

Nov. 16, 1965

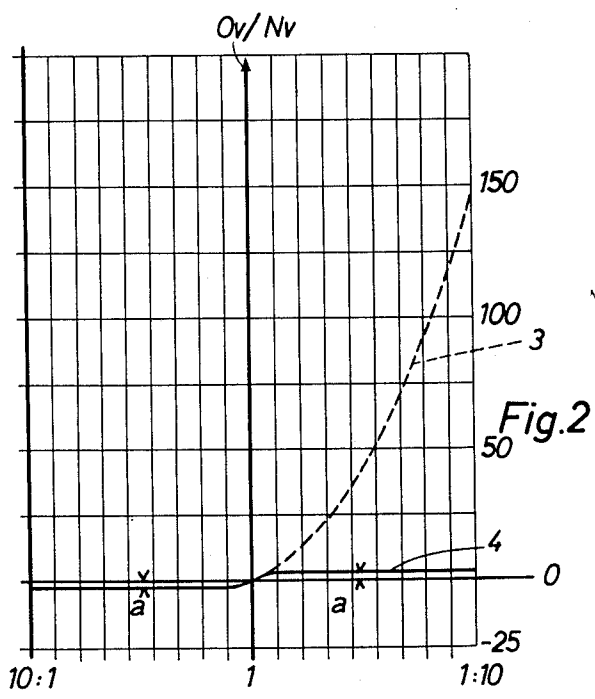
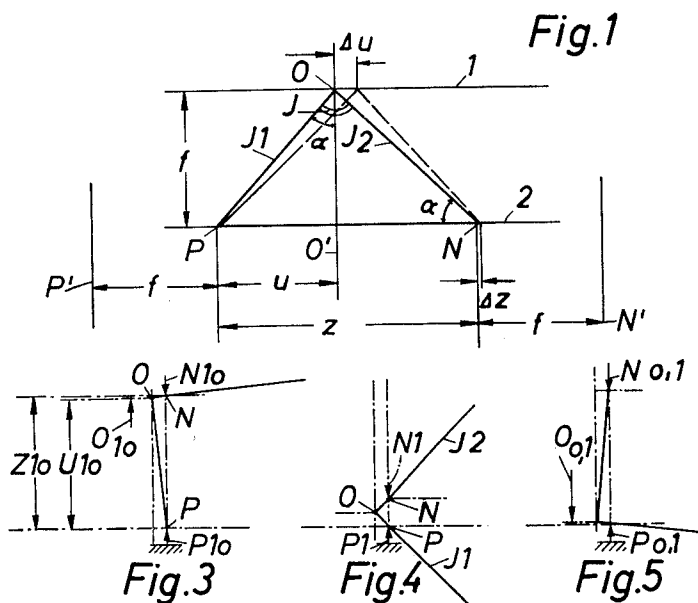
A. SEIZINGER

3,217,593

PHOTOGRAPHIC REPRODUCTION APPARATUS

Filed June 26, 1962

7 Sheets-Sheet 1



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3,217,593

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Fig.6

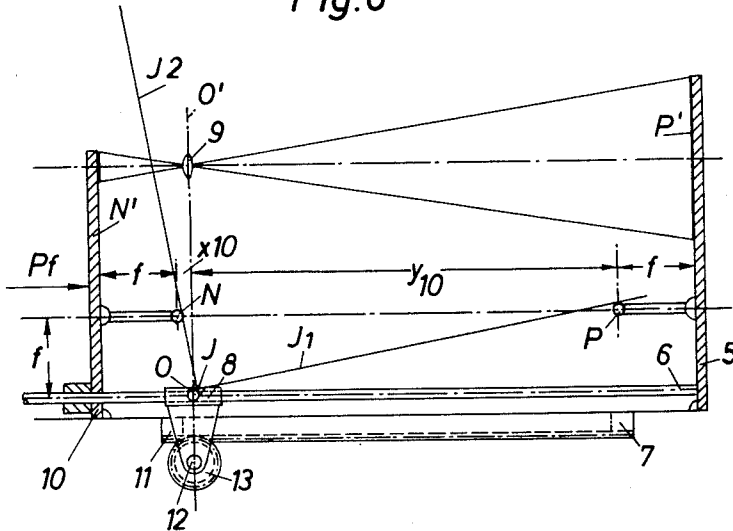
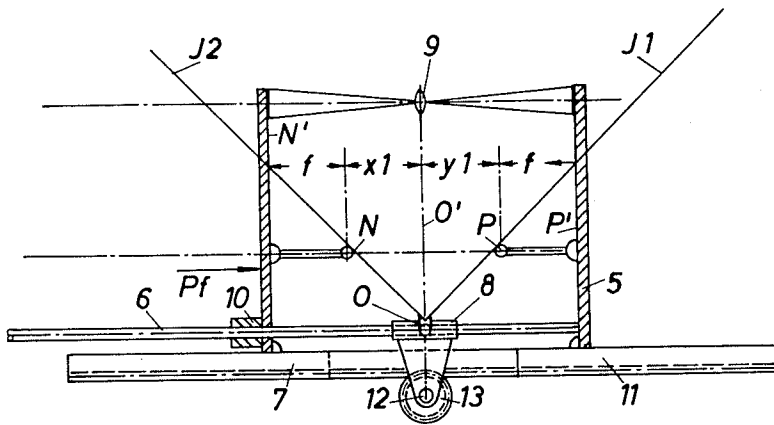


Fig.7



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Fig.8

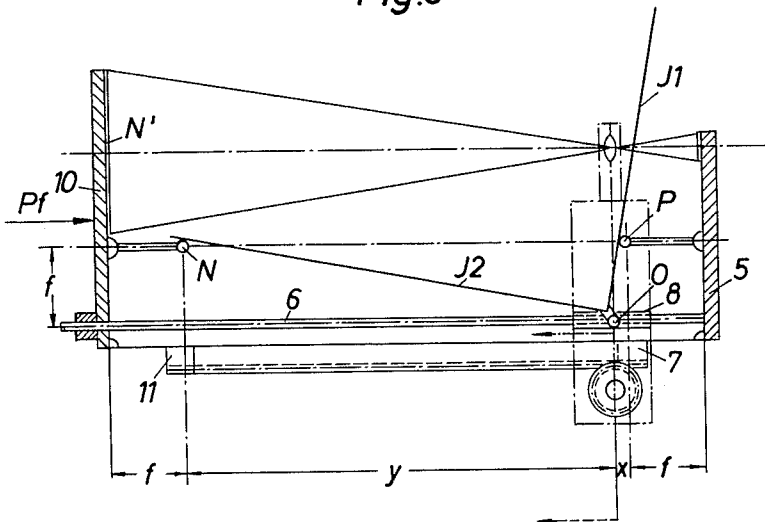
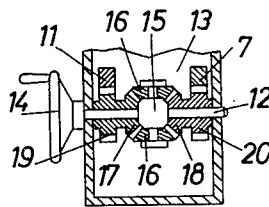


Fig.9



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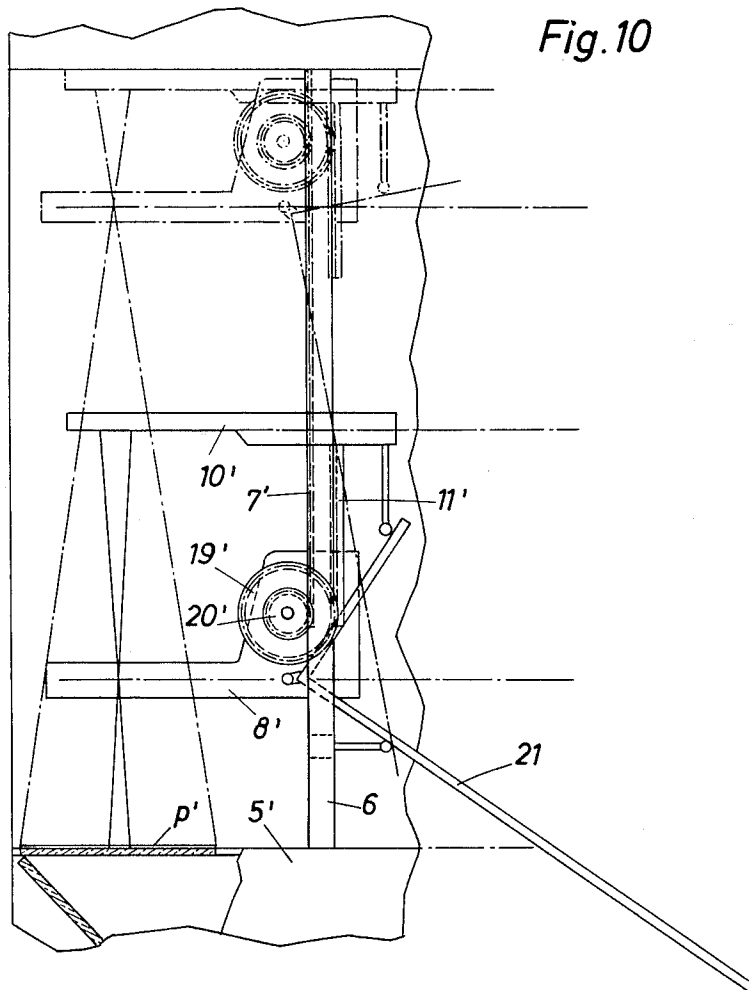
A. SEIZINGER

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PHOTOGRAPHIC REPRODUCTION APPARATUS

Filed June 26, 1962

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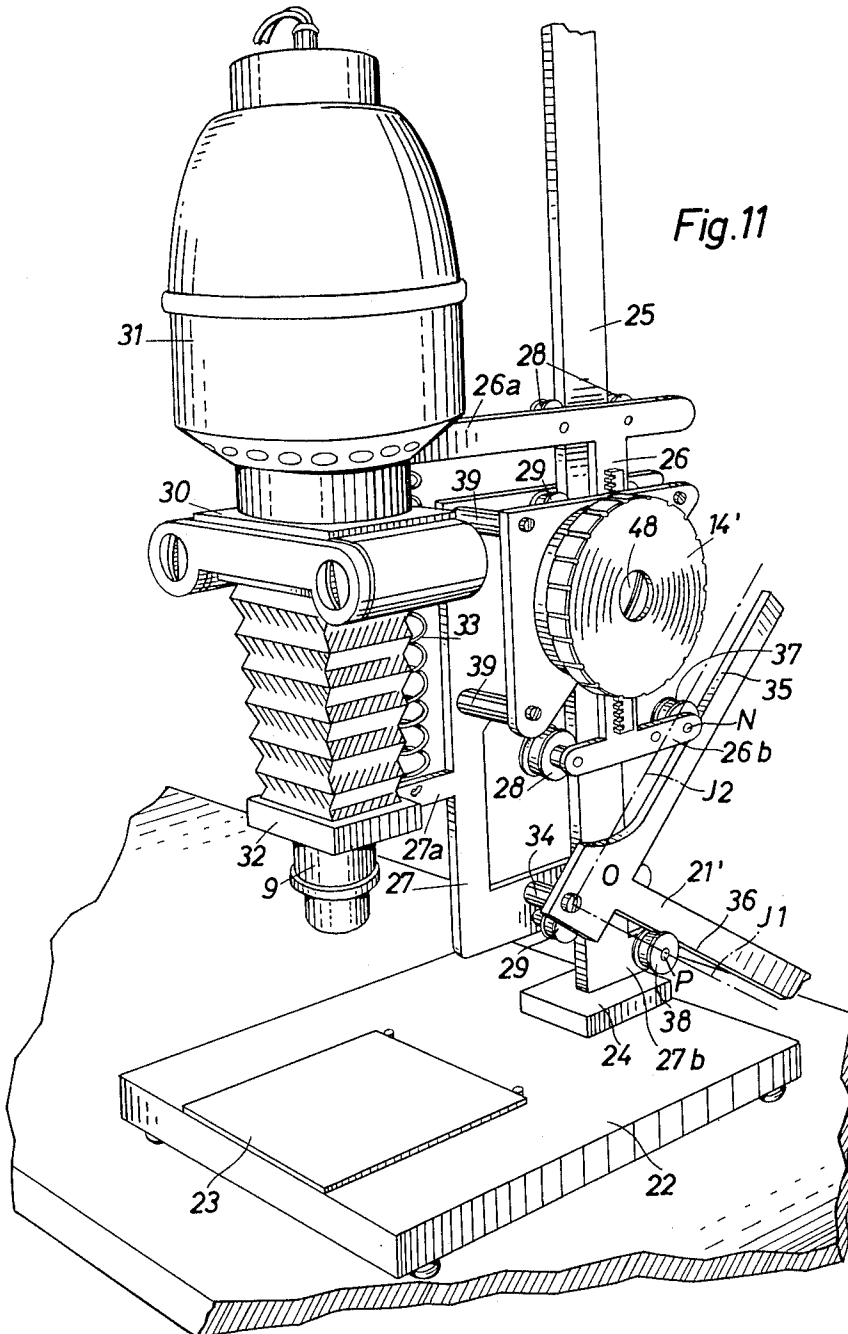
A. SEIZINGER

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Filed June 26, 1962

7 Sheets-Sheet 5



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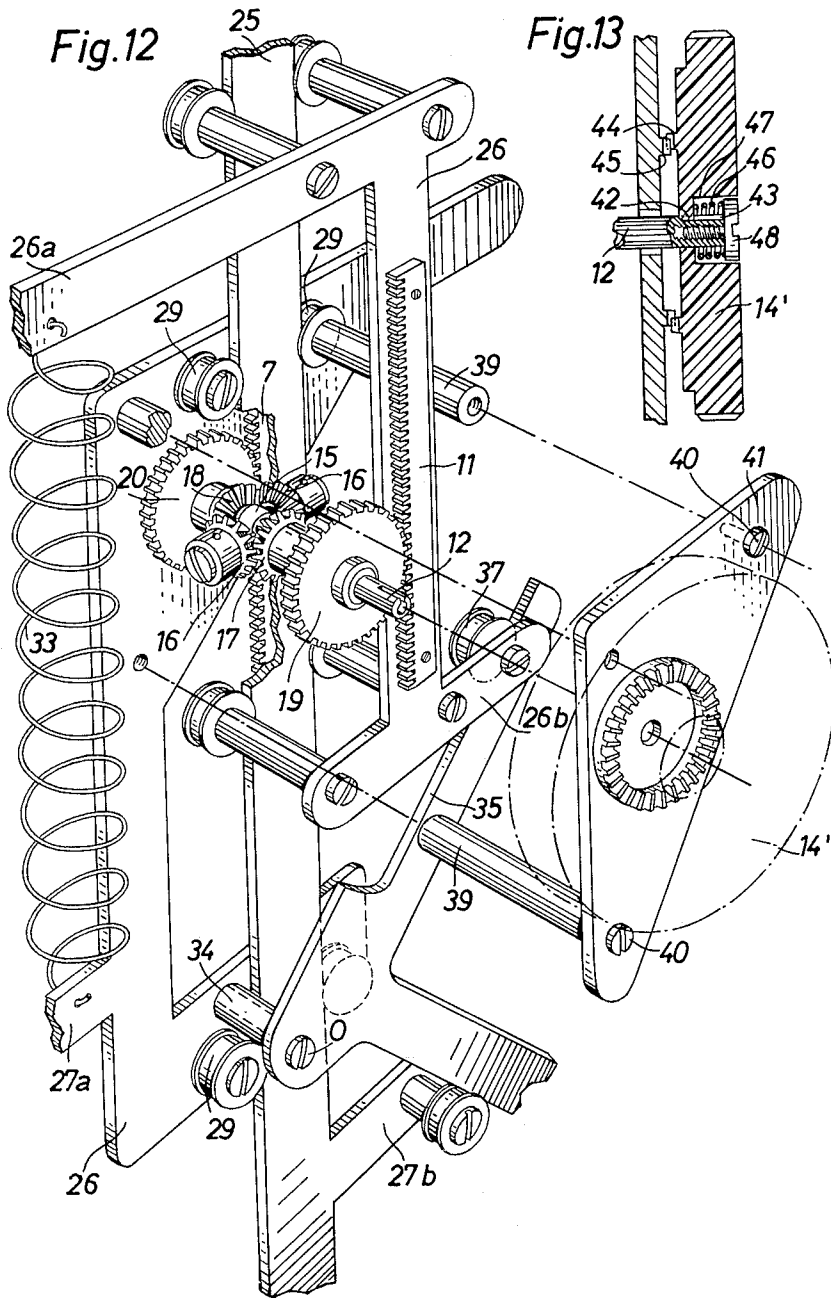
A. SEIZINGER

3,217,593

PHOTOGRAPHIC REPRODUCTION APPARATUS

Filed June 26, 1962

7 Sheets-Sheet 6



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PHOTOGRAPHIC REPRODUCTION APPARATUS

Filed June 26, 1962

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Fig. 15

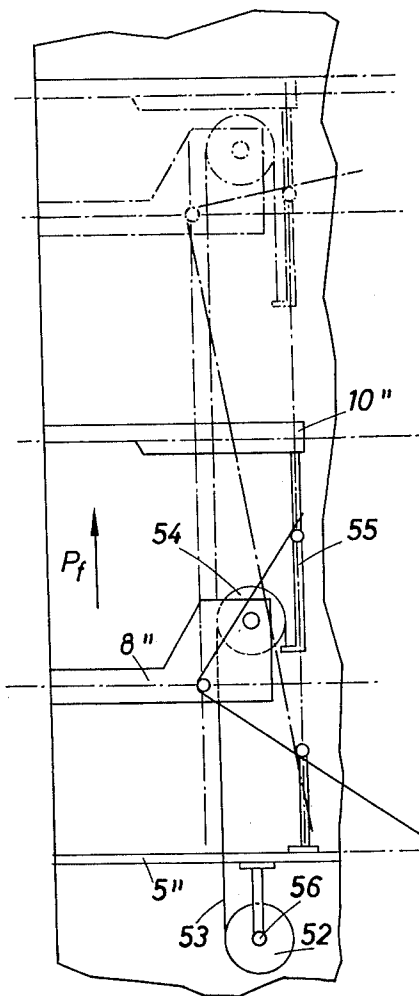
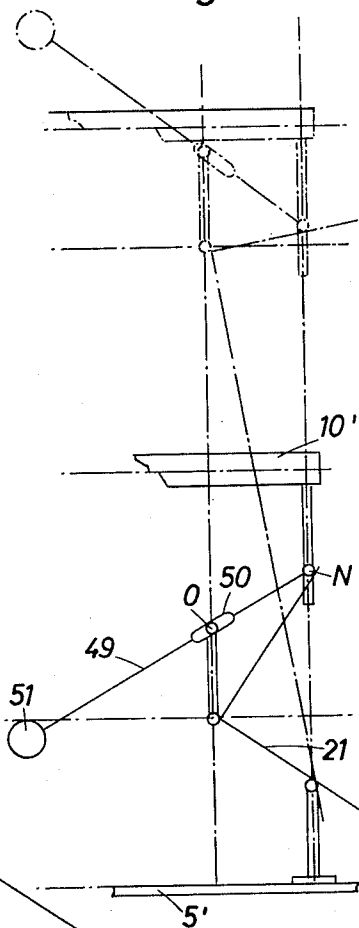


Fig. 14



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PHOTOGRAPHIC REPRODUCTION APPARATUS

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A 37,761

17 Claims. (Cl. 88—24)

The present invention relates to photographic reproduction apparatus.

More particularly, the present invention relates to a photographic reproduction apparatus such as an enlarger which is capable of making not only enlargements but also photographic reproductions smaller than the negative from which the reproductions are made. In this specification and the claims which follow the term "negative" is used to refer not only to black-and-white negatives but also to color transparencies, color-negatives and the like, and the term "positive" is used to refer not only to light-sensitive paper on which black-and-white photographs are made but also to light-sensitive paper on which color photographs are made.

In photographic reproduction apparatus of the above type when the enlargement ratio is such that the positive photograph is greater than the negative from which the positive photograph is made and when this enlargement ratio is reduced the negative and the objective both approach the positive, assuming that the enlarger is of the type where the positive remains stationary, but the objective approaches the positive at a rate greater than the negative so that while both the negative and the objective move toward the positive during a reduction in the enlargement ratio the objective moves through a greater distance toward the positive so that at this time the distance between the negative and the objective increases. These relationships continue during a reduction in the enlargement ratio down to 1:1, which is the limiting position for this relationship. When the enlargement ratio is further reduced so that the positive reproduction has a smaller size than the negative from which it is made the objective will continue to approach the positive but beyond the 1:1 ratio the negative moves away from the positive and moreover at this time the negative moves away from the positive at a rate considerably greater than that with which the objective approaches the positive. It can be seen, therefore, that considerable difficulties are involved in providing adjustment of a photographic reproduction of this type where the enlargement ratios include a range which extends on both sides of the ratio 1:1. It is known, of course, to provide separate drives for the objective and the negative which are coupled to each other so as to provide the proper position of the objective relative to the positive and negative to provide on the positive a sharp image of the negative, but these structures are extremely complex and moreover require certain correcting devices to take care of the case where the enlargement ratio goes below 1:1, and moreover such structures are designed for an objective of only one focal length and cannot be used with interchangeable objectives.

A primary object of the present invention is to provide a photographic reproduction apparatus of the above type which can be set to provide enlargement ratios both greater and smaller than 1:1 while at the same time being far simpler than known structures which can accomplish this result.

A further object of the present invention is to provide a structure of this type which is capable of maintaining substantially constant the forces required to adjust the

photographic reproduction apparatus throughout its entire range of adjustment so that in this way it is an extremely simple matter to carry out the adjustments with exercise of relatively small forces. Ordinarily it is immaterial which of the elements are moved relative to the other elements. For example, in most conventional enlargers it is the negative which is moved together with the objective relative to the positive, and after the negative has been positioned the objective itself is positioned so as to provide a sharp image on the positive. However, it will be noted from the above discussion that when the enlargement ratio is 1:1 the negative will change its direction of movement while the objective continues to move toward the positive so that at the limiting 1:1 ratio the negative actually stops moving and is moved through no distance while the objective moves toward the positive so that precisely at the limiting position it is necessary to move the objective at a ratio which is infinitely greater than the movement of the negative, and thus under these conditions the only practical manner of manipulating the photographic reproduction apparatus is to move the objective and then to adjust the negative relative thereto, so that it becomes necessary under these conditions to change the part of the photographic apparatus from which the adjustment thereof is initiated. It is precisely these difficulties which are overcome with the structure of the invention as a result of the maintenance of substantially constant forces on the parts thereof which change their positions relative to each other.

Still another object of the present invention is to bring about the substantial equalizing of the forces acting on the structures which carry the objective, the negative, and the positive with a differential mechanism which is of an extremely simple construction, particularly as compared to conventional structures of this type.

An additional object of the present invention is to provide for a structure of the above type a means which will releasably hold the parts in their adjusted positions relative to each other.

Still another object of the present invention is to provide for a structure of the above type a means which will automatically compensate for unfavorable influences which would tend to create a substantial inequality in the forces required to be exerted for adjustment of the photographic reproduction apparatus.

With the above objects in view, the invention includes, in a photographic reproduction apparatus, an objective-support means which carries an objective, a positive-support means for supporting a positive on which the photographic reproduction is to be made, and a negative-support means for supporting the negative whose image is to be reproduced on the positive. A connecting means interconnects the three support means in such a way that at least two of the support means move relative to each other and relative to the third support means along the optical axis of the objective. A focusing means acts on all three support means for maintaining the objective at all times in a position providing a sharp image of the negative on the positive. Finally, in accordance with the present invention, a differential means acts on all three support means for maintaining substantially constant the forces which are required to move the above-mentioned two support means relative to each other and to the third support means.

The novel features which are considered as characteristic for the invention are set forth in particular in the appended claims. The invention itself, however, both as to its construction and its method of operation, together with additional objects and advantages thereof, will be best understood from the following description

of specific embodiments when read in connection with the accompanying drawings, in which:

FIG. 1 is a diagrammatic illustration of the manner in which the objective and negative of a photographic reproduction apparatus move relative to each other and relative to a stationary positive in the region where the enlargement ratio is 1:1;

FIG. 2 graphically represents the adjusting forces, with and without a differential drive, with respect to the enlargement ratios;

FIG. 3 diagrammatically illustrates the position of the parts when they provide an enlargement ratio of 10:1;

FIG. 4 diagrammatically represents the position of the parts when they provide an enlargement ratio of 1:1;

FIG. 5 diagrammatically illustrates the position of the parts when they provide an enlargement ratio of 1:10;

FIG. 6 is a schematic illustration of a structure according to the present invention providing an adjustment corresponding to that shown in FIG. 3;

FIG. 7 shows the structure of FIG. 6 after it has been adjusted to provide the relationship shown in FIG. 4;

FIG. 8 shows the structure of FIG. 6 after it has been adjusted to provide the relationship shown in FIG. 5;

FIG. 9 is a schematic sectional illustration of a differential means used with the structure of the invention;

FIG. 10 is a schematic illustration of a photographic enlarger apparatus according to the invention wherein the differential means provides different transmission ratios on the parts controlled thereby;

FIG. 11 is a perspective illustration of an enlarger according to the present invention;

FIG. 12 is an exploded perspective view, on an enlarged scale, of part of the structure shown in FIG. 11;

FIG. 13 is a sectional elevation illustrating a releasable holding means forming part of the structure of FIGS. 11 and 12;

FIG. 14 is a schematic illustration of a lever-type of differential drive capable of being used with the structure of the invention; and

FIG. 15 is a schematic illustration of a band-and-pulley type of differential drive capable of being used with the structure of the invention.

Referring now to the drawings and to the diagram of FIG. 1 in particular, there is illustrated in FIG. 1 the plane P' which indicates the plane in which the positive is located. The plane O' illustrates the plane in which the objective is located, and these planes are of course parallel to each other at all times, and finally the plane N' indicates the plane in which the negative is located, these planes P', O', N' being planes of an enlarger apparatus all of which are perpendicular to the optical axis of the objective which is located at the plane O'. A focusing means is provided for maintaining, at all of the adjusted positions of the enlarger, the objective at a position where it will provide on the positive a sharp image of the negative, and this focusing means takes the form of a bell-crank J having the legs J₁ and J₂, and the turning axis O of the focusing means J is also located in the plane O' of the objective. In all of the adjusted positions of the enlarger the pivot point O of the focusing means J is located along the line 1 which extends parallel to the optical axis and of course perpendicular to the plane P', O', N'. In the illustrated solid line position of the parts of FIG. 1 the focusing means J locates the objective at a position relative to the positive and negative where the enlargement ratio is 1:1. In this position the legs J₁ and J₂ of the bell-crank J respectively pass at the points P and N through a straight line 2 which also extends parallel to the optical axis and which is spaced from the straight line 1 by a distance f which is equal to the focal length of the objective. Moreover, the point P is located at the same distance f from the positive plane P', while the point N is also located at the same distance f from the negative plane N'.

The focusing means J will automatically maintain the relationship

$$x \cdot y = f^2$$

which is the relationship which the parts must have so as to provide proper focusing, and in this relationship x is equal to the distance between the negative and the objective minus the focal length of the objective, while y is equal to the distance between the positive and the objective minus the focal length of the objective, and f of course is equal to the focal length of the objective. For a further illustration of this principle and a structure for maintaining the parts of the enlarger always positioned to satisfy this relationship so that the objective will always provide on the positive a sharp image of the negative, reference may be had to copending application Serial No. 127,719.

It will be noted that in the solid-line position of the bell-crank J shown in FIG. 1, the distance between point P and the plane O' is u, while the distance between the points P and N is z. Assuming now that the negative is moved to the right, as viewed in FIG. 1, through a relatively small distance, so that the negative plane N' is displaced to the right in FIG. 1 through such a small distance, then the bell-crank J will assume the dotted line position indicated in FIG. 1, and the distance u has been increased by the amount Δu while the distance z has been increased by the amount Δz. Inasmuch as the distance Δu is many times greater than the distance Δz, which represents the distance through which the negative plane N' is moved, there is an extremely large ratio between the speed of movement of the objective and the speed of movement of the negative in the region where the enlargement ratio is 1:1, and in the limiting case where the ratio is 1:1 and where the negative plane N' changes its direction of movement, so that it first comes to a stop before moving in the opposite direction, as pointed out above, this ratio will be infinitely great.

The horizontal arrangement illustrated in FIG. 1 corresponds substantially to the vertical arrangement illustrated in FIG. 4. In FIG. 4 there is shown at N₁ a force which acts on the negative carrier which is opposed by an equal force P₁ at the positive plane at the point P, the force N₁ acting at the point N. Therefore, with the position of the parts indicated diagrammatically in FIG. 4, where the enlargement ratio is 1:1 there is practically no adjusting force at the point O assuming that the drive for carrying out the adjustments takes place at the point O.

FIG. 3 shows the position which the parts take when providing an enlargement ratio of 10:1, and in this position of the parts the force N₁₀ is opposed by the forces O₁₀ and P₁₀. Thus, in the position of the parts shown in FIG. 3 the positive will have an image ten times greater than the negative. With the position of the parts shown in FIG. 3 the movement of the point O will still be somewhat greater than the movement of the point N, so that the upwardly directed force O₁₀ is somewhat smaller than the force N₁₀, and the relationship $Z_{10}/U_{10} = N_{10}/O_{10}$, in the position of the parts shown in FIG. 3.

When the enlargement ratio is reduced from that of FIG. 3 to that of FIG. 4 and is then further reduced so that the positive receives an image smaller than the negative, point N after having moved down from the position of FIG. 3 to that of FIG. 4 will then move up as indicated in FIG. 5, while the point O continues to approach the positive, and the parts are shown in FIG. 5 where the enlargement ratio is 1:10. It will be noted that in this case the negative moves away from the positive at a much faster rate than the objective approaches the positive so that the downwardly directed force O_{0.1} at the objective is many times greater than the force N_{0.1} which represents the load on the negative carrier.

Referring to FIG. 2, there is graphically illustrated therein the ratio of the forces acting on the objective O_v to the forces acting on the negative N_v against the en-

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largement ratio v , and this enlargement ratio is shown extending from the ratio 10:1 down to the ratio 1:1 and then further down to the ratio 1:10 where the positive will provide a reproduction ten times smaller than the negative. It will be noted that the ratio O_v/N_v is 0 at the enlargement ratio 1:1. Furthermore it is clear that the inverse ratio, namely N_v/O_v at the enlargement ratio 1:1 is equal to infinity. As was pointed out above when a relatively small enlargement ratio less than 1:1 is provided the force required to act on the objective as it approaches the positive is much greater than that which moves the negative away from the positive at this time, as is clearly shown by the dotted curve 3. However, when, in accordance with the present invention, a differential drive as described below is used in order to distribute the forces among the supports for the positive, the objective and the negative then the forces required to adjust the enlarger will follow the curve 4 shown in FIG. 2. This curve will rise very slowly from the O point at the enlargement ratio 1:1 toward the right as viewed in FIG. 2 but will never exceed a predetermined value a which will be either positive or negative depending upon whether the enlargement ratio is greater or smaller than 1:1. In order to very clearly demonstrate the relationships in the graph of FIG. 2 the forces of friction have been ignored and furthermore ancillary forces such as those which might change during adjustment of the enlarger in order to compensate for the weight of part of the enlarger. In other words the graph of FIG. 2 is made on the assumption that weight-compensating forces do not change. Where the enlarger is horizontal so that the optical axis extends horizontally the force of friction can be greater than the force represented by the ratio a required to adjust the enlarger, so that in this way the parts will remain in their adjusted positions without any additional manipulations or structure required for this purpose.

Referring now to FIGS. 6-8, there is schematically illustrated therein a structure according to the present invention. At the right of FIGS. 6-8 is shown the positive-support means 5 which locates the positive in the positive plane P', and at the left of FIGS. 6-8 is shown the negative support means 10 which locates the negative in the plane N'. Between the positive-support means 5 and the negative-support means 10 is located the objective-support means 8. A connecting means connects the three support means for movement of at least two of the support means relative to each other and relative to the third support means in a direction parallel to the optical axis of the objective 9 which is carried by the objective-support means 8, as is shown diagrammatically in FIGS. 6-8. This connecting means in the illustrated example takes the form of the column 6 which is fixed to the positive-support means 5 and extends therefrom parallel to the optical axis of the objective 9. The negative-support means 10 is slidably supported by the column 6 for movement with respect thereto parallel to the optical axis, and the objective-support means 8 is also slidably carried by the column 6 for movement parallel to the objective 9, so that in this way the column 6 forms a connecting means which, in the illustrated example, connects the negative-support means 10 and the objective-support means 8 for movement relative to each other and relative to the positive-support means 5 in a direction parallel to the optical axis of the objective 9. A differential means acts on the three support means 5, 8, and 10 so as to maintain substantially constant the forces acting thereon in order to adjust the enlarger through and beyond the enlargement ratio 1:1, and this differential means includes the elongated rack 7 which is fixedly connected to and extends longitudinally along the column 6 parallel to the optical axis of the objective 9. The differential means also includes an elongated rack 11 which is parallel to and overlaps the rack 7 and which is fixed to the negative-support means 10. Furthermore, the differential means 13 in-

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cludes the rotary shaft 12 which is supported for rotary movement by the objective-support means 8 in the illustrated example. A handwheel which is not shown in FIGS. 6-8 is fixed to the shaft 12 in order to rotate the latter. The focusing means in the example of FIGS. 6-8 takes the form of the bell-crank J which has the legs J₁ and J₂ which are perpendicular to each other, as described above, and at the intersection of its legs the focusing means J is pivotally connected at the point O to the objective-support means 8. At the points P and N the legs J₁ and J₂ respectively engage rollers which are respectively carried by the positive-support means 5 and the negative-support means 10 at distances from the planes P' and N' which are equal to the focal length f of the objective 9, so that it will be seen that the structure of FIGS. 6-8 conforms to that described above in connection with FIGS. 1 and 3-5. It will furthermore be noted that the axis of the column 6, along which the pivot point O of the focusing means J moves is located at a distance from the straight line passing through the points P and N by the same distance f . A biasing means acts on the negative-support means 10 to urge the latter to the right, as viewed in FIGS. 6-8, so as to maintain the roller at the point N in engagement with the leg J₂ of the focusing means J, and this biasing means may be in the form of a spring or of a weight-and-pulley assembly which provides the relatively light force P_f acting on the negative-support means 10 in the manner shown in FIGS. 6-8. When a lever-type of differential drive is used as described below in connection with FIG. 14, a biasing means to provide the auxiliary force P_f is not required because of the direction in which the adjusting force is provided at the handle of the lever which is actuated by the operator, as described below.

The differential means 13 is further illustrated schematically in FIG. 9 where the handwheel 14 is shown fixed to the rotary shaft 12 which is supported for rotation by the objective-support means 8 as described above. The shaft 12 fixedly carries intermediate its ends the spider 15 which supports for free rotary movement the pair of planetary gears 16 which respectively mesh with the pair of sun gears 17 and 18 which are supported for free rotation with respect to the shaft 12, the latter passing freely through axial bores of the gears 17 and 18, as shown in FIG. 9. These gears 17 and 18 are fixed to the output gears 19 and 20, respectively, as by being formed integrally therewith, and these output gears 19 and 20 respectively mesh with the racks 11 and 7, as indicated in FIG. 9.

Assuming now that the operator turns the handwheel 14 so that the shaft 12 shown in FIG. 6 turns in a counterclockwise direction, as viewed in FIG. 6, then this same direction of rotation will be imparted to the output gears 19 and 20. As a result the objective-support means 8 moves toward the positive-support means 5 and the enlargement ratio becomes smaller. The biasing means which provides the force P_f causes the negative-support means 10 to follow the movement of the objective-support means 8 by maintaining the roller at the point N in engagement with the leg J₂ of the focusing means J. Of course, the principle of operation is the same irrespective of which of the three support means 5, 8, 10 is maintained stationary.

The turning of the handwheel 14 in this manner will cause the parts to move from the position shown in FIG. 6 to that shown in FIG. 7 where the parts are shown in the position they take in order to provide an enlargement ratio of 1:1. When the parts are moved beyond the position shown in FIG. 7 so as to provide an enlargement ratio smaller than 1:1 the forces continue to act in substantially the same way, the only difference being that the light force P_f now opposes the movement of the negative-support means 10 which of course at this time moves away from the positive-support means 5 while the objective-support means 8 approaches the latter. Thus,

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the operator can continue to turn the handwell 14 so that the shaft 12 continues to turn in a counterclockwise direction and the parts will move through the position shown in FIG. 7 with the negative plane moving away from the positive plane and the objective plane approaching the positive plane, and these operations can continue until the position of the parts shown in FIG. 8 is provided. The only factor which changes substantially during the entire adjustment of the parts from the position of FIG. 6 through the position of FIG. 7 to that of FIG. 8 is that ratio of the movement of the pair of movable supports 8 and 10 relative to each other and relative to the stationary support means 5. This difference is of course compensated by the rotary movement of the planetary gears 16. Moreover, because the lever arms provided by the planetary gears 16 are equal, these gears provide adjusting forces acting from the objective-support means 8 on the negative-support means 10 and on the positive-support means 5 which are of equal magnitude.

The differential means illustrated in FIG. 10 differs from that of FIG. 9 in that the pair of output gears 19' and 20' have different diameters. Thus, the rack 7' of the differential means is in the embodiment of FIG. 10 located directly on the column 6 while the rack 11' is spaced from the rack 7' in accordance with the difference between the radii of the gears 19' and 20'. FIG. 10 schematically illustrates two end positions of the apparatus, and in the solid-line illustrated position of FIG. 10 the enlargement ratio is 2:3, in other words less than 1:1 so that the positive provides a photograph smaller than the negative, while in the dotted-line position of the parts of FIG. 10 an enlargement ratio of 5.5:1 is provided. In accordance with the average of the forces which occur during this range of adjustment the extent of movement of the negative-support means 10' with respect to the objective-support means 8' is increased as compared to the extent of movement of the objective-support means 8' with respect to the positive-support means 5'. As a result the forces required to effect the adjustment are reduced, and in this way it is possible also to compensate for additional changing forces by using a weight-compensating spring whose tension changes and which also serves to compensate for the moments provided by the focusing bell-crank 21 in the illustrated position.

In the enlarger shown in FIG. 11, the base plate 22 is the positive-support means and carries the easel 23 on which the light-sensitive printing paper is mounted. A flange 24 is fixed to the plate 22, and this flange is fixed to the bottom end of the vertical column 25 which is of rectangular cross section so that in this way the column 25 is fixed to and extends upwardly from the positive-support means 22. A carriage 26 of double-T configuration fixedly carries shafts which support for rotary movement four rollers 28 capable of rolling along the front and rear faces of the column 25, as is apparent from FIGS. 11 and 12, so that in this way the carriage 26 is connected to the column 25 for free movement therealong, and a substantially U-shaped carriage 27 carries for free rotation four rollers 29 also capable of rolling along the front and rear faces of the column 25 so that in this way the carriage 27 also is freely movable along the column 25. The carriage 26 has an arm 26a which fixedly carries the negative-support means 30 as well as the lamp housing 31, so that through the carriage 26 the negative-support means 30 is mounted for free movement along the column 25. The carriage 27 has an arm 27a which fixedly carries the objective-support means 32 on which the objective 9 is mounted, so that the carriage 27 serves to connect the objective-support means 32 to the column 25 for free movement therealong. In this way the column 25 and the carriages 26 and 27 provide a connecting means connecting the negative-support means 30 and the objective-support means 32 for movement relative to each other and relative to the positive-support means 22 in a direction parallel to the optical axis of the objective 9, this optical

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axis of course extending parallel to the column 25. An elongated coil spring 33 extends between and is connected to the arms 26a and 27a, this coil spring being under tension and serving to compensate for the weight of the parts 30 and 31. A focusing bell-crank 21' is connected at the intersection O of its legs to the carriage 27 for pivotal movement with respect thereto, and for this purpose a pivot pin 34 is fixedly carried by the carriage 27 in front of the column 25 and this pin 34 pivotally supports the focusing means 21'. The legs of the focusing means 21' are provided with elongated surfaces 35 and 36 on which rollers 37 and 38 respectively ride, and the roller 37 is turnably carried at N by the arm 26b of the carriage 26 while the roller 38 is turnably carried at P by the extension 25b of the column 25. At any given instant in all of the adjusted positions of the enlarger the distance between the points P and N is less than the distance between the positive plane provided by the support means 22 and the negative plane provided by the support means 30 by an amount equal to twice the focal length of the objective 9, and in addition the turning axis provided by the pivot 34 for the focusing means 21' is spaced from the straight line which connects the points P and N by a distance equal to the focal length of the objective 9.

As is particularly apparent from FIG. 12, spacers 39 and screw members 40 serve to fixedly connect to the objective carriage 27 the triangular plate 41 which is in this way fixed to the carriage 27 in the position spaced from and parallel thereto. The carriage 27 and the plate 41 serve to support for rotary movement the shaft 12 of the differential means which corresponds to the structure shown in FIG. 9. The rack 7 in this case is fixed directly to a side surface of the column 25 while the rack 11 is fixed to a side surface of the negative carriage 26.

The only difference between the structure of FIGS. 11 and 12 and that described above in connection with FIGS. 6-8 resides in the handwheel 14' the details of which are shown most clearly in FIG. 13. Thus, the handwheel 14' has a bore which receives the shaft 12 and at this bore the handwheel 14' is provided with an integral radial projection 42 extending inwardly and providing a key which is received in the axial groove 43 formed in the shaft 12 so that in this way the handwheel 14' can move axially with respect to the shaft 12 but is constrained to turn with the shaft 12. At its face which is directed toward the plate 41 the handwheel 14' is provided with a ring of teeth 44 which are respectively adapted to enter in the spaces between a ring of teeth 45 carried by the plate 41, and a spring 46 surrounds the portion of the shaft 12 which is located in the bore 47 of the handwheel and engages a screw member 48 threadedly carried by the shaft 12 so that this spring urges the handwheel 14' to the left, as viewed in FIG. 13, so as to maintain the teeth 44 in mesh with the teeth 45, and these meshing teeth together with the assembly in the bore 47 of the handwheel 14' provide a releasable holding means for releasably holding the parts in the adjusted position.

Thus, before the operator can adjust the enlarger so as to change the enlargement ratio the operator must pull the handwheel 14' away from the plate 41 in opposition to the spring 46, and in this way the handwheel 14' and the shaft 12 therewith is released for turning movement. At the end of the adjustment the operator will simply release the handwheel 14' so that the spring 46 will return it to the position shown in FIG. 13 where the releasable holding means again acts to releasably hold the apparatus in its adjusted position. Of course, instead of providing two rings of teeth 44 and 45, one of these rings can be replaced by a single tooth which cooperates with the other ring of teeth.

FIG. 14 shows a particularly simple form of differential drive. In this embodiment a lever-type of differential means is provided and includes the elongated lever 49 which is pivotally connected at N to the negative-support means 10'. A slide member 50 is carried by the

lever 49 for slidable movement longitudinally therealong and is formed with an opening which receives a pin which is fixed to the objective-support means so that in this way the lever 49 is connected at O to the objective-support means, and at its outer free end the lever is provided with a handle 51. The rest of the structure of FIG. 14 corresponds to that described above. In other words the positive-support means 5' which may be the same as that of FIG. 10 fixedly carries a vertical column on which the negative-support means 10' is vertically slidable and on which the objective-support means is also vertically slidable, and at a distance equal to the focal length of the objective the support means 5' carries a roller spaced from the positive plane by this latter distance and engaging one arm of the focusing bell-crank 21, while the negative-support means 10' carries a roller which at N engages the other arm of the bell-crank 21, this latter roller being spaced from the negative plane by a distance equal to the focal length of the objective. The bell-crank 21 is of course pivotally connected to the objective-support means for movement therewith and the turning axis of the bell-crank on the objective-support means is spaced from the straight line connecting the axes of the rollers which engage the legs of the bell-crank 21 by a distance equal to the focal length. It will be seen that with this construction when the operator engages the handle 51 so as to turn the lever 49 the same relationships as described above are obtained. Thus, with the embodiment of FIG. 14 when the operator turns the lever 49 the forces will be distributed and equalized in the manner described above through the lever-type of differential arrangement shown in FIG. 14 in the same way as through the gear-type differential arrangement referred to above. Thus, the focusing means 21 is not placed under load, in exactly the same way as described above.

A further embodiment of a differential drive is shown in FIG. 15, and this differential drive is a band-and-pulley type of differential drive. Thus, referring to FIG. 15 it will be seen that the positive-support means 5'' turnably carries a rotary drum 52 on which a thin steel band 53 is wound. From the drum or spool 52 the flexible steel band 53 passes upwardly to the pulley or roller 54 around which the band extends, and the free end of the band is fixed to an arm 55 which is fixed to the negative-support means 10'' the pulley or roller 54 is turnably carried by the objective-support means 8''. Thus, in this embodiment it is the roller 54 which serves as the force-equalizing element for distributing the adjusting forces. The operation is initiated by an unillustrated handwheel fixed to the shaft 56 which fixedly carries the drum 52. The same releasable holding means shown in FIG. 13 may be used with the embodiment of FIG. 15 to hold the parts in their adjusted position, and the force which compensates for the weight of the negative-support means is indicated at P_f in FIG. 15, and this biasing means may be provided by a spring or by a pulley-and-weight assembly, as described above. In the embodiment of FIG. 15, however, the force P_f must be greater than the weight of the negative-support means 10'' so as to maintain the band 53 under tension at all times.

Except for these differences the embodiment of FIG. 15 is the same as the other embodiments so that the positive-support means 5'' fixedly carries an upwardly directed column on which the negative-support means 10'' is slidable and on which the objective-support means 8'' is also slidable, and of course pivoted to the objective-support means 8'' is the focusing bell-crank whose legs respectively engage rollers connected to the positive and negative support means at distances from the positive and negative planes respectively equal to the focal length of the objective, and of course the pivot axis of the focusing bell-crank is spaced from the line which connects the axes of these rollers by a distance equal to the focal length, or as described above in connection with the other embodiments.

Of course, it is possible to provide a band-and-pulley type of differential where the roller which corresponds to the roller 54 is carried by the positive-support means 5'' and a pair of drums can be connected to the objective-support means 8'' with a band from one drum passing around the pulley which is carried by the positive-support means 5'' and the band from the other drum being connected to the negative-support means 10''. Moreover, it is possible to provide a suitable transmission ratio with such a band-and-pulley type of differential through the use of a stepped drum or spool having two steps of different diameters with the free ends of the bands respectively fixed to these portions of different diameters and respectively connected to the positive-support means and a negative-support means, so that in this way different lever arms are provided in the same way as for the gears 19' and 20' shown in FIG. 10. Also, the releasable holding means need not be constructed in the manner described in detail above. For example, in the case of FIG. 14 the turning or swinging of the handle 51 can be used to actuate a pawl which cooperates with a ratchet wheel turnable on an axis coinciding with the turning axis of the roller located at N. Furthermore, while in all of the above-described embodiments a focusing means in the form of a bell-crank has been shown and described, other types of focusing devices are suited for use with the combination of the invention which provides force equalization through a differential drive. Thus, instead of a bell-crank type of focusing device it is possible to use a pulley-and-band type of focusing device, a cam type of focusing device, or other known focusing devices which control the distances between the various parts of the enlarger.

It will be understood that each of the elements described above, or two or more together, may also find a useful application in other types of photographic reproduction device differing from the types described above.

While the invention has been illustrated and described as embodied in adjustable photographic enlargers, it is not intended to be limited to the details shown, since various modifications and structural changes may be made without departing in any way from the spirit of the present invention.

Without further analysis, the foregoing will so fully reveal the gist of the present invention that others can by applying current knowledge readily adapt it for various applications without omitting features that, from the standpoint of prior art, fairly constitute essential characteristics of the generic or specific aspects of this invention and, therefore, such adaptations should and are intended to be comprehended within the meaning and range of equivalence of the following claims.

What is claimed as new and desired to be secured by Letters Patent is:

1. In a photographic reproduction apparatus, in combination, three support means for respectively supporting an objective, a positive on which a reproduction is to be made, and a negative the image of which is to be reproduced on the positive; connecting means connecting at least two of said three support means to each other and to the third one of said support means for movement relative to each other and to said third support means along the optical axis of the objective; focusing means acting on said three support means for providing through the objective on the positive a sharp image of the photograph carried by the negative at all positions of said three support means relative to each other; and differential means operatively connected to one of said support means and acting on the other two support means for maintaining substantially constant the forces acting on said three support means during movement thereof relative to each other to provide different enlargement ratios.

2. In a photographic reproduction apparatus, in combination, three support means for respectively supporting an objective, a negative, and a positive on which an

image of the negative is to be reproduced; connecting means interconnecting said three support means for movement of at least two of said support means relative to each other and relative to the third one of said support means along the optical axis of the objective, said connecting means interconnecting said three support means for movement through and beyond the position of said three support means where the enlargement ratio is 1:1; focusing means acting on said three support means for maintaining them at all of their positions relative to each other at locations where the objective will provide on the positive a sharp image of the photograph carried by the negative; and differential means operatively connected to one of said support means and acting on the other two support means for steplessly adjusting said three support means relative to each other while moving them through a range which passes through the enlargement ratio of 1:1, said differential means maintaining substantially constant the forces which act on said three support means during movement thereof relative to each other.

3. In a photographic reproduction apparatus, in combination, objective-support means supporting an objective; positive-support means supporting a positive on which reproductions are to be made; negative-support means supporting a negative an image of which is to be reproduced on the positive; connecting means connecting two of said support means to the third of said support means for movement relative to each other and relative to said third support means along the optical axis of the objective; focusing means acting on the three support means for maintaining them in a position relative to each other, at all locations thereof, providing a sharp image of the negative on the positive; and differential means carried by said objective-support means and acting on the other two support means for maintaining substantially constant the forces acting on all of said support means during movement thereof relative to each other.

4. In an apparatus as recited in claim 3, said connecting means including an elongated rack fixed to said positive-support means and extending parallel to the optical axis and an elongated rack fixed to said negative-support means and extending parallel to the optical axis, and said differential means including a pair of output gears respectively meshing with said racks.

5. In a photographic reproduction apparatus, in combination, objective-support means supporting an objective; positive-support means for supporting a positive on which a reproduction is to be made; negative-support means for supporting a negative an image of which is to be reproduced on the positive; connecting means connecting at least two of said support means to the third of said support means for movement relative to each other and relative to the third support means along the optical axis of the objective, said connecting means including a pair of elongated racks respectively fixed to said two support means and extending parallel to the optical axis; focusing means acting on all three support means for maintaining the objective in a position relative to the positive and negative providing a sharp image of the negative on the positive at all positions of all three support means; and differential means carried by said third support means and acting on the other two support means for maintaining substantially constant the forces acting on all three support means during movement thereof relative to each other, said differential means including a rotary shaft turnably carried by said third support means, a spider fixed to said shaft for rotary movement therewith, a pair of planetary gears turnably carried by said spider, a pair of sun gears carried for free rotation by said shaft and meshing with said planetary gears, and a pair of output gears respectively fixed to said sun gears for rotary movement therewith and respectively

meshing with said racks, said racks both being located on the same side of said output gears.

6. In a photographic reproduction apparatus, in combination, three support means for respectively supporting an objective, a negative, and a positive on which a reproduction of the negative is to be made; connecting means connecting at least two of said support means to the third support means for movement relative to each other and relative to said third support means along the optical axis of the objective; focusing means acting on all three support means to maintain said objective at a position relative to the positive and negative providing a sharp image of the negative on a positive; and differential means carried by one of the support means and acting with substantially equal transmission ratios on the other two support means for maintaining substantially constant the forces acting on all three support means during movement thereof relative to each other.

7. In a photographic reproduction apparatus, in combination, three support means for respectively supporting an objective, a negative and a positive on which a reproduction of the negative is to be made, connecting means connecting at least two of said support means to the third support means for movement relative to each other and relative to said third support means along the optical axis of the objective; focusing means acting on all three support means to maintain said objective at a position relative to the positive and negative providing a sharp image of the negative on the positive; and differential means carried by one of said support means and acting on the other two support means with different transmission ratios, respectively, for moving all three support means relative to each other with substantially constant forces while compensating through the different transmission ratios for unfavorable reactions which would otherwise require unequal forces to act on the support means for moving them relative to each other.

8. In a photographic reproduction apparatus, in combination, objective-support means supporting an objective; positive-support means supporting a positive on which a reproduction is to be made; negative-support means for supporting a negative the image of which is to be reproduced on the positive; connecting means connecting at least two of said support means to the third support means for movement relative to each other and relative to said third support means along the optical axis of the objective; focusing means acting on all three support means to maintain at all times the objective in a position relative to the positive and negative providing a sharp image of the negative on the positive; and differential means acting on all three support means for maintaining substantially constant the forces applied to all three support means during movement of said two support means relative to each other and relative to the third support means, said differential means including a rotary pulley carried by said objective-support means and a band passing around said pulley and connected to the remaining two support means, respectively, one of said remaining two support means including a drum on which the band is wound.

9. In a photographic apparatus as recited in claim 8, said drum being turnably carried by said positive-support means and serving as an actuating element for actuating the differential means to adjust the position of all of said support means relative to each other.

10. In a photographic reproduction apparatus, in combination, objective-support means for carrying an objective; positive-support means for carrying a positive on which a reproduction is to be made; negative-support means for carrying a negative an image of which is to be reproduced on the positive; connecting means connecting at least two of said support means for movement relative to each other and relative to the third support means along the optical axis of the objective; focusing means acting on all three support means for maintaining

the objective at all times at a position providing a sharp image of the negative on the positive; and differential means acting on all three support means for maintaining substantially constant the forces required to move said two support means relative to each other and third support means, said differential means including a two-armed lever turnably connected to said objective-support means.

11. In a photographic reproduction apparatus, in combination, objective-support means supporting an objective; positive-support means for supporting a positive on which a reproduction is to be made; negative-support means for supporting a negative an image of which is to be reproduced on the positive; connecting means connecting said objective-support means and said negative-support means to each other for relative movement with respect to each other and to said positive-support means for movement relative thereto; focusing means acting on all three support means for maintaining at all times the objective in a position relative to the negative and positive providing a sharp image of the negative on the positive; and differential means cooperating with all three support means for maintaining substantially constant the forces acting on all three support means during movement of said objective-support means and said negative-support means relative to each other and relative to said positive-support means, said differential means including an elongated two-armed lever pivotally connected to said objective-support means, having one free end pivotally connected to said negative-support means, and having an opposite free end adapted to be engaged by the operator for turning said lever so as to actuate the differential means.

12. In a photographic reproduction apparatus, in combination, three support means for respectively supporting an objective, a positive, and a negative an image of which is to be reproduced on the positive; connecting means connecting at least two of said support means to the third support means for movement relative to each other and relative to said third support means along the optical axis of the objective; focusing means acting on all three support means for maintaining the objective at all times at a position providing a sharp image of the negative on the positive; differential means acting on the three support means for maintaining substantially constant the forces required to move said two support means relative to each other and relative to said third support means; and releasable holding means operatively connected to at least one of said two support means for releasably holding the latter in an adjusted position.

13. In a photographic reproduction apparatus as recited in claim 12, said differential means including an actuating element which is moved in order to actuate the differential means, and said releasable holding means being operatively connected to said actuating element to be controlled thereby.

14. In a photographic reproduction apparatus, in combination, three support means for respectively supporting an objective, a positive, and a negative; connecting means connecting at least two of said support means for movement relative to each other and relative to the third support means along the optical axis of the objective; focusing means acting on all three support means for maintaining the objective at all times at positions providing a sharp image of the negative on the positive; and differential means acting on all three support means for maintaining substantially constant the forces required to move said two support means relative to each other and a third support means, said differential means including a rotary shaft and a manually engageable hand-wheel axially movable on said shaft but not rotatable with re-

spect thereto; and spring means urging said wheel to a position engaging an element which supports the shaft for rotary movement so as to releasably hold the three support means in an adjusted position relative to each other.

15. In a photographic reproduction apparatus, in combination, three support means for respectively supporting an objective, a positive, and a negative; connecting means connecting at least two of said support means for movement relative to each other and relative to the third support means along the optical axis of the objective; focusing means acting on all three support means for maintaining the objective at all times at positions providing a sharp image of the negative on the positive; differential means acting on all three support means for maintaining substantially constant the forces required to move said two support means relative to each other and a third support means, said differential means including a rotary shaft and a manually engageable hand-wheel axially movable on said shaft but not rotatable with respect thereto; and spring means urging said wheel to a position engaging an element which supports the shaft for rotary movement so as to releasably hold the three support means in an adjusted position relative to each other, said hand-wheel and said element which supports the shaft for rotary movement respectively having releasable locking elements which engage each other when the spring means urges the hand wheel toward said element.

16. In a photographic reproduction apparatus, in combination, three support means for respectively supporting an objective, a positive, and a negative an image of which is to be reproduced on the positive; connecting means connecting at least two of said support means for movement relative to each other and relative to the third support means along the optical axis of the objective; bell-crank means acting on all three support means for maintaining the objective at all times in a position providing a sharp image of the negative on the positive; and differential means acting on all three support means for maintaining substantially constant the forces required to move said two support means relative to each other and relative to the third support means.

17. In a photographic reproduction apparatus, in combination, three support means for respectively supporting an objective, a positive, and a negative an image of which is to be reproduced on the positive; connecting means connecting at least two of said support means for movement relative to each other and relative to the third support means along the optical axis of the objective; bell-crank means acting on all three support means for maintaining the objective at all times in a position providing a sharp image of the negative on the positive; and differential means acting on all three support means for maintaining substantially constant the forces required to move said two support means relative to each other and relative to the third support means, said bell-crank being pivotally connected to the support means for the objective.

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