

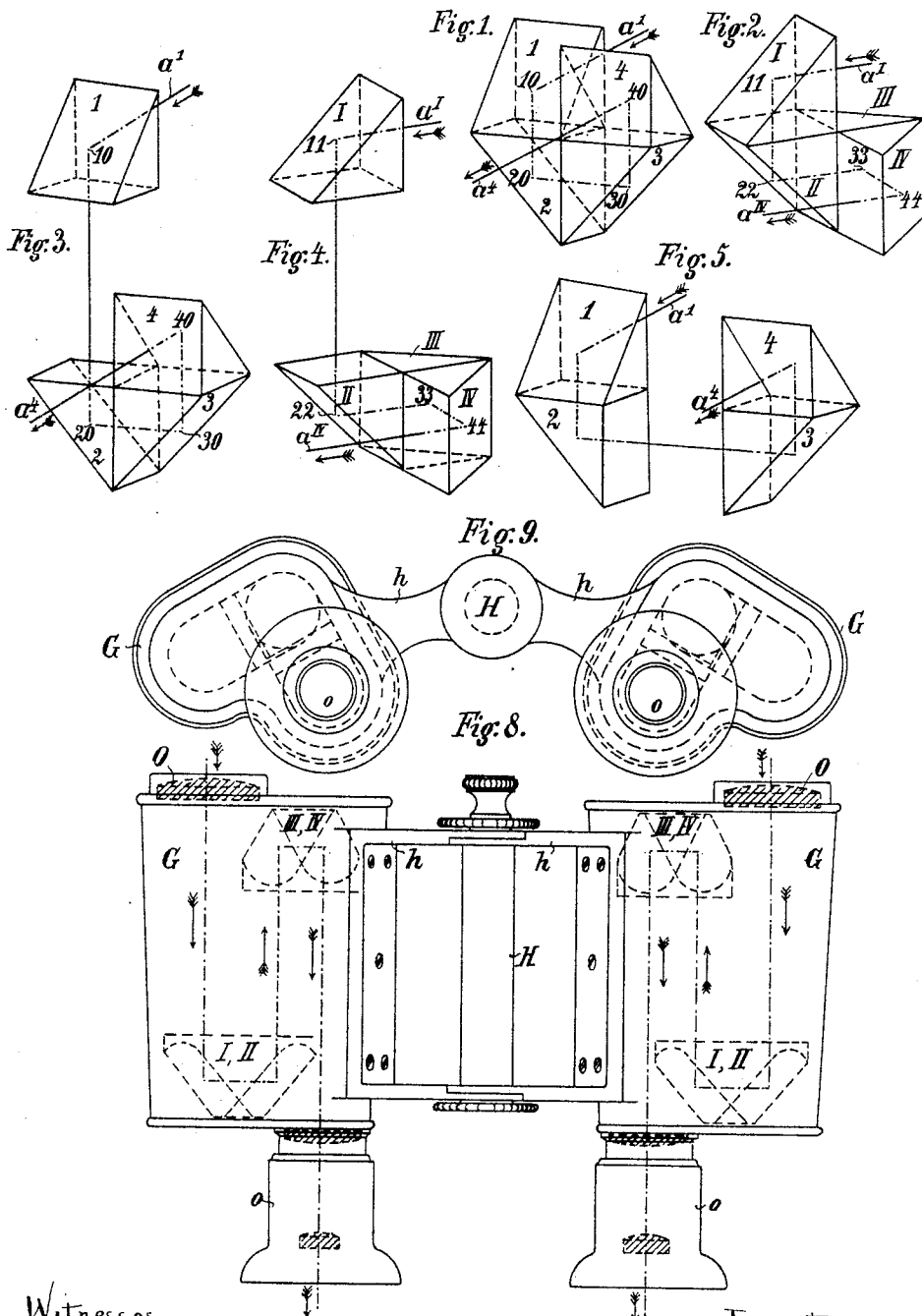
(No Model.)

2 Sheets—Sheet 1.

E. ABBE.
TELESCOPE.

No. 584,976.

Patented June 22, 1897.



Witnesses

F. B. Keefe
Bruce & Co.

Inventor

Ernst Abbe
by *Marshall Bailey*
his attorney

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Fig. 6.

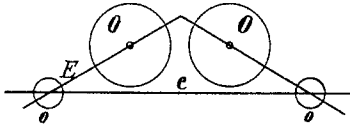


Fig. 13.

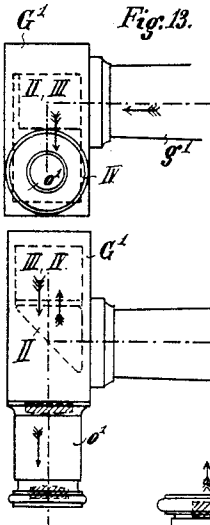


Fig. 14.

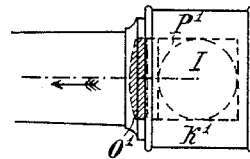
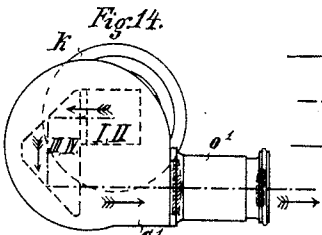


Fig. 12.

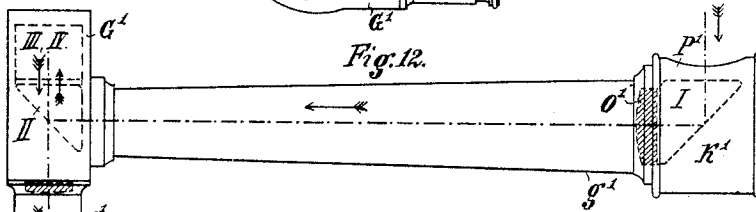


Fig. 10.

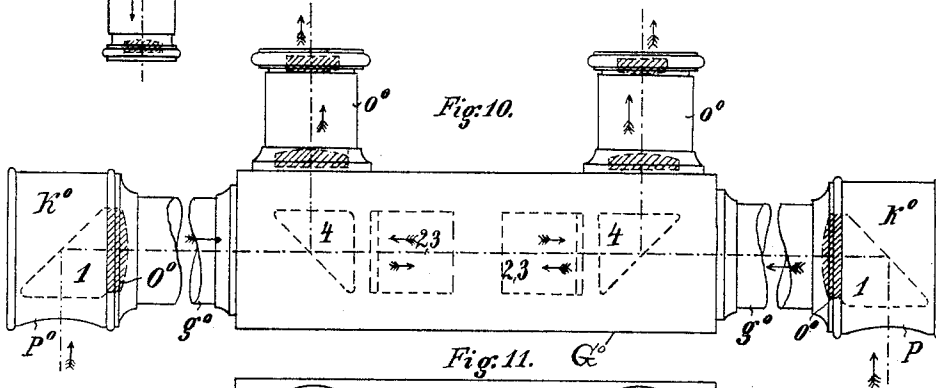


Fig. 11.

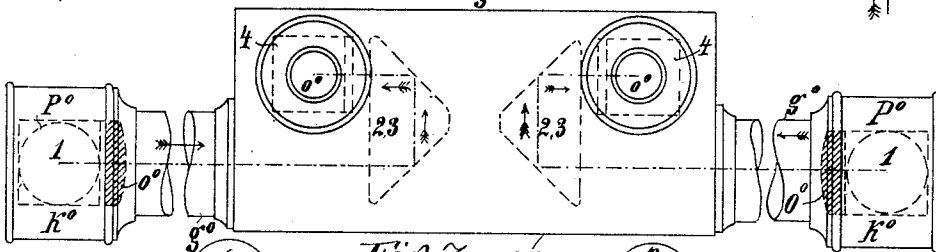
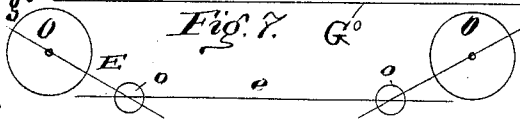


Fig. 7.



Witnesses

Bruce & Co.
Witnesses

Inventor

Ernst Abbe
by Marshall S. Gay
his attorney.

UNITED STATES PATENT OFFICE.

ERNST ABBE, OF JENA, GERMANY, ASSIGNOR TO THE FIRM OF CARL ZEISS, OF SAME PLACE.

TELESCOPE.

SPECIFICATION forming part of Letters Patent No. 584,976, dated June 22, 1897.

Application filed November 26, 1894. Serial No. 530,002. (No model.) Patented in Germany July 9, 1893, No. 77,086; in Switzerland October 30, 1893, No. 7,791; in France November 8, 1893, No. 233,915; in Austria April 5, 1894, No. 59,205; in Hungary April 5, 1894, No. 95,358; in England April 21, 1894, No. 7,942, and in Italy May 14, 1894, LXXI, 302.

To all whom it may concern:

Be it known that I, ERNST ABBE, doctor of philosophy, a subject of the Grand Duke of Saxe-Weimar, residing at Jena, in the Grand Duchy of Saxe-Weimar, Germany, have invented new and useful Improvements in Telescopes, (for which I have obtained patents in Germany, No. 77,086, bearing date July 9, 1893; in Great Britain, No. 7,942, bearing date April 21, 1894; in France, No. 233,915, bearing date November 8, 1893; in Austria, No. 59,205, bearing date April 5, 1894; in Hungary, No. 95,358, bearing date April 5, 1894; in Italy, No. 302, Vol. LXXI, bearing date May 14, 1894, and in Switzerland, No. 7,791, bearing date October 30, 1893,) of which the following is a specification.

This invention relates to telescopes, and especially to binocular telescopes, in which the two objectives or objective-apertures are arranged at a greater distance apart than are the two eyeglasses for the purpose of increasing the parallax differences of the images produced in both component telescopes, so as to increase the perception of the depth of the objects—that is to say, to make the combined image more in relief. One feature of the invention consists in improved means for effecting the said greater distance of the objectives.

Hitherto binocular telescopes of this description, named “telestereoscopes of Helmholtz,” have consisted of a pair of telescopes, which are constructed in the following manner: The optical components of an ordinary terrestrial telescope—that is to say, an objective-glass and a so-called “terrestrial” eyepiece, consisting of a positive eyeglass and a lens system for erecting the image—are combined with two plane mirrors or reflecting-prisms in such a way that one is placed before the objective-glass at an angle of forty-five degrees, so as to direct the axis of the objective-glass perpendicularly to the optical axis of the objective opening or aperture through which the rays enter the telescope, and the other is placed between the objective and the eyepiece in proximity to the latter,

also at an angle of forty-five degrees, so as to direct the axis of the eyepiece perpendicularly to the axis of the objective-glass, which is also the axis of the tube of the telescope, and parallel to the optical axis of the objective-aperture. Both telescopes are connected together in such a way that the axes of their tubes form one straight line, the eyeglasses being a distance apart approximating the distance between the human eyes, and the objective-apertures being at a greater distance apart.

The same result may be obtained according to this invention without any supplemental parts solely by means of the constitutive elements of terrestrial telescopes, if for erecting the image instead of the inverting lens system of the so-called “terrestrial” eyepiece one of two combinations of prisms is used, which are suggested in the French weekly magazine *Cosmos*, Vol. II, 1853, p. 222, and Vol. IX, 1856, p. 401, by the Italian engineer Porro, for the purpose of lessening the length of terrestrial telescopes. Either of these combinations of prisms combined with an objective and a mere astronomical (positive) eyepiece produces in addition to the erection of the image a dislocation of the eyeglass-axis from the objective-axis, and it is the main feature of the present invention to make use of this quality of the Porro telescopes for constructing improved telestereoscopes. To this object, two equal Porro telescopes are connected together in such relative positions that they form a binocular glass, the objectives of which have a greater separation than the eyeglasses.

Another feature of this invention consists in improved arrangements of either of the above said combinations of prisms, in which adjacent elements are separated from each other for the purpose of increasing the distance between the axis of the eyeglass and the axis of the objective-glass or of the objective-aperture. A telescope provided with such a modified combination of prisms of Porro is well adapted to be used as a single or monocular glass for some special purposes,

and it may be combined with a second one to form a telescereoscope of very great distance of the objectives.

In order that this invention may be fully understood, I shall now proceed more particularly to describe the same, and for that purpose I refer to the accompanying drawings.

Figures 1 and 2 represent perspective views of the two combinations of prisms of Porro. Fig. 3 represents a modified arrangement of the combination of Fig. 1. Fig. 4 represents a modified arrangement of the combination of Fig. 2. Fig. 5 represents another modified arrangement of the combination of Fig. 1. Fig. 6 represents a diagrammatic view of a binocular telescope the objectives of which have a less distance than the eyeglasses. Fig. 7 represents another diagrammatic view of a binocular telescope the objectives of which have a greater distance than the eyeglasses. Fig. 8 represents a plan and Fig. 9 a front view of a binocular glass constructed from two Porro telescopes. Fig. 10 represents a plan and Fig. 11 a front view of a binocular glass constructed from two Porro telescopes modified according to this invention. Fig. 12 represents a plan, Fig. 13 a front view, and Fig. 14 an end view, of a modified Porro telescope arranged for use as a single or monocular glass.

The first of Porro's combinations of prisms (represented by Fig. 1) consists of four rectangular isosceles prisms 1, 2, 3, and 4, constructed from one piece of glass or connected to form one piece. The entering ray a' , which coincides with the optical axis, strikes at 10 the hypotenuse surface of the prism 1 at an angle of forty-five degrees and being reflected at the same angle relatively to this surface is at this point deflected by ninety degrees from its original direction. The same effects are successively produced by the hypotenuse surfaces of the prisms 2, 3, and 4 at the points 20, 30, and 40, so that the direction of the emerging ray a'' is parallel to that of the entering ray a' , and both lines of direction or optical axes have a distance apart equal to the distance between the points 20 and 30, which is determined by the dimensions of the prisms. The second of Porro's combinations of prisms (represented by Fig. 2) consists also of four rectangular isosceles prisms I, II, III, and IV, deflecting the entering ray a^I four times at an angle of ninety degrees at the points 11, 22, 33, and 44, but arranged in a different manner from that shown in Fig. 1, so that the line of direction of the emerging ray a^{IV} has a distance from the line of direction of the entering ray equal to the hypotenuse of a right-angled triangle, the small sides of which are formed by the lines 11 22 and 33 44, this distance being therefore likewise determined by the dimensions of the prisms. It is obvious that either of these combinations of prisms may be interposed between the objective and the eyeglass of a telescope for the

purpose of erecting the image if the axes of the objective and the eyeglass are respectively separated the distance of the entering and the emerging ray in the combination of prisms. Therefore Porro's telescopes have an objective arranged eccentric to the eyeglass at a distance depending from the dimensions of the prisms used for erecting the image. This is not altered by the fact that none of Porro's combinations of prisms are inserted into his telescopes in one piece. His aim being solely the lessening of the length of the telescopes, he has separated, in the arrangement of Fig. 1, the prisms 2 3 from the prisms 1 4, and to compensate for the separation by which the paths of the rays between points 10 and 20 and between points 30 and 40 are lengthened the distance between the objective and the eyeglass might be shortened at the same rate. For the same reason in the arrangement of Fig. 2 he has separated the prisms III and IV from the prisms I and II, lengthening thereby the space between 22 and 33, passed by the rays in a direction contrary to that in which they enter into prism I and emerge from prism IV.

Two equal Porro telescopes connected together to form a binocular telescope may be arranged with the distance of the objectives from each other different from that between the eyeglasses. If the objectives have a less distance apart than the eyeglasses, and this distance may be lessened by so much that the objectives touch each other, the images shown by the binocular glass appear less in relief, approaching to mere plane images. If, on the contrary, according to the present invention the objectives have a greater distance than the eyeglasses, and this distance may surpass that of the eyeglasses up to the full sum of the distances of the objective and eyeglass axes of either telescope, the contrary effect is obtained, as has been above described. Both effects may be obtained with the same binocular glass, as is illustrated by Figs. 6 and 7. The sketch in Fig. 6 shows the objectives O nearer together than the eyeglasses o, the planes E, each of which includes the objective O and the eyeglass o of one of the telescopes, being inclined to the plane e, including the axes of both eyeglasses o at acute internal angles. The telescopes may be so arranged that the objectives O are brought into the position shown in Fig. 7, in which they are more distant from each other than the eyeglasses, and the planes E are inclined at acute external angles to the plane e.

For the purpose of enabling the binocular telescope to be adapted for use by different individuals the single telescopes are preferably hinged together or connected otherwise so as to allow the eyeglasses to be adjusted toward or away from each other.

Figs. 8 and 9 show a binocular glass consisting of two Porro telescopes containing the combination of prisms of Fig. 2. Each set of double prisms I II and III IV is inclosed in a

casing G, which carries at the front side the eyepiece o and at the opposite end the objective O. Both casings G are connected by means of brackets h , hinged together on a common bolt H, and by turning them around this hinge-bolt the distance of both eyeglasses may be adjusted to suit the individual, and both parts of the binocular glass may be closely brought together for enabling the same to be inclosed into a rather small case. For the double prisms I II and III IV, equivalent to the combination of prisms of Fig. 2 and characterizing one kind of Porro's telescopes, may be substituted a double prism 2 3 and two united prisms 1 4, equivalent to the combination of prisms of Fig. 1 and characterizing the other kind of Porro's telescopes with no further alterations of the telescope than a different shape of the casings G.

In the binocular glass shown in Figs. 8 and 9 the distance between the objectives does not exceed considerably the distance between the eyeglasses. Notwithstanding this the perception of depth increases remarkably, as may be understood from considering the optical principle that for the user of a binocular glass the ability of distinguishing differences of distance is proportional to the product of the rate of magnification and the distance between the centers of the objective-apertures. Therefore the above-described glass shows images which in regard to the relief appearance of the objects are equal to images produced by an ordinary binocular telescope of a higher magnifying power and correspondingly smaller field of sight.

A binocular glass of a more considerable stereoscopic effect may be constructed, as already has been mentioned, by separating the components of the combination of prisms in such directions that the perpendicular distance between the ray which enters the first prism 1 or I and the ray which emerges from the fourth prism 4 or IV is increased, which increase is determined by the dimensions of the prisms.

Of all arrangement of prisms suitable to increase the distance between the entering ray and the emerging ray the most simple and the most important consists in dividing the prisms of Figs. 1 and 2 into only two parts. In the arrangement shown in Fig. 3 and corresponding to Fig. 1 the first part 1 is separated from the main part 2 3 4. In the arrangement shown by Fig. 4 and corresponding to Fig. 2 the first part I is separated from the main part II III IV. In a third arrangement shown by Fig. 5 and corresponding to Fig. 1 the prisms 1 2 are separated from the prisms 3 4.

Figs. 10 and 11 represent a binocular telescope provided with the arrangement of prisms shown in Fig. 3. Both component telescopes are rigidly connected together by a common casing G^0 , which includes both sets of prisms 2 3 4, and carries at its front side the eyepieces O^0 and at either lateral side

a tube g^0 , at the extremity of which is arranged the objective-casing K^0 , which carries at the side opposite to the eyepiece the objective-aperture P^0 and contains the first prism 1 in front of the objective-glass O^0 , the latter being placed in this way within the described combination of prisms. The distance between prism 1 and prisms 2 3 4 is nearly equal to the whole focal distance of the objective. The prisms 2 and 3 form a double prism and the prism 4 is closely connected to them. It will be easily understood that similar binocular glasses may be constructed with the combination of prisms shown in Fig. 4 and the combination of Fig. 5. In all these cases it is immaterial whether the separated part of the combination of prisms is arranged in front of the objective, as in Figs. 10 and 11, or between the objective and the eyeglass, as in Figs. 8 and 9.

With the arrangements of prisms shown in Figs. 3 and 4 it may sometimes even be of advantage, especially in slightly-magnifying telescopes which often have an objective of less diameter than the ocular field, to place the one separated prism near the eyeglass and the three remaining prisms near the objective, for the reason that in consequence of this changed disposition three small prisms and a large one may be used instead of three large prisms and a small one.

The modified Porro telescopes herein described as components of binocular glasses are also, as applied to single telescopes, to be considered as an object of the present invention. The distance of the axis of the objective-aperture from the axis of the eyeglass considerably exceeding the corresponding distance in the original Porro telescopes enables them to be used for observing at an angle or around the corner. This application of single Porro telescopes, modified according to this invention, is of importance for military purposes, allowing an observer to remain behind a cover while observing. Such a result could up to the present only be obtained by combining with an ordinary telescope an additional set of reflecting-prisms, while according to this invention it is obtained without requiring more elements than constitute a terrestrial telescope.

Figs. 12, 13, and 14 represent a single telescope of this description constructed with an arrangement of prisms corresponding to that of Fig. 4. The separated prism I is placed behind the objective-aperture P' within the objective-casing K' and close to the objective-glass O' , and the prisms II, III, and IV are inclosed in a casing G' , carrying at its front side the eyeglass o' and connected with the objective-casing K' by the tube g' . The four prisms may also be arranged according to Fig. 3 or Fig. 4, with no further alterations of the telescope than a different shape of the casing G' .

What I claim as my invention is—

1. A binocular telescope of stereoscopic ef-

fect, (a telestereoscope) consisting of two parallel Porro telescopes and presenting, when ready for use, a greater distance between the objectives than between the eyeglasses, substantially as shown and described.

2. A telestereoscope consisting of two parallel Porro telescopes and presenting, when ready for use, a greater distance between the objectives than between the eyeglasses, each single telescope having the components of Porro's combination of prisms separated in such a way, that the distance of the objective-

aperture and the axis of the eyeglass is increased beyond the amount determined by the dimensions of the prisms, substantially as described.

In testimony whereof I have hereunto set my hand in the presence of two subscribing witnesses.

ERNST ABBE.

Witnesses:

T. CRAPSKI,
M. FISCHER.