1,008,309

PATENT SPECIFICATION

DRAWINGS ATTACHED

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COMPLETE SPECIFICATION

Variable Focal Length Lens System

We, ETABLISSEMENTS PIERRE ANGENIEUX, SOCIÉTÉ ANONYME, a Body Corporate organized and existing under the laws of France, of 34 Boulevard Haussmann, Paris, France, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to variable focal length lens systems of the type wherein a substantially non-focal device comprising movable component elements, which will be termed hereinafter "variator", is disposed in front of a fixed component element to be termed hereinafter "basic lens member". As a rule, variable focal length lens systems of this character are so designed that said basic lens member has a relatively long focal length with respect to the dimensions of the image size to be covered, so that the angle of view of this basic lens member considered separately be relatively reduced.

Under these conditions, it is easier to obtain a variator which, in combination with said basic lens member, will give good-quality images. An arrangement of this character is particularly suited for motion-picture purposes, especially sub-standard motion pictures, but an objection arises when it is desired to apply this device to the sizes normally used in still photography, for in this case abnormally large dimensions are attained. In fact, it is current practice to use, notably in the case of motion pictures, a basic lens member having a focal length of about three times that of the diagonal of the image size to be covered. In the case of a 24 x 36 mm. size giving a diagonal of about 43 mm., if it is desired to use a device of this type a basic lens member having a focal length of about 130 mm. must be provided. Under these conditions, it is clear that the basic lens and the variator constitute a very cumbersome assembly. To avoid this drawback, the focal length of the basic lens member must be reduced, but in this case the difficulty lies in obtaining a variator capable of producing good quality images under these specific conditions.

It is the chief object of the present invention to avoid this drawback by providing a variable focal length lens system wherein the basic lens member has a focal length less than twice the diagonal of the picture size to be covered.

According to the present invention there is provided a variable focal length lens system comprising a first fixed convergent member, a second axially movable divergent member, a third axially movable convergent member, these three members being aligned on a common optical axis and constituting a substantially non-focal device disposed in front of a basic lens member aligned on the same optical axis, the first member consisting of at least three lens elements of which at least one is divergent, the second member consisting of at least three lens elements constituting two divergent sections separated by an air gap, the third member consisting of at least two lens elements of which at least one is divergent and has a concave front face located behind a convergent lens element of which the rear face is convex, this assembly meeting the following requirements:

$$\begin{array}{llll} 0.80\ F & < f\ 1 & & < 2.\ F \\ 0.50\ F & < f\ 3 & & < 1.50\ F \\ 0.4 & < G & & < 1.3 \\ 0.5\ f\ 3 & < R\ 14 & & < R\ 13 < 1.3\ f\ 3 \end{array}$$

$$\frac{1}{50\ f\ 3} < \frac{1}{R\ 14} - \frac{1}{R\ 13} < \frac{1}{f\ 3}$$

wherein f 1 is the focal length of the first member, f 3 the focal length of the third member F the focal length of the basic lens member, G the image magnification produced by said second member, R 13 the absolute value of the radius of curvature of the rear face of said convergent lens element of said third member, and R 14 the absolute value of the radius of curvature of the front face of said divergent lens element of said third member.

In this lens system the first three members located preferably in front of the aperture stop or diaphragm constitute the variator, the fourth member disposed preferably behind the aperture stop or diapragm constituting the basic lens member. This basic lens member is of course convergent. The variation in the focal length is effected mainly by displacing the second member, the chief purpose of the displacement of the third member being to keep the position of te final image in a fixed plane.

A preferred form of embodiment of this invention consists in utilizing as a first component member a device comprising only three lens elements. In this case, this first component member comprises at the front a first section consisting of a divergent lens element followed by a biconvex lens element (these two lenses being cemented or not) and at the rear another section consisting of a converging meniscus lens element having its convexity directed forwards. In this case it is advantageous to meet the following requirements:

$$4 f 1 < \varphi$$
$$3 f 1 < R 1$$

wherein φ is the focal length of the first section, R 1 designating the absolute value of the radius of curvature of the front face of the front lens element of said first section, this front face being convex or concave.

In another preferred form of embodiment of the invention the third member consists of only two lens elements, the front lens element being biconvex and the rear one a divergent meniscus. In this case, it is advantageous to adhere to the following prescriptions:

$$R 12 < R 15$$
$$0.6 f 3 < R 12 < 1.6 f 3$$

wherein R 12 designates the absolute value of the radius of curvature of the front face of the biconvex lens element and R 15 the absolute value of the radius of curvature of the rear face of the divergent meniscus lens element.

In the accompanying drawing given by way of example the reference symbols C 1, C 2, C 3 designate in the front to rear direction the first, second and third members, of the assembly which constitute the variator. C 4 designates the basic lens member; 1, 2, 3, ... 11 designate the various lens elements; t 1, t 2, t 3 . . . . t 11 designate the lens thicknesses; s 1, s 2, s 3, ... s 9 designate the air gaps provided between adjacent lens elements, and R 1, R 2, R 3, ... R 21 designate the radii of curvature of the lens surfaces. The aperture stop or iris diaphragm is positioned between member C 3 and the basic lens member C 4. The numerical characteristics of the system are set forth in the table hereunder:

Lens Element	N	ν	Radii in mm.	Thicknesses in mm.
1	1.7313	28.4	R 1 + 464.80 R 2 + 66.205	t 1 1.15 s 1 0.21
2	1.6202	60.2	R 3 + 69.80 R 4 — 236.20	t 2 6.29 s 2 0.07
3	1.6202	60.2	R 5 + 50.04 R 6 + 283.60	t 3 4.26 s 3 from 1.25 to 22.27 and to 23.79
4	1.6909	54.8	R 7 + 232.70 R 8 + 23.84	t 4 0.77 s 4 4.50
5	1.6169	54.0	R 9 — 45 R 10 + 22.77	t 5 0.58
6	1.7313	28.4	R 11 + 574	t 6 3 s 5 from 14.12 to 2.31 and to 0.70
7	1.7199	50.3	R 12 + 45 R 13 — 63.50	t 7 3 s 6 0.49
8	1.7313	28.4	R 14 — 42.42 R 15 — 119.82	t 8 1.49 s 7 from 11.21 to 2 and to 2.09
9	1.7199	50.3	R 16 + 21.80 R 17 — 2182	t 9 4.04 s 8 2.70
10	1.6985	30.2	R 18 — 62.77 R 19 + 19.50	t 10 0.97 s 9 8
11	1.7199	50.3	R 20 + 129.80 R 21 — 37.88	t 11 2.43

The focal length varies from 46.51 to 82.78 and to 87.73

The focal length φ of the first section of the first member is +483.87

In this table as in the drawing the lens elements are designated in the front to rear direction in column 1; the indices of refractions *N* for the spectrum lines *D* and the conventional dispersive powers (Abbe number) are given in columns two and three; the radii of curvature of the lens surfaces, the thicknesses *t* of these lens elements and the air gaps *s* are shown in the fourth and fifth columns respectively.

In this table the air gap *s* 3 provided between the first and second members corresponds to the focusing of the lens system on an object situated at infinity, but member *C* 1 is displaceable axially forwards to permit the focusing on nearby objects.

The focal length of *C* 1 is equal to 80.73 mm, that of member *C* 2 is 26.95 mm, and that of member *C* 3 is 64.41 mm and that of the basic lens member *C* 4 is 63.14 mm. The

focal length of the lens system is adjusted to its minimum value which is 46.51 mm when $s\ 3 = 1.25$ mm; $s\ 5 = 14.12$ mm; $s\ 7 = 11.21$ mm; it is adjusted to a focal length $f = 82.78$ mm when $s\ 3 = 22.27$ mm; $s\ 5 = 2.31$ mm; $s\ 7 = 2$ mm; and finally, it is adjusted to its maximum focal length which is then 87.73 when $s\ 3 = 23.79$ mm; $s\ 5 = 0.70$ mm; $s\ 7 = 2.09$ mm.

In this example, as the divergent member $C\ 2$ moves axially, member $C\ 3$ moves likewise axially in conformity with the law establishing the position of these two members with a view to obtaining a fixed position of the final image.

The movements of the axially movable members C_2 and C_3 are such that the variable distances S_3, S_5 and S_7 confirm the double equality:

$$S_3 + S_5 + S_7 = 26.58$$

The magnification G_2 of the image given by the second member C_2 is:

$G_2 = 0{,}562$ when $S_3 = 1.25$ $S_5 = 14.12$ $S_7 = 11.21$
$G_2 = 1{,}000$ when $S_3 = 22.27$ $S_5 = 2.31$ $S_7 = 2$
$G_2 = 1{,}060$ when $S_3 = 23.79$ $S_5 = 0.70$ $S_7 = 2.09$

WHAT WE CLAIM IS:—

1. A variable focal length lens system comprising a first fixed convergent member, a second axially movable divergent member, a third axially movable convergent member, these three members being aligned on a common optical axis and constituting a substantially non-focal device disposed in front of a basic lens member aligned on the same optical axis, the first member consisting of at least three lens elements of which at least one is divergent, the second member consisting of at least three lens elements constituting two divergent sections separated by an air gap, the third member consisting of at least two lens elements of which at least one is divergent and has a concave front face located behind a convergent lens element of which the rear face is convex, this assembly meeting the following requirements:

$$\begin{array}{lll} 0.80\ F < f\ 1 & & < 2.\ F \\ 0.50\ F < f\ 3 & & < 1.50\ F \\ 0.4 < G & & < 1.3 \\ 0.5\ f\ 3 < R\ 14 & & < R\ 13 < 1.3\ f\ 3 \\ \dfrac{1}{50\ f\ 3} < \dfrac{1}{R\ 14} & - & \dfrac{1}{R\ 13} < \dfrac{1}{f\ 3} \end{array}$$

wherein $f\ 1$ is the focal length of the first member, $f\ 3$ the focal length of the third member, F the focal length of the basic lens member, G the image magnification produced by said second member, $R\ 13$ the absolute value of the radius of curvature of the rear face of said convergent lens element of said third member, and $R\ 14$ the absolute value of the radius of curvature of the front face of said divergent lens element of said third member.

2. A variable focal length lens system as set forth in claim 1, wherein said first member comprises two sections, the first section consisting of a divergent lens element followed by a biconvex lens element, the second section consisting of a convergent meniscus lens element having its convexity directed forwards, said first component meeting the following requirements:

$$\begin{array}{l} 4\ f\ 1 < \varphi \\ 3\ f\ 1 < R\ 1 \end{array}$$

wherein φ designates the focal length of said first section, $R\ 1$ representing the absolute value of the radius of curvature of the front face of the front lens element of said first section.

3. A variable focal length lens system as set forth in claim 1, wherein said third member comprises two lens elements, the front lens element being biconvex and the rear lens element in the form of a divergent meniscus, said third member meeting the following requirements:

$$\begin{array}{lll} R\ 12 & < & R\ 15 \\ 0.6\ f\ 3 & < & R\ 12 < 1.6\ f\ 3 \end{array}$$

wherein $R\ 12$ designates the absolute value of the radius of curvature of the front face of the biconvex lens and $R\ 15$ the absolute value of the radius of curvature of the rear face of the lens element having the shape of a divergent meniscus.

4. A variable focal length lens system substantially as described hereinabove with reference to the accompanying drawings.

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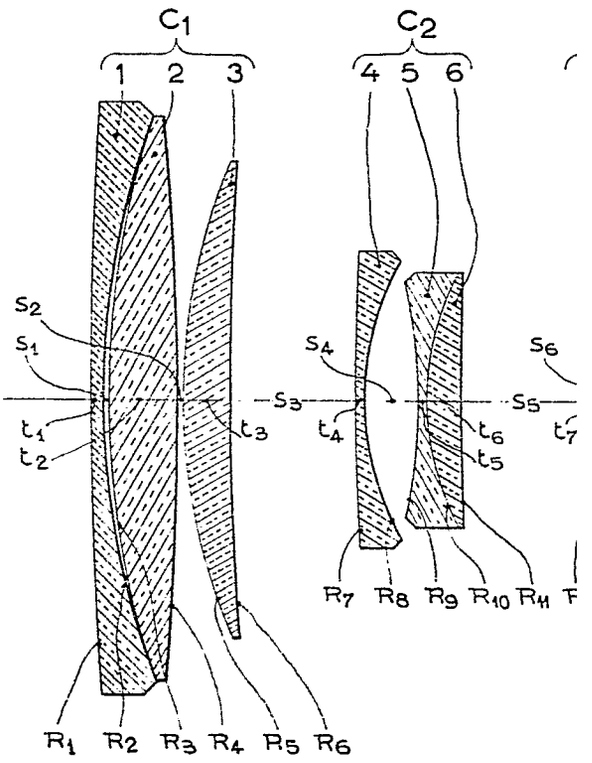
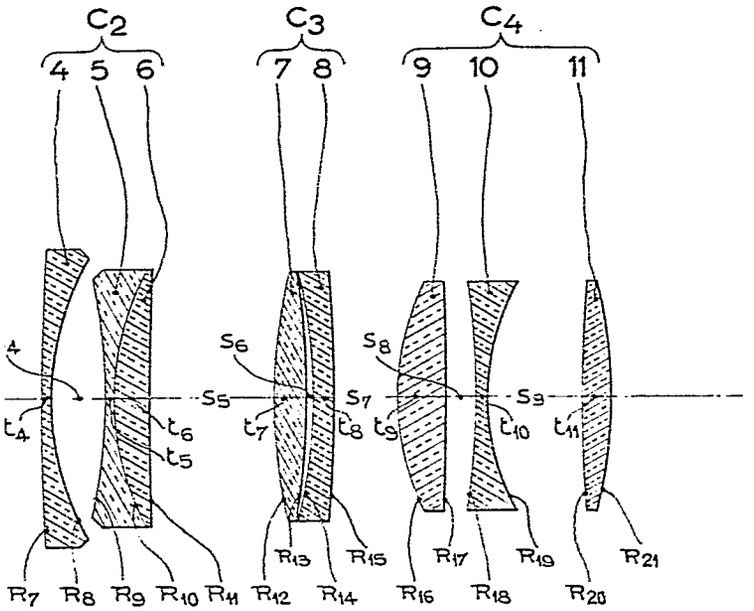

C1
C2
1
2
3
4
5
6
S2
S1
S4
S6
S3
S5
t1
t2
t3
t4
t5
t6
t7
R1
R2
R3
R4
R5
R6
R7
R8
R9
R10
R11

1008309 COMPLETE SPECIFICATION

1 SHEET *This drawing is a reproduction of the Original on a reduced scale*



R6

1008309 COMPLETE SPECIFICATION
1 SHEET

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