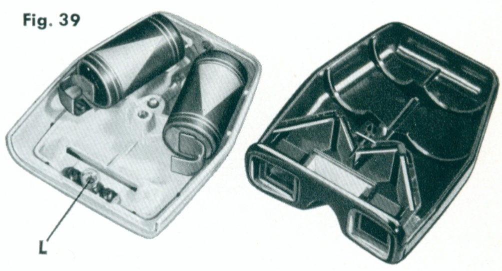
Due to the necessity of incorporating an illumination box, the use of artificial illumination has become almost imperative. As can be seen in fig. 39 the cover of the viewer-casing contains holders for two 1.5 volt mono-cells which feed a 2.5 volt, 0.3 amp torch bulb (L). This lamp will automatically be placed

Fig. 38



ZEISS IKON OO-*stereo viewer, according to diagram fig. 37.*

Fig. 39



ZEISS IKON OO-*stereo viewer, open.*

in the illumination compartment when the cover is put on the viewer and can be operated by means of a press-button switch S (fig. 38). The viewer can also be connected to 110–130 volts or 220–240 volts A. C. mains by using the plug-in transformer (shown in fig. 34).

Finally, it should be mentioned that the current ZEISS-IKON stereo systems described in these pages can and will be developed further and their scope extended.

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