June 11, 1929. H. M. EDMUNDS 1,716,768

GUIDE PLATE FOR REPRODUCING THREE DIMENSIONAL FIGURES AND APPARATUS FOR AND PROCESS OF MAKING THE SAME

Filed Jan. 17, 1923 2 Sheets-Sheet 1

Fig:1.

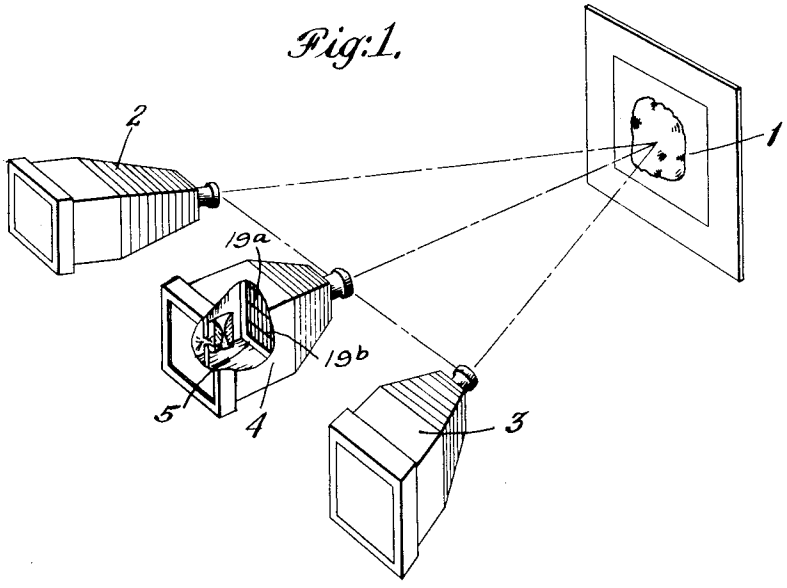
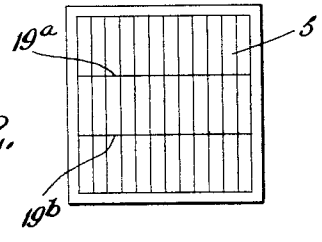


Fig:2.



Howard M Edmunds Inventor

By Frederick S. Duncan Attorney

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Fig: 3.

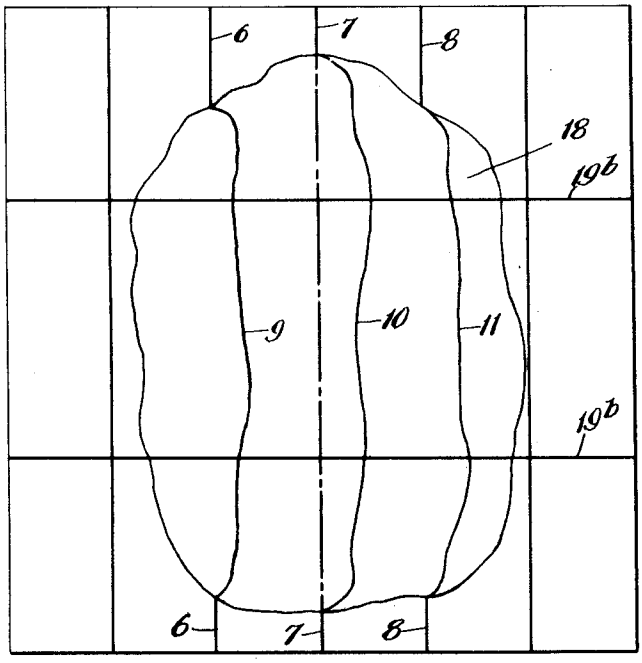
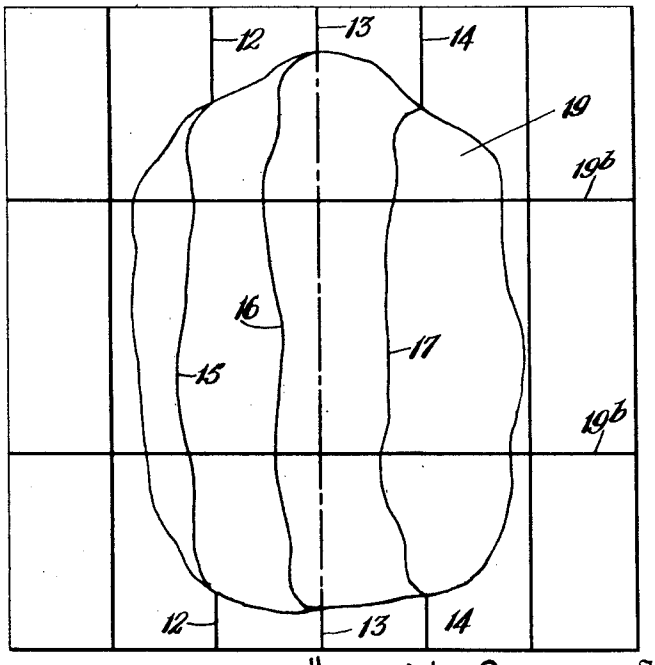


Fig: 4.



Howard M. Edmunds, Inventor

By Frederick B. Duncan Attorney

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UNITED STATES PATENT OFFICE.

HOWARD M. EDMUNDS, OF BRIGHTON, ENGLAND.

GUIDE PLATE FOR REPRODUCING THREE DIMENSIONAL FIGURES AND APPARATUS FOR AND PROCESS OF MAKING THE SAME.

Continuation of application Serial No. 393,962, filed July 3, 1920, and in Great Britain January 18, 1922. This application filed January 17, 1923. Serial No. 613,244.

In my United States Letters Patent No. 1,485,493, dated March 4, 1924, I describe a process of reproducing the surface of three dimensional figures, which process, broadly described, consists in preparing a plate provided with a lineal guiding element defining with respect to the locus of the known line on said plate the contour lines of said figure. The plate is then preferably by means of a suitable machine moved in its own plane in such manner that any point in the plate describes a line similar to the known line, and thereby actuates a graver having sliding connection with the guiding element. Simultaneously with this motion, a block of material is actuated in a plane transverse to that of the motion of the graver and in coordination with the movement of the plate. More specifically, the process described in said application consists in projecting a spiral on a figure and it may be on a screen against which the figure is set in relief, and then photographing the figure and the resulting displaced spiral from such position that an apparent magnitude of the displacement of the spiral from its projection thereon on a given or assumed plane of relief is registered on the photographic negative.

By way of example of the manner in which the aforementioned plate can be utilized, I also, in the above mentioned application, describe a machine which is adapted to impart suitable motion to the plate whereby the graver is actuated in coordination therewith to carve the reproduction of the relief surface in suitable material.

The present application relates to a modified method of carrying out this process and of utilizing the guide plates produced, and consists essentially in the utilization of a lineal design consisting of straight lines as distinguished from curved lines. While, preferably, these straight lines are parallel and equally spaced, it may well be that it would be found desirable that they simply be non-intersecting on the screen and variably spaced whether parallel or not. The reason, however, why I prefer that the lines be parallel and uniformly spaced is that the guide plate produced may be used with greater facility in a machine, and a machine adapted for utilizing such a plate is of relatively simple construction.

One object of the invention is to provide a method of producing a guide plate in which the base lines with reference to which the contour lines are located shall be straight.

Another object is to provide a guide plate for the above described purpose which may be easily used in a machine of simple construction.

Another object is to provide a guide plate for the above-described purpose of such nature that the contour lines thereon may be easily followed in case a machine is used wherein the guiding of the drill or graver is effected by following the contour lines with the eye, usually by means of a microscope provided with cross hairs.

The principles of which I make use in preparing the guide plate have been described in full in my patent above referred to, but I will briefly summarize them for the purpose of making their adaptation to the present modification clear.

If by means of a transparency placed in the usual manner in an optical projector, preferably provided with a well corrected lens, an image of a line be thrown on an object, each point in the line so thrown may be considered as having been displaced from the position on any assumed plane of relief which it would have occupied were not the object interposed between the projector lens and the said plane, the measure of actual displacement being the distance from the point on the surface of the object to the point on the plane from which it is considered as having been displaced. It follows, therefore, that the entire line may be considered as having been displaced from the position which it would have occupied on the plane were not the object interposed. This principle may be availed of and the extent of displacement recorded on a photographic negative if the image be recorded by means of a camera so positioned that the rays passing through the camera lens proceed from the object at an angle to the line in which they are projected. If the position on the camera plate of the corresponding base line, that is, the point of projection on the plane of the lineal design, be known or ascertainable, a plate is produced on which is defined a line, every point in which is distant from a known or ascertainable point on the plate according to a ratio that is at least substantially constant for every contour point on

the surface of the object and its corresponding point of projection on the plane.

In this application I show the use of two cameras, the incident nodal points of the lenses of which for truest accuracy are carefully adjusted to lie in the emergent nodal plane of the projector lens, this plane being parallel to the screen and normal to the axis of the projector lens. The virtue of this particular arrangement arises out of the fact that the displacement as recorded on the photographic negatives is precisely the same in both cases. This fact makes it possible to utilize two cameras and two guide plates in a carving machine. I do not, however, limit my invention to this precise arrangement. It is merely shown as being a preferable form of apparatus, the practical reasons being that, in the case of most objects which it would be desired to reproduce, such as the head of a person, one camera cannot "see" or record all points thereon. All points of such an object may, however, as a rule be recorded by two cameras placed in the relative positions herein shown. It is a fact, however, that if the incident nodal point of the camera lens is in the emergent nodal plane of the projector lens and this plane is parallel to the screen, the ratio of apparent displacement to actual displacement comes the nearest to being a constant for all points on the surface of the figure to be reproduced. In other words, if one camera only is employed, the extent of variation in the distances of the projector lens and the camera lens from the screen is determined solely by the accuracy of the reproduction desired. On the other hand, when two cameras are used, it is highly important that the precise arrangement of camera and projectors be adhered to, as otherwise the apparent displacement of any given point would vary as between the two photographic negatives, and consequently it would be difficult to utilize the two plates in one machine.

It has been shown that in the prescribed position of camera and projector, displacements of all points which lie at a fixed distance from the hypothetical plane of relief are equal and take place in directions which are all parallel to each other. It will be obvious that if there is a departure from the ideal position of the camera herein specified, the above laws will no longer rigidly apply but in such a case measurably accurate results may still be obtained.

Referring to the drawings:

Figure 1 is a perspective view of the apparatus for taking the photographic negatives which may serve as guide plates or as means for making guide plates for use in a machine for carving the reproduction.

Figure 2 is a diagrammatic view of a suitable form of right line design for use as a transparency in the projector.

Figure 3 is a diagrammatic view of a photograph or guide plate, as the case may be, taken from the camera situated to the left of the projector. The broken line shown in this figure would not appear in the actual photograph.

Figure 4 is a view of the photograph or guide plate, as the case may be, taken by the camera situated at the right of the projector. The broken line shown in this figure would not appear in the actual photograph.

The apparatus as shown in Figure 1 consists of a suitable screen 1, preferably two cameras 2 and 3 and a light projector 4 by means of which the transparency may be thrown on an object 4^a placed before the screen. Preferably the relative positions of these various members of the unit are as follows:

The screen is erect. The projector is placed so that the axis of its lens strikes the approximate center of the screen perpendicularly. The cameras are placed one on either side of the projector, the incident nodal points of their lenses being in line with the emergent nodal point of the projector lens, this line being preferably horizontal. In the form of transparency indicated by the numeral 5, Figure 2, the right lines are shown as parallel and uniformly spaced.

The foregoing describes a preferable arrangement only and one that is adapted to secure the best and most accurate results. Many of these requirements may, however, be dispensed with or varied to a considerable extent without seriously impairing the accuracy of the results obtained. For instance, a single camera may be used, in which event its distance from the screen as compared with the distance of the projector may be varied considerably without markedly affecting the correctness of the reproduction. The axis of the camera lenses may intersect the screen at the point of intersection of the axis of the projector lens, altho for purposes of use in a machine correction of the negative or guide plate, as the case may be, would be necessary, unless complicated mechanical motions were utilized. The vertical position of the screen is of course a matter of convenience only, and it is not necessary that the axis of the projector lens be perpendicular to the screen, or that the incident nodal points of the camera lenses be in a straight line with the emergent nodal point of the projector lens; altho if two cameras be used, it is highly desirable that such should be the arrangement. The lines of the grid are preferably perpendicular to the line joining the lenses of the cameras and projector, altho such a relationship is not necessary for carrying out the principle involved, it simply being a requirement that makes the resulting negatives more easily utilized in a machine for carving.

The resultant photographs are shown diagrammatically in Figures 3 and 4, Figure 3

showing the photograph with the displaced lines as taken by camera 2, and Figure 4 showing the negative with distorted lines taken by camera 3. It is necessary to show these photographs diagrammatically for the reason that in actual practice the lines on the transparency would be so spaced as to produce on the photograph a spacing of from fifty to one hundred lines to the inch.

Referring more particularly to Figure 3, the lines 6, 8 and the solid portions of line 7 indicate the exposed portion of the lines thrown on the screen, while the lines 9, 10 and 11 indicate the displacements of these lines as registered on the negative. The image of the object is indicated by the numeral 18 in Figure 3 and by 19 in Figure 4. The broken portion of the line 7 would not appear on the actual photograph. It is, however, desirable to show it for the purpose of indicating the position of the imaginary base line corresponding to the contour line 10. Of course, the contour lines 9 and 11 are fixed with reference to similar base lines which it is not considered necessary to show in the drawing.

Referring to Figure 4, the lines 12, 14 and the solid portions of line 13 represent the same three lines as are indicated in Figure 3 by the numerals 6, 7 and 8, while the lines 15, 16 and 17 represent the apparent displacements of these lines as registered by camera 3. As in the case of the line 7, the broken portion of the line 13 would not appear in the actual photograph. It is, however, desirable to show it for the purpose of indicating the position of the imaginary base line coresponding to the contour line 16. Of course, the contour lines 15 and 17 are fixed with reference to similar base lines which it is not considered necessary to show in the drawings.

When two cameras are employed in the preferred arrangement above described, any given point on the object is displaced the same distance from its corresponding base point whether registered by camera 2 or by camera 3, except that the displacement is to one side or the other of the base point depending upon the side of the projector from which the negative is taken. This means that there are two photographs produced identical with each other, except for the direction of apparent displacement of the points.

It is obvious from the foregoing description that either one of these photographs is a graphical representation on a plane surface of the orientation of all points on the object upon which the lines from the projector fall. As a matter of fact the lines are preferably placed so close together in practice that virtually the entire surface of the object is covered. Either one of these photographs may be utilized in a suitable pantograph machine for reproducing the original subject of the photographs in any degree of relief that may be required. As the photographs are counterparts of each other, with the exception above mentioned as to the direction of displacement of the points, either one may be used in such a pantograph, or both if desired, the motion of the pantograph being adapted to this difference. A pantograph or machine for utilizing the negatives in the reproduction of the original forms the subject matter of a separate Patent No. 1,615,261, dated January 25, 1927.

It is not ordinarily convenient to secure a negative having lines of proper dimensions for utilization in a given machine. Therefore to secure a guide plate suitable for use in a suitable machine, it is usually necessary to increase or decrease, as the case may be, the size of the negative so that the base lines thereon will be properly coordinated with a machine in which provision is made for step by step motion; that is to say, the spacing of the base lines on the guide plate must be precisely coordinated with the relative step by step motion of the carriage of the machine and the guide plate. Of course the necessity for this adjustment of size of the guide plate is not necessary for use in a machine in which provision is made for adjusting the step by step and other coordinated motions. However, I have found it more convenient to adjust the size of the guide plate to the machine, the latter being adapted for a fixed motion; and to assist me in doing so, I provide on the transparency the lines 19^a which are reproduced on the guide plate as shown by the lines 19^b. These lines on the transparency are perpendicular to the vertical lines and are of known distance apart. The photograph is ordinarily taken without reference to the size of the guide plate desired, and as the distance apart of the vertical lines is also known, these horizontal lines 19^b serve as a means of ascertaining what size of guide plate is necessary for use in the machine; that is to say, in order to bring the vertical lines a suitable distance apart for use in the machine, it is merely necessary to produce a guide plate from the negative in which the horizontal lines are placed apart a distance proportionate to any required change in the distance between the vertical lines.

It is obvious that since these horizontal lines are parallel with line joining camera and projector nodes that they will appear straight and parallel on the guide plate, so that the spacing of these lines will be an absolute measure of the scale of the guide plate, provided the hereinbefore specified positional arrangement of the units of the apparatus has been accurately carried out.

For purposes of considering the principles involved in my invention, it is convenient to assume the use of an actual screen which may serve as a plane of relief with respect to which

the contour lines are displaced. It is not to be considered, however, that, in actual practice, an actual screen is necessary, or in many cases, even desirable. The reproduction may be made with respect to any actual or hypothetical plane of relief desired. This hypothetical plane of relief lies parallel to the plane of the transparency in the projector and is preferably positioned about the axis of the projector lens and normal to that axis. The preferred position of the transparency in the projector is normal to the axis of the projector lens with its central point lying in said axis.

It is obvious that with the axis of the projector lens parallel with the axis of the camera lens the less the divergence of the rays from the projector lens, the less will be the error due to lateral distortion; that is to say, the further from the object the projector is placed (the camera at the same time being placed an approximately equal distance from the object), the less will be this lateral distortion of the finished figure.

Having thus described my invention and with the knowledge that changes and modifications may be made which will nevertheless come within the spirit and scope thereof as defined by the appended claims, I claim:

1. The process of making a guide plate for use in producing solid reproductions of objects either in full or altered scale and in full or altered degree of relief, which consists in throwing, by means of a light projector, a series of non-intersecting right lines on an object in relief against a screen which is normal to the optical axis of said projector and photographing said line by means of a camera, the axis of the lens of which is parallel to the axis of the projector lens and the emergent nodal point of the lens of which is in a plane normal to said optical axis and passing through the emergent nodal point of the lens of said projector.

2. The process of making a guide plate for use in producing solid reproductions of objects either in full or altered scale and in full or altered degree of relief which consists in the optical projection of a series of non-intersecting right lines upon the object and the photographing of such object by a camera so positioned that the emergent nodal point of the projector lens and the incident nodal point of the camera lens lie in a plane normal to the optical axis of the camera lens the axes of both projector and camera lenses being parallel.

3. The process of representing in a plane the contour of a relief surface which consists in throwing a grid transparency on said surface by means of a projector having its optical axis normal to the plane of relief, and photographing the design thus thrown by means of a camera positioned with its optical axis also normal to the said plane of relief whereby an apparent displacement of said design from said plane of relief is registered on the photographic plate.

4. The process of representing on a pair of coordinated guide plates the contour of a relief surface which comprises throwing a design consisting of a series of uniformly spaced parallel straight lines on said surface by means of a projector having its optical axis normal to the plane of relief, and photographing the design thus thrown by means of a pair of cameras, one on either side of said projector, so positioned that the optical axes of their lenses are also normal to the said plane of relief whereby an apparent displacement of said design from said plane of relief is registered on photographic plates.

5. The process of making a graphical record on a plane surface of the shape of a solid object which consists in the optical projection thereon of a system of markings composed of a series of non-intersecting straight lines and the photographing of such object by two cameras so positioned that the incident nodal points of the lenses of said cameras and the emergent nodal point of the projector lens are in an imaginary line joining them, said line being parallel to a desired plane of relief, the said cameras being located one on either side of the projector lens, the said lines being at right angles to the said parallel lines.

6. The process of making a graphical record on a plane surface of the shape of a solid object which consists in the optical projection thereon of a system of markings composed of a series of non-intersecting straight lines and the photographing of such object by two cameras so positioned that the incident nodal points of the lenses of said cameras and the emergent nodal point of the projector lens are in an imaginary line joining them, said line being parallel to a desired plane of relief and the said cameras being located one on either side of the projector lens and being spaced equidistant therefrom, the said lines being at right angles to said parallel lines.

7. A guide plate for use in reproducing relief surfaces on which is defined a series of lines defining with reference to known or ascertainable straight lines on said plate, the contour of a relief surface taken with reference to and substantially in projection from similar lines in the plane of relief of said relief surface, the perpendicular distance from said straight lines to the first mentioned lines being the same for all points in any given plane parallel with the plane of relief of the surface to be reproduced.

8. A guide plate for use in producing relief surfaces comprising a plate on which is defined a series of lines defining the contour of a relief surface with reference to a series of straight lines on said plate, said straight lines corresponding to similar lines in the plane of relief of the surface that is to be re-

produced, said contour being taken substantially in projection from said straight lines, the perpendicular distance from said straight lines to the first mentioned lines being the same for all points in any given plane parallel with the plane of relief of the surface to be reproduced.

9. A guide plate for use in producing relief surfaces comprising a plate on which is defined a series of lines defining with references to the locus of a grid on said plate the contour of a given relief surface in projection from a similar grid in the plane of relief of said given relief surface, each point in said first-mentioned lines being displaced from said locus in the plane thereof and the direction of displacement of all of said points being parallel, the perpendicular distance from the lines of the grid on the plate to the contour lines thereon being the same for all points in any given plane parallel with the plane of relief of the surface to be reproduced.

10. A complement of guide plates for use in reproducing a given object in partial or full relief each of which consists of a plane surface on which is defined a series of lines representing with respect to a grid design on said plate an apparent lateral displacement in a given plane of relief of said object of a similar grid design projected on said object, the said apparent lateral displacement being the same for all points in a given plane parallel with the plane of relief.

11. A complement of guide plates for use in reproducing a given object in partial or full relief, each of which consists of a plane surface on which is defined a series of lines representing with respect to a grid design on said plate an apparent lateral displacement in a given plane of relief of said object of a similar grid design projected on said object, said displacements being in opposite directions and said apparent lateral displacement being the same for all points in a given plane parallel with the plane of relief.

12. In apparatus for reproducing three-dimensional figures, a projector and a camera and their lens axes parallel and the emergent nodal plane of the projector lens coincident with the incident nodal plane of the camera lens, a transparency of straight parallel lines placed in the projector in a plane normal to the projector lens axis and with its center lying approximately in said axis and the plate of the camera lying also in the plane normal to the lens axis, the lines of the transparency being placed at right angles to the line joining the projector and camera nodes.

In testimony whereof, I have signed this specification.

HOWARD M. EDMUNDS.