HIGH APERTURE PHOTOGRAPHIC LENS

Filed June 14, 1956
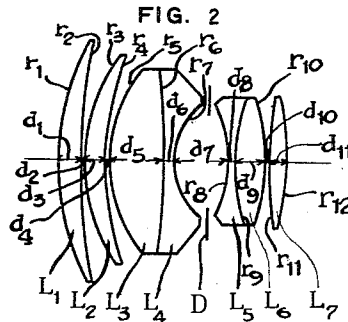
FIG. 1

FIG. 2

FIG. 3

FIG. 4

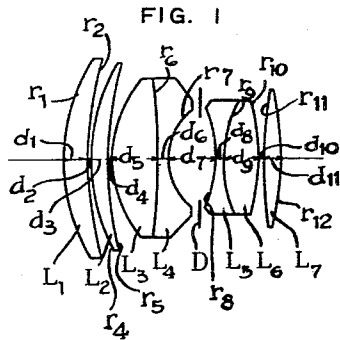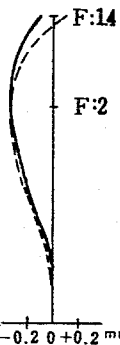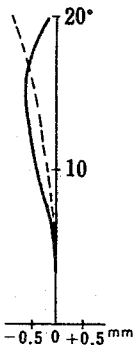FIG. 5
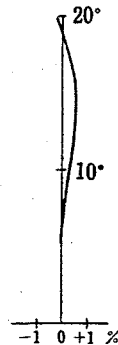
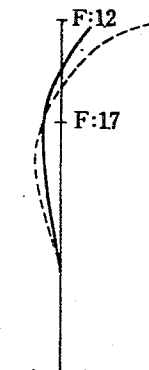SPHERICAL ABERATION AND
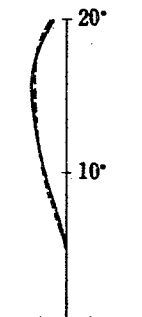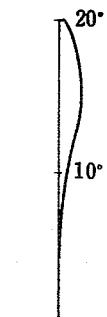UNSATISFIED AMOUNT OF
SINE CONDITION

ASTIGMATISM

DISTORTION

FIG. 6

FIG. 7

FIG. 8

SPHERICAL ABERATION AND
UNSATISFIED AMOUNT OF
SINE CONDITION

ASTIGMATISM

DISTORTION

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This invention relates to a photographic objective and more particularly to an improved high aperture Gauss-type objective.

An object of this invention is to provide an objective of remarkably high aperture by effectively correcting particularly zonal spherical aberration.

It is generally known that there are remarkably numerous kinds of high aperture Gauss-type objectives consisting of six lens elements. These lenses have a common defect in producing no little flair when used at almost full opened diaphragm, since there remains more or less oblique spherical aberration in almost every lens. As I have shown in my prior U. S. Patent No. 2,681,594 entitled, "Photographic objective of Gauss-type" granted June 22, 1954 (corresponding to Japanese Patent No. 205,109, publication No. 6,685/1953), this defect can be remarkably improved by appropriate selection in the arrangement of the refractive indices and radii of curvature at their cemented surfaces of each glass member constituting the Gauss-type lens consisting of six lens elements.

A clearer concept and purpose of this invention may be obtained from the following description, taken in connection with the attached drawing, in which:

Fig. 1 shows a first illustrative embodiment of the objective of my instant invention of F:1.4;

Fig. 2 shows a second embodiment thereof of F:1.2;

Figs. 3, 4 and 5 show the aberrations of the objective shown in Fig. 1; and

Figs. 6, 7 and 8 show the aberrations of the objective shown in Fig. 2.

As shown in the drawing, the objective comprises five components consisting of seven single lenses axially aligned, the first and the second components L_1 and L_2 being meniscus positive single lenses with their convex surfaces towards the object side of the objective, the third component being a meniscus negative lens with its convex surface also towards the object side comprising two cemented lenses, biconvex lens L_3 and biconcave lens L_4, the fourth component being a meniscus positive lens with its convex surface towards the image side of the objective and comprising two cemented lenses, biconcave lens L_5 and biconvex lens L_6, and the fifth component being single biconvex lens. D is a diaphragm positioned between the third component and the fourth component.

The first and second components are two independent single meniscus convex lenses having approximately equal focal lengths. These two lenses correspond to the convex lens of the first component of the conventional Gauss-type objective comprising six lens elements, and

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provide remarkably superb correction of zonal spherical aberration. Furthermore, by selectively observing the following conditions in respect of the refractive index, radii of curvature and thickness of each lens element of the two cemented meniscus lens components, L_3, L_4, L_5 and L_6, a high aperture Gauss-type lens yielding, for instance, an aperture of F:1.2 and angular field (2ω) of approximately 40° can be obtained:

(1)

$$0.15 > n_4 - n_3 > 0.05, \quad v_3 > v_4$$
$$1.83 > n_4 > 1.63$$
$$\infty > |r_6| > 150$$

(2)

$$0.25 > n_6 - n_5 > 0.05 \quad 1.83 > n_6 > 1.60$$
$$61 > v_6 > 49$$
$$70 > |r_8| > 38$$
$$100 > r_9 > 40$$

(3)

$$60 > r_5 > 45, \quad 30 > r_7 > 22$$

(4)

$$32 > d_5 + d_6 > 20$$

and the refractive indices of the three positive lenses L_1, L_2 and L_7 all lie in the range from 1.83 to 1.65.

Conditions (1) serve to have more effective corrections for spherical and chromatic aberrations; conditions (2) are to have more effective correction particularly for oblique spherical aberration, and conditions (3) and (4) are necessary to eliminate astigmatism.

The data of two embodiments of my invention follow, wherein the value of the focal length f is 100, the radii of curvature from the object side of the objective towards the image side thereof is represented consecutively by r_1, r_2 . . . r_{12}, the axial distance between adjacent curved surfaces is d_1, d_2 . . . d_{10}, the refractive index for the D-line of the spectrum and dispersive index of the glass which constitutes the lens element are respectively in order n_1, n_2 . . . n_7 and v_1, v_2 . . . v_7:

Example 1 (Fig. 1)

[f=100   F: 1.4 2ω=40°]

Radius	Thickness and Spacing	Refractive Index n_d	Dispersive Index v
$r_1 = 70.00$			
	$d_1 = 8.0$	$n_1 = 1.6584$	50.8
$r_2 = 150.00$			
	$d_2 = 0.2$		
$r_3 = 72.00$			
	$d_3 = 7.0$	$n_2 = 1.6584$	50.8
$r_4 = 150.00$			
	$d_4 = 0.2$		
$r_5 = 45.97$			
	$d_5 = 17.1$	$n_3 = 1.6385$	49.0
$r_6 = -299.80$			
	$d_6 = 4.9$	$n_4 = 1.7400$	28.2
$r_7 = 26.18$			
	$d_7 = 18.0$		
$r_8 = -43.40$			
	$d_8 = 2.0$	$n_5 = 1.5317$	48.9
$r_9 = 56.60$			
	$d_9 = 14.0$	$n_6 = 1.6584$	50.8
$r_{10} = -69.00$			
	$d_{10} = 0.3$		
$r_{11} = 172.40$			
	$d_{11} = 6.5$	$n_7 = 1.6584$	50.8
$r_{12} = -102.62$			

The focal lengths of the first and second components are 191.7 and 203.1 respectively.

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Example 2 (Fig. 2)

[f=100 F: 1.2 2ω=40°]

Radius	Thickness and Spacing	Refractive Index n_d	Dispersive Index v
$r_1 = 94.00$			
	$d_1 = 9.00$	$n_1=1.6935$	53.5
$r_2 = 251.93$			
	$d_2 = 0.21$		
$r_3 = 68.99$			
	$d_3 = 8.00$	$n_2=1.7173$	47.9
$r_4 = 120.34$			
	$d_4 = 0.96$		
$r_5 = 50.96$			
	$d_5 = 20.48$	$n_3=1.6385$	55.5
$r_6 = -321.70$			
	$d_6 = 4.39$	$n_4=1.7174$	29.5
$r_7 = 27.44$			
	$d_7 = 21.31$		
$r_8 = -43.02$			
	$d_8 = 2.13$	$n_5=1.5174$	52.5
$r_9 = 76.74$			
	$d_9 = 12.40$	$n_6=1.6935$	53.5
$r_{10} = -72.86$			
	$d_{10} = 2.13$		
$r_{11} = 181.58$			
	$d_{11} = 7.17$	$n_7=1.6935$	53.5
$r_{12} = -94.29$			

The focal lengths of the first and second component are respectively 211.2 and 211.6.

Figs. 3, 4, 5, 6, 7 and 8 show the abberation curves for the D-line of the spectrum of the two foregoing embodiments, from which curves the superb performance of objectives according to this invention can readily be recognized.

What I claim is:

1. A high aperture photographic objective of an improved Gauss-type comprising five components consisting of seven elements, the first component L_1 and the second component L_2 being spaced single meniscus positive lenses having substantially equal focal lengths, the third component being a negative meniscus cemented lens having a first front biconvex element L_3 and a first rear biconcave element L_4 of which the convex outer surface faces the object side, the fourth component being a positive cemented lens having a second front biconcave element L_5 and a second rear biconvex element L_6 of which the convex outer surface faces the image side, the fifth component being a spaced third biconvex element L_7, and the object fulfills the following conditions, where $n_{subscript}$ is the index of refraction of the lens element, $v_{subscript}$ the index of dispersion of the d-line of the lens element, and $r_{subscript}$ the radius of curvature of the refracting surface, the subscript in each case increasing from the object to the image side:

$$0.15 > n_4 - n_3 > 0.05 \quad v_3 > v_4$$
$$1.83 > n_4 > 1.63$$
$$\infty > |r_6| > 150$$
$$0.25 > n_6 - n_5 > 0.05 \quad 1.83 > n_6 > 1.60$$
$$61 > v_6 > 49$$
$$70 > |r_8| > 38$$
$$100 > r_9 > 40$$
$$60 > r_5 > 45 \quad 30 > r_7 > 22$$

2. A high aperture photographic objective according to claim 1 in which the refractive index of each single element positive component is in the range from 1.65 to 1.83 and the objective also fulfills the condition $32 > d_5 + d_6 > 20$, where $d_{subscript}$ is the thickness of the lens, respectively the spacing between lenses, along the optical axis, the subscript increasing from the object to the image side of the objective.

3. A high aperture photographic objective of improved Gauss type having improved spherical, particularly oblique spherical, and chromatic aberration correction

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having five air spaced components consisting of a total of seven lens elements of which the numerical data is substantially as follows:

[f=100 F:1.4 2ω=40°.]

Lens	Radius	Thickness and Spacing	Refractive Index	Abbe Number
L_1	$r_1=70.00$	$d_1=8.0$	$n_1=1.6584$	$v_1=50.8$
	$r_2=150.00$	$d_2=0.2$		
L_2	$r_3=72.00$	$d_3=7.0$	$n_2=1.6584$	$v_2=50.8$
	$r_4=150.00$	$d_4=0.2$		
L_3	$r_5=45.97$	$d_5=17.1$	$n_3=1.6385$	$v_3=49.0$
L_4	$r_6=-299.80$	$d_6=4.9$	$n_4=1.7400$	$v_4=28.2$
	$r_7=26.18$	$d_7=18.0$		
L_5	$r_8=-43.40$	$d_8=2.0$	$n_5=1.5317$	$v_5=48.9$
L_6	$r_9=56.60$	$d_9=14.0$	$n_6=1.6584$	$v_6=50.8$
	$r_{10}=-69$	$d_{10}=0.3$		
	$r_{11}=172.40$	$d_{11}=6.5$	$n_7=1.6584$	$v_7=50.8$
L_7	$r_{12}=-102.62$			

where $L_{subscript}$ is the lens element, $r_{subscript}$ the radius of curvature of the lens element, $d_{subscript}$ the thickness of the lens element or the spacing therebetween along the optical axis, $n_{subscript}$ the index of refraction of the lens element, and $v_{subscript}$ the Abbe number representing the dispersion index of the lens element, each series of subscripts increasing in order from the object to the image side of the objective.

4. A high aperture photographic objective of improved Gauss type having improved spherical, particularly oblique spherical, and chromatic aberration cohrection having five air spaced components consisting of a total of seven lens elements of which the numerical data is substantially as follows:

[f=100 F:1.2 2ω=40°.]

Lens	Radius	Thickness and Spacing	Refractive Index	Abbe Number
L_1	$r_1=94.00$	$d_1=9.00$	$n_1=1.6935$	$v_1=53.5$
	$r_2=251.93$	$d_2=0.21$		
L_2	$r_3=68.99$	$d_3=8.00$	$n_2=1.7173$	$v_2=47.9$
	$r_4=120.34$	$d_4=0.96$		
L_3	$r_5=50.96$	$d_5=20.48$	$n_3=1.6385$	$v_3=55.5$
L_4	$r_6=-321.70$	$d_6=4.39$	$n_4=1.7174$	$v_4=29.5$
	$r_7=27.44$	$d_7=21.31$		
L_5	$r_8=-43.02$	$d_8=2.13$	$n_5=1.5174$	$v_5=52.5$
L_6	$r_9=76.74$	$d_9=12.40$	$n_6=1.6935$	$v_6=53.5$
	$r_{10}=-72.86$	$d_{10}=2.13$		
	$r_{11}=181.58$	$d_{11}=7.17$	$n_7=1.6435$	$v_7=53.5$
L_7	$r_{12}=-94.29$			

where $L_{subscript}$ is the lens element, $r_{subscript}$ the radius of curvature of the lens element, $d_{subscript}$ the thickness of the lens element or the spacing therebetween along the optical axis, $n_{subscript}$ the index of refraction of the lens element, and $v_{subscript}$ the Abbe number representing the dispersion index of the lens element, each series of subscripts increasing in order from the object to the image side of the objective.

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