

[54] **AUTO-FOCUS PRINTING BELOW $1 \times$ MAGNIFICATION**

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[58] Field of Search **355/56, 58, 59**

[56] **References Cited**

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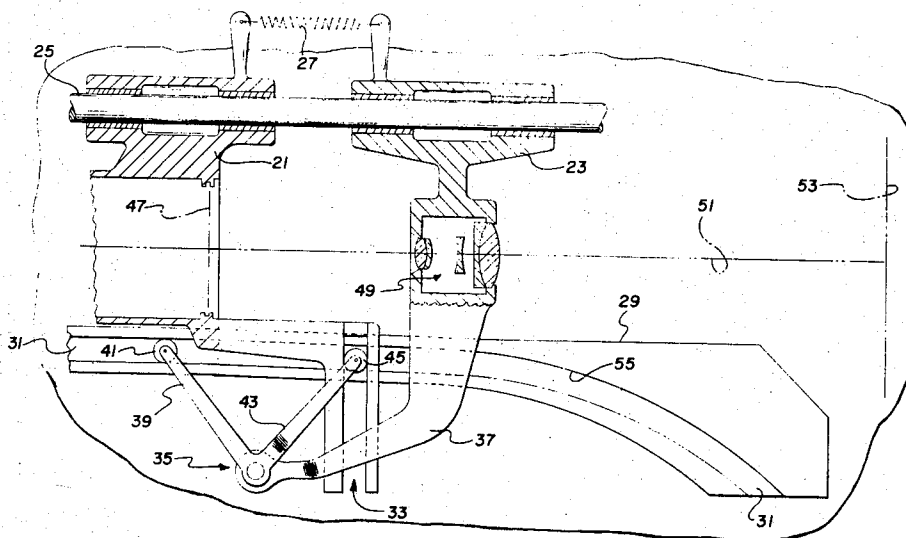
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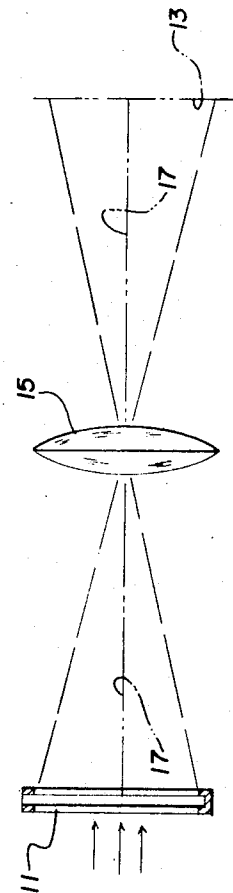
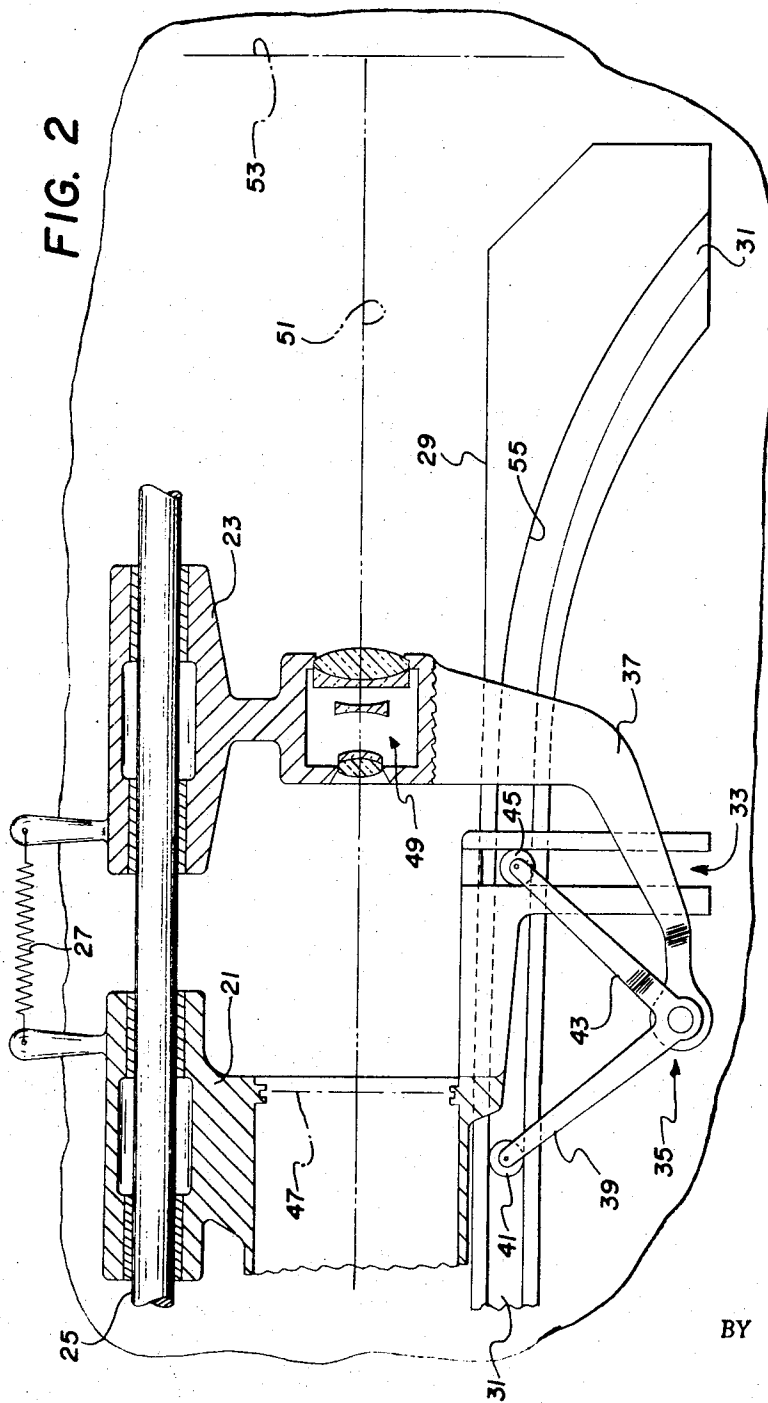
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[57] **ABSTRACT**

Automatic focusing is achieved for magnification factors ranging from above $1 \times$ through and below $1 \times$ by a mechanism which positions the negative with respect to the lens for a given magnification. The lens is positioned with respect to the image plane to establish the desired magnification. The negative holder is linked to the lens via a cam and follower which is configured to automatically establish the proper negative to lens spacing to maintain the system in focus.

4 Claims, 2 Drawing Figures





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AUTO-FOCUS PRINTING BELOW 1,1 × MAGNIFICATION

BACKGROUND OF THE INVENTION

The commercial printing of photographs from negatives has many requirements for varying print sizes either from a single negative or from a series of negatives. In many instances the required magnification factors vary above and below unity. Once the system has been set for a sharp focus, it is highly desirable to be able to maintain this focus automatically as the system is changed for varying magnifications. On the other hand, it has long been known that it is difficult to maintain the focus as the magnification factor is changed through the 1× magnification. This is due to the fact that the overall (conjugate) distance decreases as the magnification factor approaches 1× from above, but increases below 1×. The kinematics to be accomplished by the cam and linkage system in maintaining focus through the 1× magnification zone are impractical and therefore effectively limit the auto-focus capability to magnifications above or below 1×, but not both. The known systems capable of automatically maintaining focus above, through and below unity are very complex, expensive and, in some instances, difficult to use and maintain. In effect the prior art systems operate simultaneously, but independently, on the lens carriage and the negative holder.

An example of the prior art mechanism which provides autofocus capability is disclosed in U.S. Pat. No. 3,408,145 issued on Oct. 29, 1968 to Bermarr M. S. Walzberg entitled, "Auto-Focus Camera and Diaphragm Means Therefor." Walzberg's apparatus utilizes a fixed copy holder and adjustable lens and negative holders. The distance between the lens and the copy holder is controlled by a crank and linkage connected therebetween and pin-pivoted at both ends. The distance between the lens and copy holder is controlled through the action of a crank, cam track, follower and arm linked therebetween. Thus this apparatus requires two non-linear control mechanisms. Further, such apparatus has inherently limited magnification capability because of the structure of its cam and cam track.

OBJECTS AND SUMMARY OF THE INVENTION

Accordingly, it is a principal object of this invention to provide improved photographic apparatus capable of providing magnification factors extending above and below unity while maintaining focus automatically.

Another object of this invention is to provide automatic-focusing photographic apparatus which is relatively simple in construction and operation.

A more specific object of this invention is to provide automatic-focus photographic printing apparatus which extends through unity magnification and uses a singular cam and linkage to maintain the automatic focus.

Still another object of this invention is to provide automatic-focus photographic printing apparatus wherein the automatic-focus capability is continuous rather than incremental.

The foregoing and other objects are accomplished according to one aspect of the invention wherein the printer operator changes the magnification factor by first varying the position of the magnifying lens with

respect to the image plane and the photographic paper. A cam and linkage connects the negative holder to the lens in a manner which automatically varies the negative to lens distance to maintain the sharp focus. The cam and linkage operates solely to adjust the lens/negative distance based upon the magnification factor and therefore is relatively simple of design and construction.

DESCRIPTION OF THE DRAWING

FIG. 1 is a diagrammatic optical representation of photographic printing apparatus in which the present invention finds utility; and

FIG. 2 is a side view in section of automatic-focus photographic printing apparatus according to the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

While the following description relates to photographic printing apparatus, it will be readily apparent to those skilled in the art that it is equally applicable to a camera system requiring automatic focusing capabilities.

Referring now to FIG. 1, there is shown in diagrammatic form a photographic system including a negative plane 11 and an object plane 13 with a lens 15 interposed therebetween. Assuming a lens having a focal length f , to obtain a focused image at a magnification m , the proper distances along the optical axis 17 between the negative plane 11 and the lens 15 (i.e., object distance) and between the lens 15 and the print plane 13 (i.e., image distance) are:

$$\text{Object Distance} = f(1 + 1/m)$$

$$\text{Image Distance} = f(1 + m)$$

Discounting the hiatus of the lens 15, the conjugate distance, O.A., between the negative plane 11 and the print plane 13 for a magnification m , is given by the equation:

$$\text{O.A.} = [b'f(1+m)^2]/m$$

If we were to assume a lens having a focal length, f , of 4 inches, for magnification factors varying from 4 down to 0.6, we would find the various relations between the magnification, object distance, image distance, and conjugate distance to be as given in the following table:

TABLE I

Magnification	Object Distance	Image Distance	Conjugate Distance
4	5.000	20.000	25.000
3	5.333	16.00	21.333
2	6.000	12.000	18.000
1	8.000	8.000	16.000
0.9	8.444	7.600	16.044
0.8	9.000	7.200	16.200
0.7	9.714		16.514
0.6	10.667		17.067

We can note the following relations between the distances described by the above equations. First, as the magnification factor decreases, the distance between the film negative 11 and the lens 15 increases. Conversely as the magnification decreases, the distance between the lens 15 and the print plane 13 decreases. The difficult factor is the conjugate distance, O.A., which, as can be seen from the above table, decreases

as magnification approaches one from above and then increases again as the magnification diminishes below one. It is this factor which has made it particularly difficult to develop auto-focus apparatus with fixed print or negative plane, since in relating the lens and the negative to the print plane, or conversely the lens and the print plane to the negative plane, there is defined thereby a complex hyperbolic equation which is difficult to reduce to a mechanical configuration. The principal difficulty with the equation occurs as the magnification factor approaches unity, where the cam angle becomes too steep for practical application. In some instances at unity magnification, the cam angle would be 90°, an impossible system. According to the present invention there lies the recognition that there is a direct relation between the magnification desired and the image distance or the distance between the lens 15 and the print plane 13. Since the image distance can be adjusted in a relatively simple fashion, rather than determining an equation that will relate the negative plane 11 to the print plane 13 for a given magnification and first adjusting the negative or print plane, we instead first adjust the lens with respect to print plane 13 for a given magnification. Then the negative 11 is positioned with respect to the lens 15. It can be seen from the above table and the defined equations that this function is relatively simple.

Referring next to FIG. 2, there is shown in detail printing apparatus with an automatic focus capability according to the present invention. A negative carriage 21 and a lens carriage 23 are supported on a common guide bar 25. The tops of the negative carriage and the lens carriage are connected by a constant tension spring 27 to eliminate any play in the apparatus. The printer frame 29 includes a cam groove 31. Integral with the negative carriage 21 at the bottom thereof is a nest 33 in the form of a forked section extending down from the carriage. A bell crank 35 is attached to and pivots on an arm 37 of the lens carriage 23. The arm 39 of the bell crank 35 supports a cam follower bearing 41 which rides in the cam groove 31. Another arm 43 of the bell crank supports a negative carriage positioning bearing 45 which rides in the nest 33 of the negative carriage.

In the negative carriage 21 is the negative focal plane 47 which is adapted to support a film negative. In the lens carriage 23 is supported a suitable lens array 49. The optical centerline 51 passes through the center of the negative plane 47, the lens array 49 and impinges on the center of the image or print plane 53.

In FIG. 2, it can be seen that the cam groove 31 gradually slopes downwardly going from left to right until the knee 55 is reached, at which point the groove falls off rapidly. As will become more readily apparent, the knee 55 represents the position of the cam follower bearing for unity magnification, with positions to the left of the knee conforming to magnifications in excess of unity and positions to the right of the knee being magnifications less than unity.

In operation, the lens carriage 23 is moved relative to the print plane 53 to give a desired factor of magnification. Movement may be accomplished by any known motive means such as a chain belt drive or motor and drive screw. With reference to FIG. 2, if the lens carriage is moved from left to right, the cam following

bearing 41 tracking in the cam groove 31 will move gradually downwardly as it approaches the knee 55 of the cam groove 31. The downward movement of the bearing 41 in the cam groove 31 causes the bell crank 35 to be pivoted counterclockwise about the arm 37 of the lens carriage. Pivoting of the bell crank 35 in turn causes the negative carriage positioning bearing 45 to move in the nest 33 to move the negative carriage 21 relatively away from the lens carriage 23. Thus, while the conjugate distance will be decreasing the object distance and the image distance will be changing in the proper proportions to insure automatic focusing for a given magnification above unity.

The increasing separation between the negative carriage 21 and the lens carriage 23 is gradual until the point where the cam following bearing 41 reaches the knee 55 of the cam groove 31. At this point the cam following bearing 41 will move rapidly downwardly in the cam groove 31. The configuration of the cam groove 31 is such that movement of the cam following bearing 41 to the right of the knee 55 will cause the separation between the lens carriage 23 and the negative carriage 21 to increase more rapidly than the decrease in separation between the lens carriage 23 and the print plane 53 so that the conjugate distance begins to increase to maintain automatic focusing for a given magnification below unity.

While the equations relating to FIG. 1 ignored the hiatus of the lens array, the actual configuration of the cam groove 31 can be determined in the following manner:

Let X = abscissa of the cam follower bearing 41, which equals the distance from the cam follower bearing to the print plane 53;

Let Y = ordinate of the cam follower bearing 41, which is the distance from the cam follower bearing to the end of the arm 37 of the lens carriage; then

$$X = ME + F_1 + L + F_2 + k - \cos(\alpha + \theta)R \text{ and}$$

$$Y = \sin(\alpha + \theta)R, \text{ where}$$

M = magnification of the system,

E = effective focal length of the lens array,

F_1 = front focus of the lens array,

F_2 = back focus of the lens array,

L = length of the lens array, and

k = a constant, being the horizontal distance between the back of the back focus of the lens array and the pivot point at the end of the arm 37 of the lens carriage 23,

R = effective radial length of the arms 39, 43 of bell crank 35;

θ = angle between the arms 39, 43 of the bell crank 35;

α = angle between the arm 43 of the bell crank 35 and the horizontal axis.

The angle α is readily determinable since it is equal to $\cos^{-1} b/R$ where b , which is the horizontal distance between the pivot axis of the bell crank 35 and the vertical centerline of the nest, may be calculated from the known apparatus geometry by subtracting from the horizontal distance between back focus F_2 and pivot axis of the bell crank, the difference between the effective focal length of the lens E divided by the selected magnification M and the horizontal distance between the negative focal plane 47 and the vertical centerline of the nest.

With the configuration for the cam groove 31 as calculated above, it has been found that by positioning the lens carriage 23 the proper distance from the print plane 53 to obtain the desired magnification, the negative carriage 21 is automatically positioned properly to maintain the apparatus in focus. The cam groove 31 configuration is relatively simple in form so that no undue stresses are placed on the apparatus, and it is relatively easy to maintain the alignment of the apparatus.

Referring back to the simplified formulas set out in the discussion of FIG. 1, it can be seen that the object distance, that is the distance between the lens and the negative, approaches f , the lens focal length, as the magnification approaches infinity. Therefore, the groove 31 of the cam of FIG. 2 flattens out as the magnification increases and the only limitation on the maximum magnification available with the apparatus according to the present invention, is on the length of the printer frame in which the cam groove is machined.

The invention has been described in detail with particular reference to preferred embodiments thereof, but it will be understood that variations and modifications can be effected within the spirit and scope of the invention.

I claim:

1. In photographic printing apparatus including a housing and a print plane, a negative holder and a magnifying lens of fixed focal length positioned in a lens carriage in said housing between said print plane and said negative holder, an automatic focusing drive mechanism operative to maintain said apparatus in focus for a continuous range of magnification varying from less than unity to substantially more than unity, said mechanism comprising:
 - first linear positioning means coupled to said lens carriage and operative to position said lens the required distance from said print plane to effect a given magnification;
 - second positioning means coupled to said negative holder;
 - support means extending from said lens carriage;
 - a bell crank having first and second arms, said bell crank being pivotally supported by said support means;
 - bearing means supported on said first arm of said bell crank and connected to said second positioning means to control the position thereof;
 - cam groove means supported by said housing and cam follower means supported by said second arm of

said bell crank and positioned to ride in said cam groove means whereby movement of said cam follower means in said cam groove means upon movement of said lens by said first positioning means will cause rotation of said bell crank and corresponding movement of said bearing means to control the relative position between said lens carriage and said negative holder for the required distance to maintain focus or any selected magnification.

2. The invention according to claim 1 wherein the required distance between the negative holder and the lens is in substantial agreement with the equation $f(1 + 1/m)$, where f is equal to the focal length of the lens and m is the given magnification factor.

3. The apparatus of claim 2, wherein said second positioning means includes an arm extending from said negative holder, said arm having a nest in the end thereof vertically oriented with respect to the optical axis of said lens and wherein said bearing means rides in said nest.

4. The apparatus of claim 3, wherein said cam groove means is configured to be in substantial agreement with the equations:

$$X = ME + F_1 + L + F_2 + k - \cos(\alpha + \theta)R \text{ and}$$

$$Y = \sin(\alpha + \theta)R, \text{ where}$$

M = magnification of the system;

E = effective focal length of said magnifying lens;

F_1 = front focus of said magnifying lens;

F_2 = back focus of said magnifying lens;

L = length of said magnifying lens;

k = a constant, being the horizontal distance between the back focus of said magnifying lens and the pivot axis of said bell crank at the end of said support extending from said lens carriage;

R = radial length between the axis of said bearing means and the pivot axis of said bell crank;

θ = angle between said first and second arms of said bell crank;

α = angle between said first arm of the bell crank and the horizontal axis which is equal to $\cos^{-1}(b/R)$ where b may be calculated from the apparatus geometry by subtracting from the horizontal distance between back focus and pivot axis of said bell crank, the difference between the effective focal length of said magnifying lens divided by the selected magnification and the horizontal distance between said negative holder and the vertical centerline of said nest.

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