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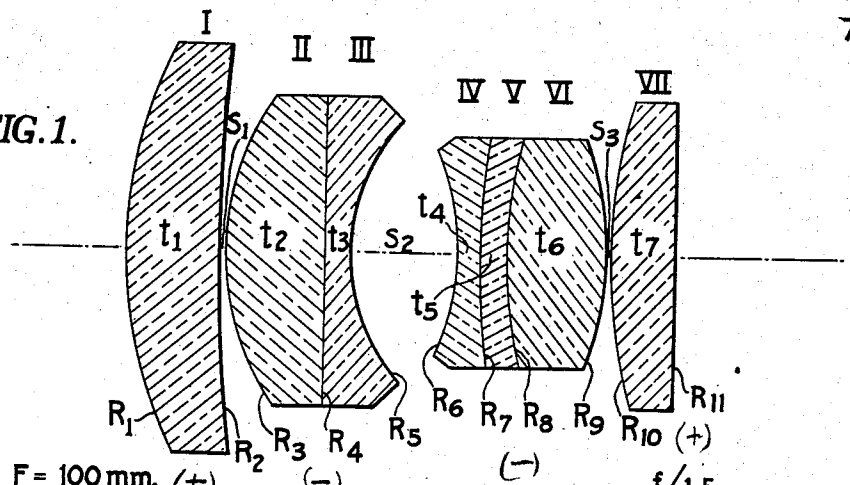
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PHOTOGRAPHIC OBJECTIVE

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FIG. 1.



F = 100 mm. f/1.5

LENS	GLASS		RADII	SPACINGS
I	N_D = 1.639	ν = 55.5	R_1 = + 70.2 mm	t_1 = 14.9 mm
			R_2 = + 535.0	S_1 = 4
II	= 1.523	= 58.6	R_3 = + 41.2	t_2 = 15.6
III	= 1.649	= 33.8	R_4 = ∞	t_3 = 4.0
			R_5 = + 29.5	S_2 = 16.9
IV	= 1.500	= 61.8	R_6 = − 38.0	t_4 = 3.6
V	= 1.720	= 29.3	R_7 = + 198.5	t_5 = 4.0
VI	= 1.639	= 55.5	R_8 = + 68.5	t_6 = 15.5
			R_9 = − 49.6	S_3 = .4
VII	= 1.620	= 60.4	R_{10} = + 80.3	t_7 = 9.9
			R_{11} = ∞	

F = 100 mm. f/1.5

LENS	GLASS		RADII	SPACINGS
I	N_D = 1.617	ν = 55.0	R_1 = + 64.7 mm	t_1 = 12.9 mm
			R_2 = + 505.0	S_1 = .1
II	= 1.541	= 59.9	R_3 = + 37.5	t_2 = 15.7
III	= 1.649	= 33.8	R_4 = ∞	t_3 = 3.9
			R_5 = + 26.3	S_2 = 16.0
IV	= 1.516	= 64.0	R_6 = − 43.5	t_4 = 3.5
V	= 1.720	= 29.3	R_7 = + 196.0	t_5 = 3.9
VI	= 1.744	= 45.8	R_8 = + 44.8	t_6 = 13.3
			R_9 = − 65.4	S_3 = 6.3
VII	= 1.617	= 55.0	R_{10} = + 89.0	t_7 = 5.3
			R_{11} = ∞	

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BY

ATTORNEY

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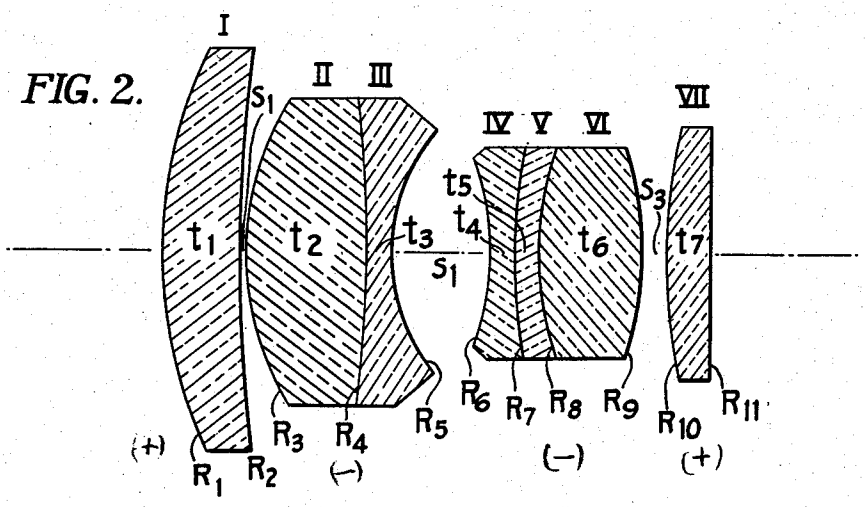
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PHOTOGRAPHIC OBJECTIVE

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FIG. 2.



F = 100 mm. f/1.5

LENS	GLASS		RADII	SPACINGS
I	N_D = 1.639	ν = 55.5	R_1 = + 78.8mm	t_1 = 12.3 mm
			R_2 = +1038.0	S_1 = .4
II	= 1.620	= 60.4	R_3 = + 43.2	t_2 = 19.2
III	= 1.649	= 33.8	R_4 = − 278.5	t_3 = 4.0
			R_5 = + 28.4	S_2 = 15.4
IV	= 1.464	= 65.7	R_6 = − 40.5	t_4 = 4.0
V	= 1.720	= 29.3	R_7 = + 90.8	t_5 = 4.0
VI	= 1.588	= 53.4	R_8 = + 48.2	t_6 = 15.8
			R_9 = − 52.1	S_3 = 4.0
VII	= 1.620	= 60.4	R_{10} = + 83.5	t_7 = 7.0
			R_{11} = ∞	

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UNITED STATES PATENT OFFICE

2,252,682

PHOTOGRAPHIC OBJECTIVE

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Application May 17, 1940, Serial No. 335,784

7 Claims. (Cl. 88—57)

This invention relates to lenses and particularly to high aperture photographic lenses.

It is an object of the invention to provide a lens having a high relative aperture, a high covering power and a high degree of correction for the various aberrations including spherical aberration, chromatic aberration, lateral color, curvature of field, astigmatism, sine condition, coma, distortion, Petzval condition, ghost images, vignetting, and flare.

Specifically it is object of the invention to provide a high quality objective covering over 22 degrees from the axis and capable of being used at f/1.5.

Photographic objectives can be divided into certain types. The present objective belongs to a type having four components of which the two outer ones are positive and the two inner ones are highly meniscus concave to the diaphragm which is placed therebetween. Whether the individual components are simple, compound cemented or compound air spaced, the four of them are axially aligned and separated from one another by air spaces. Thus, this type of objective always includes at least three air spaces. In general, the outer positive components are single elements but may be compound or even consist of separated, i. e. air spaced elements. The present invention is equally applicable to all variations in these outer components, but is here described particularly with reference to single outer components since this is the simplest form of this type of objective and since the need for the invention is greatest in this simple case. On the other hand, the invention may be combined with that described in my copending application Serial No. 335,783, filed concurrently herewith or with those of Herzberger and Frederick and Herzberger described respectively in applications Serial Numbers 335,785 and 335,786, also filed concurrently herewith. The invention is not specifically concerned with the second component which in this type of lens is generally a doublet with a crown glass cemented to the front of a flint glass, the cemented surface being flat or only slightly curved positive (convex to the incident light) or negative (concave to the incident light).

If a lens of this general type is designed to work at a large aperture such as f/1.5 and to cover a large field such as 22 degrees from the axis, the spherical aberration cannot be fully corrected without throwing off the color correction. Also, the field is badly curved and distortion is prevalent. According to the present invention these difficulties are overcome by making a third component in the form of a triplet with the front element of very low index glass and the second element of high index glass at least .15 greater than that of the front element and preferably with a dispersive index (D) at least 20 less than that of the front element. The index and dispersion of the third element of the triplet is not critical but in the preferred form has an index intermediate to the other two elements or only slightly greater than that of the middle element. The high index of the middle element with its low dispersive index not only provides improved color correction while the spherical aberration is corrected but also apparently has a beneficial effect on the rim ray agreement.

According to a preferred embodiment of the invention, the distortion and rim ray agreement are even further corrected by using a very low index glass in the front element and by shifting powers accordingly. In this preferred embodiment, it happens that so-called chromatic differences in spherical aberration and lateral color can both be improved by making the cemented surface of the second component of the lens slightly negatively curved preferably to about —3F.

Specifically the third component should have a front surface with a negative radius of curvature between .3F and .5F where F is the focal length of the objective; the next surface which is a cemented one should have a radius of curvature between .5F and infinity, the third should have a radius between .3F and 3F and the rear surface of this triplet should have a radius of curvature between .25F and .75F.

The form of the rear component is immaterial to the present invention, the examples given below have a plano rear surface, but biconvex elements and various compound forms including those already well known and those described by Herzberger mentioned above are equally satisfactory. In the accompanying drawings:

Fig. 1 illustrates two embodiments of the invention.

Fig. 2 illustrates a preferred embodiment of the invention.

The lenses shown in cross section in the drawings have the following characteristics:

Fig. 1 (first table)

F=100 mm.				f/1.5
Lens	Glass		Radii	Spacings
I	N_D=1.639	ν=55.5	R_1=+70.2 mm. R_2=+535.0	t_1=14.9 mm. s_1=.4
II	=1.523	=58.6	R_3=+41.2	t_2=15.6
III	=1.649	=33.8	R_4=∞	t_3=4.0
			R_5=+29.5	s_2=16.9
IV	=1.500	=61.8	R_6=−38.0	t_4=3.6
V	=1.720	=29.3	R_7=+198.5	t_5=4.0
VI	=1.639	=55.5	R_8=+68.5	t_6=15.5
			R_9=−49.6	s_3=.4
VII	=1.620	=60.4	R_{10}=+80.3	t_7=9.9
			R_{11}=∞	

Fig. 1 (second table)

F=100 mm.				f/1.5
Lens	Glass		Radii	Spacings
I	N_D=1.617	ν=55.0	R_1=+64.7 mm. R_2=+505.0	t_1=12.9 mm. s_1=.1
II	=1.541	=59.9	R_3=+37.5	t_2=15.7
III	=1.649	=33.8	R_4=∞	t_3=3.9
			R_5=+26.3	s_2=16.0
IV	=1.516	=64.0	R_6=−43.5	t_4=3.5
V	=1.720	=29.3	R_7=+196.0	t_5=3.9
VI	=1.744	=45.8	R_8=+44.8	t_6=13.3
			R_9=−65.4	s_3=6.3
VII	=1.617	=55.0	R_{10}=+89.0	t_7=5.3
			R_{11}=∞	

Fig. 2

F=100 mm.				f/1.5
Lens	Glass		Radii	Spacings
I	N_D=1.639	ν=55.5	R_1=+78.8 mm. R_2=+1038	t_1=12.3 mm. s_1=.4
II	=1.620	=60.4	R_3=+43.2	t_2=19.2
III	=1.649	=33.8	R_4=−278.5	t_3=4.0
			R_5=+28.4	s_2=15.4
IV	=1.464	=65.7	R_6=−40.5	t_4=4.0
V	=1.720	=29.3	R_7=+90.8	t_5=4.0
VI	=1.588	=53.4	R_8=+48.2	t_6=15.8
			R_9=−52.1	s_3=4.0
VII	=1.620	=60.4	R_{10}=+83.5	t_7=7.0
			R_{11}=∞	

When this invention is applied to the simplest form of this general lens type, namely, that in which the front half of the lens consists of a single element followed by a doublet this front half must follow established rules, namely, R_1 must be between .3F and F, R_2 is preferably greater than F or at least its absolute value is greater than F, i. e. it is between −F and F, R_3 should be between .3F and .6F and R_5 should be between .2F and .5F.

Having thus described three preferred embodiments of my invention, I wish to point out that it is not limited to the specific examples, but is of the scope of the appended claims.

What I claim and desire to secure by Letters Patent of the United States is:

1. A photographic objective of the type having four components separated by air and axially aligned of which the two outer components are positive and the two inner ones are highly meniscus concave toward a diaphragm therebetween characterized by the inner component immediately behind the diaphragm consisting of three cemented elements, the surface adjacent to the diaphragm being concave to the diaphragm and having a negative radius of curvature between .3F and .5F where F is the focal length of the objective, the next and cemented surface being convex toward the diaphragm and having a radius of curvature between .5F and infinity, the third and cemented surface being convex toward the diaphragm and having a radius of curvature between .3F and 3F and the rear surface of said component being concave toward the diaphragm and having a radius of curvature between .25F and .75F, the index of refraction of the middle element of the three said elements being at least .15 greater than that of the element adjacent the diaphragm.

2. A lens according to claim 1 in which the rear element of the three cemented ones has an index of refraction intermediate to that of the other two elements.

3. A lens according to claim 1 in which the dispersive index of said element adjacent to the diaphragm is at least 20 more than the dispersive index of said middle element.

4. A photographic objective of the type having four components separated by air and axially aligned of which the two outer components are single positive elements and the two inner ones are compond menisci concave toward a diaphragm therebetween and in which the front surface of the front component is convex toward the front and has a radius of curvature between .3F and F where F is the focal length of the objective, the rear surface of the front component has a radius of curvature with its absolute value greater than F, the front surface of the second component has a radius of curvature between .3F and .6F, the rear surface of the second component has a radius of curvature between .2F and .5F, characterized by the third component being a cemented triplet with a front surface being concave toward the diaphragm and having a radius of curvature between .3F and .5F, its rear surface being concave toward the diaphragm and having a radius of curvature between .25F and .75F, the front one of its cemented surfaces being convex toward the diaphragm and having a radius of curvature between .5F and infinity, the rear one of its cemented surfaces being convex toward the diaphragm and having a radius of curvature between .3F and 3F and the index of refraction of the middle element of the triplet being at least .15 greater than that of the element cemented to the front thereof whose dispersive index is at least 20 greater than that of said middle element.

5. A lens according to claim 4 in which the

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compound second component is a doublet with a plano cemented surface.

6. A lens according to claim 4 in which the compound second component is a doublet with a negatively curved cemented surface whose radius of curvature is about 3F.

7. A lens according to claim 1 in which the front element of the three cemented ones has an index of refraction about 1.46, the next element has one about 1.72 and the rear element has one about 1.6.

GEORGE H. AKLIN.