W. SELKE.

APPARATUS FOR PLASTICALLY REPRODUCING OBJECTS.

APPLICATION FILED DEC. 14, 1910.

1,155,010.

Patented Sept. 28, 1915.

2 SHEETS—SHEET 1.

Fig. 1.

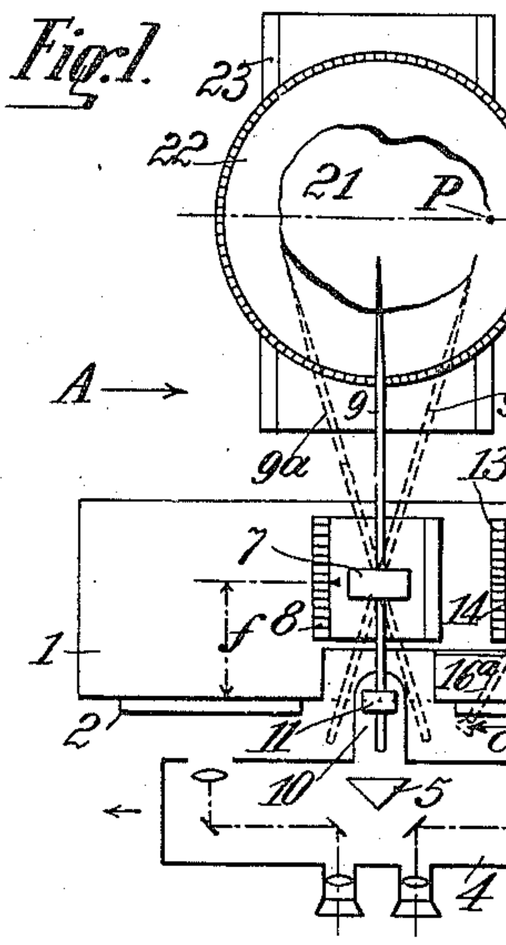


Fig. 3.

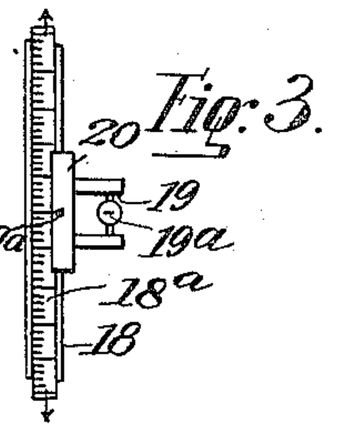


Fig. 2.

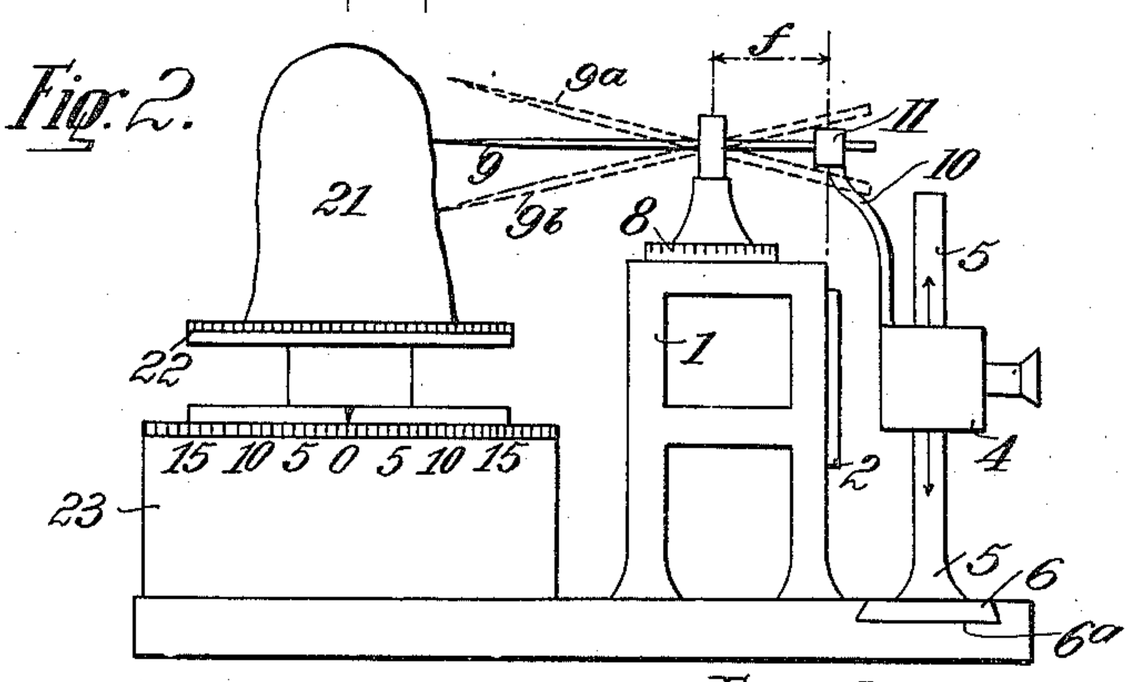


Fig. 4.

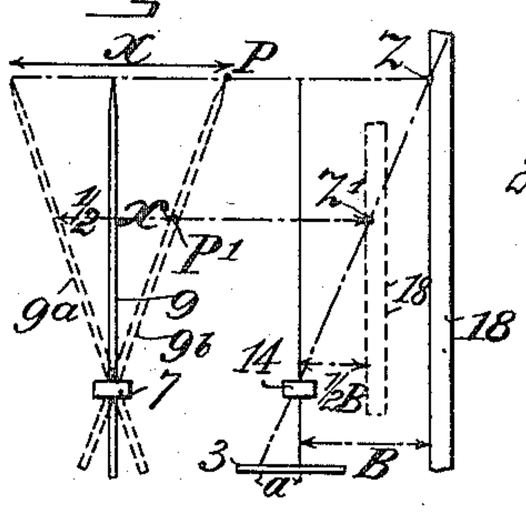
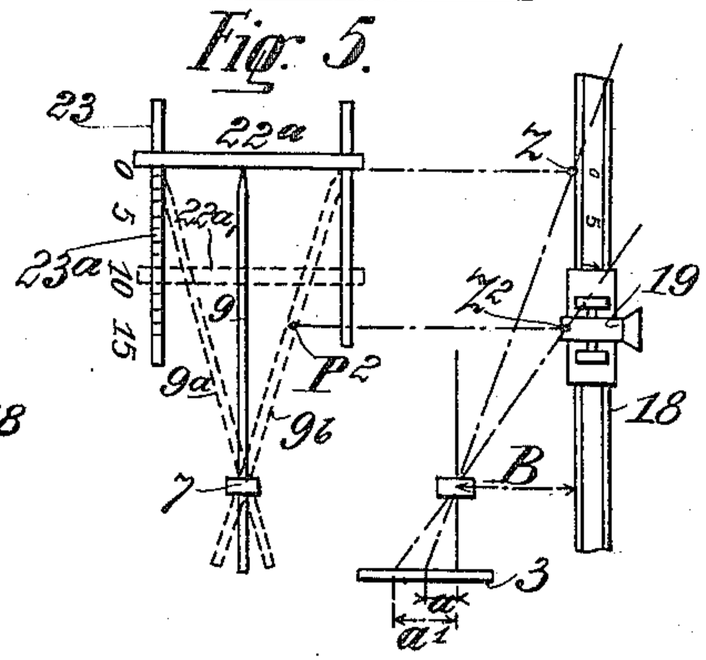


Fig. 5.



Witnesses

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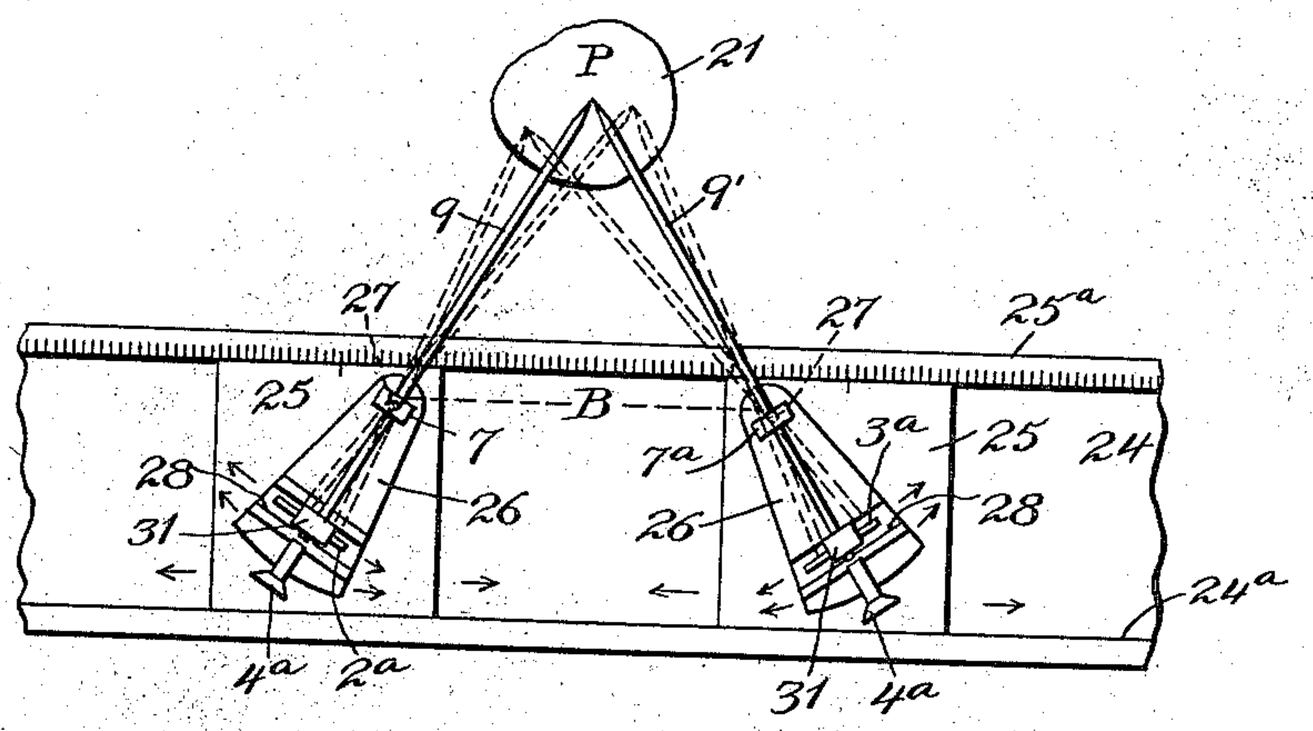
2 SHEETS—SHEET 2.

Fig. 6.



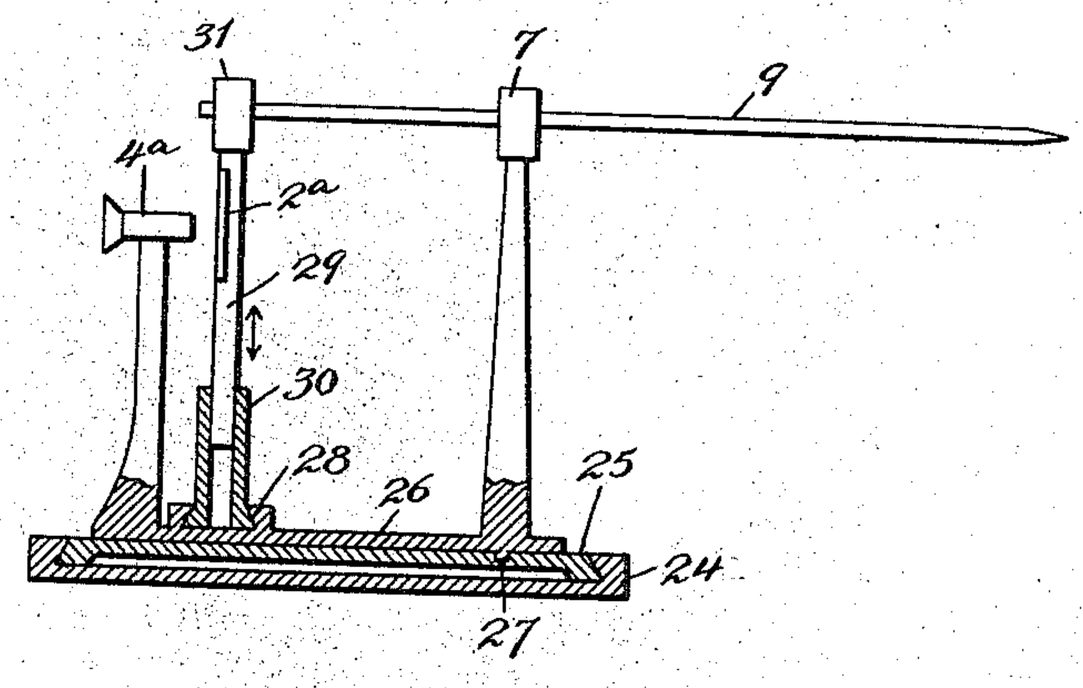


Fig. 7.

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UNITED STATES PATENT OFFICE.

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APPARATUS FOR PLASTICALLY REPRODUCING OBJECTS.

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To all whom it may concern:

Be it known that I, WILLY SELKE, a subject of the German Emperor, and residing at Berlin, Germany, have invented a certain new and useful Improved Apparatus for Plastically Reproducing Objects, of which the following is a specification.

My invention relates to the plastic reproduction of objects, and a primary object is to provide an improved apparatus for plastically reproducing objects by means of phototheodolitic, *i. e.* photogrammetric or stereogrammetric photographs or plates, points from the phototheodolitic photographs being directly transferred by means of suitable mechanical or optical means to a plastic mass.

In the accompanying drawings various forms of the improved apparatus are diagrammatically represented by way of example.

In said drawings:—Figure 1 is a plan view of one form of apparatus, comprising a microscope-stereoscope, adapted to plastically reproduce objects from stereogrammetric theodolitic photographs or plates, which are transferred in such a manner that points in space are determined by the instruments, corresponding to certain points on the photographs; Fig. 2 is a side elevation of the same as seen in the direction of the arrow A in Fig. 1, and Fig. 3 shows a detail in side elevation; Fig. 4 is a diagram indicating how the scale, on which the reproduction is to be made, can be varied, and Fig. 5 is a like view indicating how the object can be reproduced in relief; Fig. 6 is a plan view of an apparatus for the plastic reproduction with the aid of photogrammetric theodolitic plates, Fig. 7 is a vertical section of the same apparatus

Referring first to Figs. 1 to 3, the numeral 1 designates the frame which carries the two phototheodolitic photographs or plates 2 and 3 located in one vertical plane. A binocular microscope-stereoscope 4, which is movable vertically on the guide 5 whose base 6 is slidable in a guide-way 6^a in the base of the frame, can be moved horizontally and vertically in a plane parallel to that of the plates 2, 3 and is arranged in front of the latter for observing the same. A graduated slide 8 which can be moved at right angles to the plane of the plates 2, 3 is slidable on the top of the frame 1 and carries a cardanic suspension 7, in whose center a pointer 9 is mounted axially displaceable. An arm 10 is firmly connected with the microscope-stereoscope 4 and is provided at its top end with a cardanic suspension 11 or the like, in whose center the pointer 9 is likewise mounted.

Obviously, all the horizontal and vertical movements of the microscope-stereoscope 4 are automatically imparted by the arm 10 to the pointer 9, and as the latter is free to rock in all directions, it may for example, occupy the positions 9^a and 9^b indicated by dotted lines. The original relative position of the pointer 9, the plates 2 and 3 and the microscope-stereoscope 4 is determined in such a manner that the direction of 9 stands perpendicularly to the plane of the plate 2 and that the optical axes of the observing instrument 4 pass through the centers of the plates 2 and 3. Now if f be the focal length of the lenses of the phototheodolitic camera used in exposing the plates 2, 3, and if the distance between the cardanic suspensions 7 and 11 be adjusted equal to the distance f, and if any desired image-point on the left-hand plate 2 be sighted by moving the microscope-stereoscope 4 both horizontally and vertically, the pointer 9 will simultaneously be moved automatically in space into, *e. g.* the position 9^b and its longitudinal axis will exactly represent the direction of that ray of light which during the exposure of the plates went from the point of the object in question and formed the corresponding image-point on the plate. Consequently, the longitudinal axis of the pointer in the position 9^b or the extension thereof is the optical line in the three-dimensional space in which the point P which is being sought is to be found.

It now remains to determine the distance of the sought point P in this line from the vertical plane which is parallel to the plates 2, 3 and passes through the center of rotation of the cardanic suspension 7. I do this as follows:—The right-hand phototheodolitic plate 3 is carried by a horizontally movable slide 12 mounted on the frame 1, and is displaceable horizontally by means of the said slide in its own plane, in order that the corresponding image-points, which differ from each other only in the horizontal direction, can be adjusted. The frame 1 also carries a horizontally movable, graduated

slide 13, the movement of which is the same as that of the part 8 and is determined by the focal length f and which carries a bearing 14 revoluble about a vertical axis. A bearing 15 likewise revoluble about a vertical axis is connected vertically above the plate 3 with the slide 12.

A telescope 16 having vertical wires, marks or the like is mounted in the two bearings 14 and 15, it being firmly connected with the bearing 14 while it is freely axially displaceable in the bearing 15. The frame 1 has a lateral, horizontal, graduated slide bar 17 parallel with the plane of the plates 2, 3. A horizontal arm 18 having a millimeter scale 18^a, which is longitudinally movable in the direction of the arrows, as shown in Fig. 3 is slidable freely on this bar 17. A carriage 20 is slidable along this arm 18 and carries a telescope 19 which has a vertical wire, mark, or the like 19^a.

For the purpose of enlarging the range of vision of the telescope 19 I prefer to arrange the latter to rock, as shown, in a plane parallel with the plane of the plates about a horizontal axis. The support 20 of the telescope 19 has a short vertical mark 20^a which corresponds with the mark 19^a of the telescope 19, as shown in Fig. 3. Now when a parallax a (by parallax is to be understood the value, by which the two images of a point deviate from one another, when the two photographs are supposed to be superposed, the one on the other, in such a manner that the two images of an infinitely distant point coincide) is set by moving the plate 3 horizontally, the telescope 16 will simultaneously automatically swing, for example, out of its normal position shown in full lines into the position 16^a shown in dotted lines. But as this telescope is at the same height as the arm 18, when looking through the telescope located in the position 16^a the arm 18 will be seen. When using the instrument the distance of the arm 18 from the vertical axis of the bearing 14 is made equal to the base B, *i. e.* the distance between the objectives when the exposure was made, and then the point Z at which the visual ray of the telescope in the position 16^a strikes the arm 18 is the sought distance of that image point whose parallax a has been set. Now while one person looks through the telescope 16 in the position 16^a, by shifting the telescope 19 along the arm 18 its vertical mark 20^a is caused to register with the scale division which is seen in the telescope 16, when the optical axis of the telescope 19 will lie in the required plane. When the telescope 19 is in this position, its optical axis is located in the so-called Z-plane of all image points of like parallax a and consequently this plane contains the point P which is being sought in space. It now only remains to look through the telescope 19 to sight the pointer 9 in its position 9^b and simultaneously to displace the pointer 9 axially until its point apparently contacts with the vertical mark 19^a in the field of the telescope 19. At this moment the point of the pointer 9 represents the image point P placed back into space.

Instead of the pointer 9 I may use a telescope and transfer the point P, at which the two visual rays of the telescopes intersect when in the positions 9^b and 19^b, by means of suitable modeling instruments to the plastic mass.

The work-piece or plastic mass 21 is arranged behind the frame 1 on a rotatable graduated table or plate 22 which can be displaced on the graduated table 23 in a direction at right angles to the plane of the plates 2, 3. After the desired number of image points have been transferred in the above described manner to the one side of the work-piece, the latter is rotated an angle equal to the angle which another pair of stereophotogrammetric plates formed during the exposure with that last employed, whereby it is possible to work another side of the work-piece in accordance with other phototheodolitic plates.

Fig. 4 illustrates how plastic reproductions may be made on various scales according to my invention. For example, if it is wished to make the reproduction half the natural size, I place the arm 18 at a distance $\frac{1}{2}$B from the axis of rotation of the bearing 14 equal to half the base B which was used when the exposures were made. The Z-plane is now obtained at Z^1, so that the image point P is displaced to P^1 and the natural dimension x of the plastic reproduction is diminished in all three dimensions to $\frac{1}{2}x$.

Fig. 5 illustrates how reliefs can be made one-third the natural height according to my invention. Any image point which *e. g.* has the parallax a and is afterward to be located in the plane of the background of the relief is first selected on the plates 2 and 3 and the range-plane of this point is found in the manner described above with reference to Figs. 1 to 3. Instead of the rotatable plate 22, a vertical background plate 22^a is then placed on the table 23 and pushed into the position shown in full lines with its face in this range-plane found for the said selected point. The movable scale 18^a in the arm 18 Fig. 3 is then shifted longitudinally until the zero point of its scale coincides with the range-plane, as shown. Any other desired image point, which *e. g.* has the parallax a^1, is then selected on the plates 2 and 3, whereupon the appertaining range-plane z^2, *e. g.* at the division 15 of the scale 18^a, is found according to the above described mode of operation, and the appertaining point P^2 in space. This point is located at a natural

and correct distance, *e. g.* 15 divisions, from the face of the background 22^a. Now when a relief is to be made having one-third this natural and correct height, the background plate is placed with the aid of the scale 23^a two-thirds of 15 divisions toward the front, *i. e.* at division 10 of the scale 23^a in the position shown at $22^{a'}$ in dotted lines. The remaining distance from $22^{a'}$ to the point P^z is then equal to the height of the relief, *i. e.* to one-third the natural height. The heights of all the other measured points of the work-piece are reduced in the same manner, so that a relief one-third the natural height is produced. Reliefs may also be made according to my invention in another manner. Referring to Fig. 1, if the distance of the axis of rotation of the suspension 7 from the similar axis of the suspension 11^a is made equal to $\frac{1}{3}f$ instead of equal to f, when sighting the plate 2, the point of the pointer 9 will move three times the normal distance, so that the face of the work-piece or plastic mass becomes enlarged threefold; the natural correct depths, however, simultaneously remain as in Fig. 1, so that these are now too small relatively to the threefold frontal expansion, and therefore a relief having one-third the natural height is obtained.

Fig. 6 shows how an apparatus for plastic reproduction with the aid of photogrammetric plates, *i. e.* phototheodolitic plates, whose axes formed an angle with one another when exposed. A ground-plate 24 is provided with a guide-way 24^a, two slides 25 being horizontally movable along this guide-way. A plate 26 is fitted on each of these slides rotatable about a pivot 27 and carries a microscope 4^a fixed to it, a guide-way 28 and a cardanic-suspension 7 and 7^a respectively, the center of which latter lies vertically above the pivot 27. The plates 2^a and 3^a are fixed each on a support 29, which support is vertically movable by means of a guide-way 30. Each of the pointers 9 and 9^1 passes through the cardanic-suspension 7 and 7^a respectively and through a cardanic-suspension 31, which latter is fixed on the top of the support 29 corresponding to it. The two plates 2^a and 3^a are placed at an angle to one another corresponding to that used during the exposure, exactly as previously the stereogrammetric plates were arranged parallel to one another corresponding to their parallel position during exposure. First the image points of the left-hand plate 2^a are sighted with one ocular, preferably by a microscope 4^a, when the pointer 9 swings automatically exactly as described above with reference to Fig. 1, in the three-dimensional space and fixes the direction in which the sought point P is located in space. This same operation is then repeated with the right-hand plate 3^a and the direction of the other corresponding sighted image point determined in like manner by a second pointer 9^1. The distance between the centers of rotation 7 and 7^a is equal to the base B used during the exposure of the photogrammetric plates. As soon as the points of the two pointers touch one another, the sought point P is automatically located in the three-dimensional space and can be transferred to the work-piece 21. In this case also one or two sighting devices, such as 16 in Fig. 1, may be employed instead of one or both pointers.

Reproductions on a changed scale are made by the distance B between the two bearings 7 and 7^a being varied in proportion to the desired enlargement or reduction. This distance can be read off on a scale 25^a provided on the ground-plate 24^a.

The hereindescribed apparatuses for plastically reproducing phototheodolitic photographs or plates may be very considerably constructively varied without departing from the spirit and scope of my invention. For example, the automatic movements of the sighting devices 9 and 16 may be brought about by connecting these devices with the two plates and making these movable, while the microscope-stereoscope remains stationary. Likewise, the two phototheodolitic plates may be mounted horizontally and the driving and supporting bearings for the sighting devices 9 and 16 may be arranged in other suitable manner. Also, the telescopes 16 and 19 may be substituted by metallic pointers. The movements of the telescope 19, of the arm 18 and of the various slides may be brought about in any desired manner.

I am aware that it has heretofore been proposed to make plastic reproductions according to ordinary photographic plates or photographs by means of a stippling process. I am also aware that it is well-known to measure stereogrammetric phototheodolitic photographs or plates by means of a microscope-stereoscope and directly to transfer the measurements to drawing devices, with the aid of which plans or maps can be made. Also, it is well-known to observe virtual images through a Wheatstone's mirror-stereoscope for the purpose of constructing topographical plans. I do not broadly claim any apparatus for carrying into practice these known methods, but—

I claim:—

1. An apparatus for plastically reproducing an object with the aid of two phototheodolitic photographs of the said object comprising optical observing instruments, means for moving the said photographs and the said optical observing instruments relatively to one another for directing the said instruments on corresponding points of the said photographs, a plurality of movable carriers

of directional lines and means for transmitting positively the said relative movement to said movable carriers.

2. An apparatus for plastically reproducing an object with the aid of two phototheodolitic photographs of the said object, which photographs lie in one plane, comprising optical observing instruments, means for moving the said photographs and the said optical observing instruments relatively to one another for directing the said instruments on corresponding points of the said photographs, three movable carriers of directional lines and means for transmitting positively the said relative movement to two such carriers, the latter carriers being rotatable about adjustable points, the third carrier containing a mark, being displaceable in the direction parallel to the photographs and being adapted to coact with one of the said two other carriers.

3. An apparatus for plastically reproducing an object with the aid of two phototheodolitic photographs of the said object, which photographs lie in one plane, comprising optical observing instruments, means for moving the said photographs and the said optical observing instruments relatively to one another for directing the said instruments on corresponding points of the said photographs, three movable carriers of directional lines and means for transmitting positively the said relative movement to two such carriers, the latter carriers being rotatable about adjustable points, the third carrier containing a mark, being displaceable in the direction parallel to the photographs and being adapted to coact with one of the said two other carriers, the dependency of the angular movements of this latter carrier on the relative movements of the observing instrument and the photograph, which both pertain to this carrier, being variable.

4. An apparatus for plastically reproducing an object with the aid of two phototheodolitic photographs of the said object, which photographs lie in one plane, comprising optical observing instruments, means for moving the said photographs and the said optical observing instruments relatively to one another for directing the said instruments on corresponding points of the said photographs, three movable carriers of directional lines and means for transmitting positively the said relative movement to two such carriers, the latter carriers being rotatable about adjustable points, the third carrier containing a mark, being displaceable in the direction parallel to the photographs and being adapted to coact with one of the said two other carriers, the distance between the plastic reproduction and the photographs being variable.

In testimony whereof, I affix my signature in the presence of two witnesses.

WILLY SELKE.

Witnesses:
HENRY HASPER,
WOLDEMAR HAUPT.