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[54] **WIDE ANGLE OBJECTIVE LENS SYSTEM WITH LARGE BACK FOCUS**

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[52] **U.S. Cl.** **350/214**
[51] **Int. Cl.** **G02b 9/00**
[58] **Field of Search** 350/214

[56] **References Cited**

FOREIGN PATENTS OR APPLICATIONS

45-11790 12/1966 Japan 350/214

Primary Examiner—Ronald L. Wibert
Assistant Examiner—Conrad Clark
Attorney, Agent, or Firm—Wolder & Gross

[57] **ABSTRACT**

A compact, wide angle lens system having a ratio of back focus to focal length exceeding 1.85:1 and excellent optical properties includes eleven lenses successively designated as the first to the eleventh lens in which the seventh and eighth lenses are a cemented doublet, and first, third, fourth, eighth and tenth lenses are negative and the remaining lenses are positive, the lens system satisfying the following conditions:

$$F/2.3 < |F_{1.2.3.4}| < F/1.4,\ F_{1.2.3.4} < 0 \tag{1}$$

$$F/1.2 < F_{1.2.3.4.5.6} < F/0.6 \tag{2}$$

$$0.5F < |r_{14}| < 0.8F,\ r_{14} < 0 \tag{3}$$

$$0.25 < n_8 - n_7 < 0.35 \tag{4}$$

$$0.9F < r_{19} < 1.5F \tag{5}$$

$$0.8F < F_7 < 1.2F \tag{6}$$

$$1.2 < |F_7|/|F_8| < 2.0,\ F_8 < 0$$

wherein F is the focal length of the entire lens system, F_i is the focal length of the i-th lens, $F_{1.2\ .\ .\ .\ i}$ is the focal length of the lens sub-assembly including the first lens to the i-th lens, N_i is the refractive index of the i-th lens at the d-line, r_{14} is the radius of curvature of the mating rear and front faces of the seventh and eighth lenses respectively and r_{19} is the radius of curvature of the rear face of the tenth lens.

2 Claims, 4 Drawing Figures

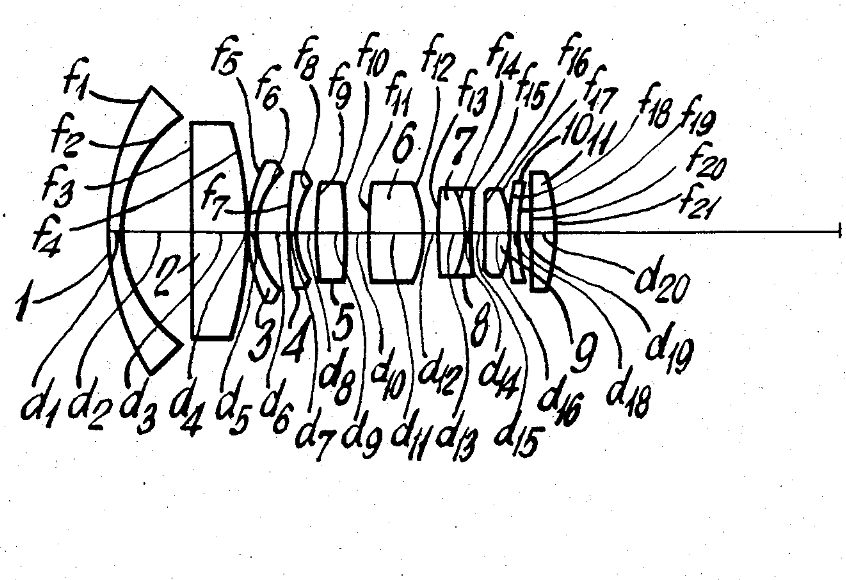
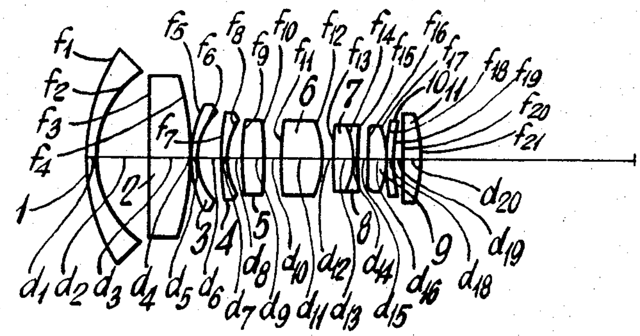


Fig - 1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6
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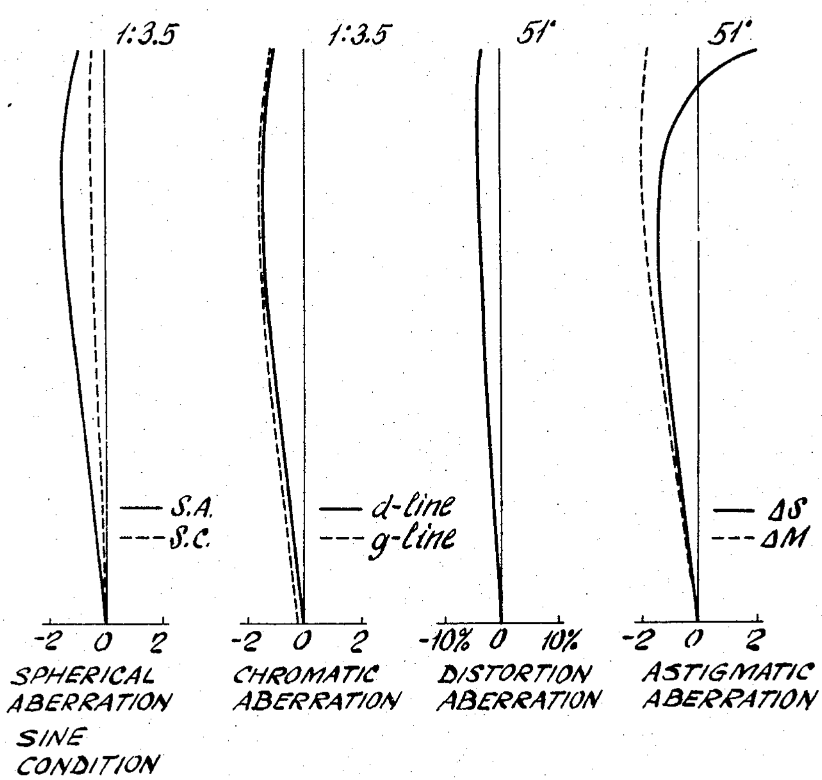
Fig - 2


1:3.5
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--- S.C.
-2 0 2
SPHERICAL ABERRATION
SINE CONDITION
1:3.5
— d-line
--- g-line
-2 0 2
CHROMATIC ABERRATION
51°
-10% 0 10%
DISTORTION ABERRATION
51°
— ΔS
--- ΔM
-2 0 2
ASTIGMATIC ABERRATION

Fig - 3

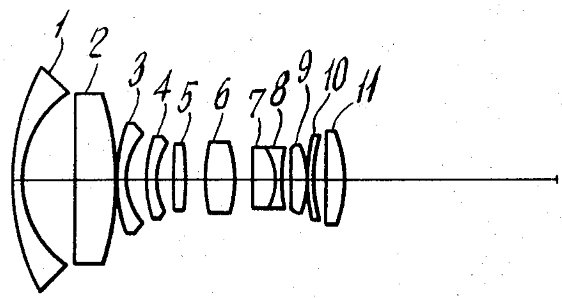
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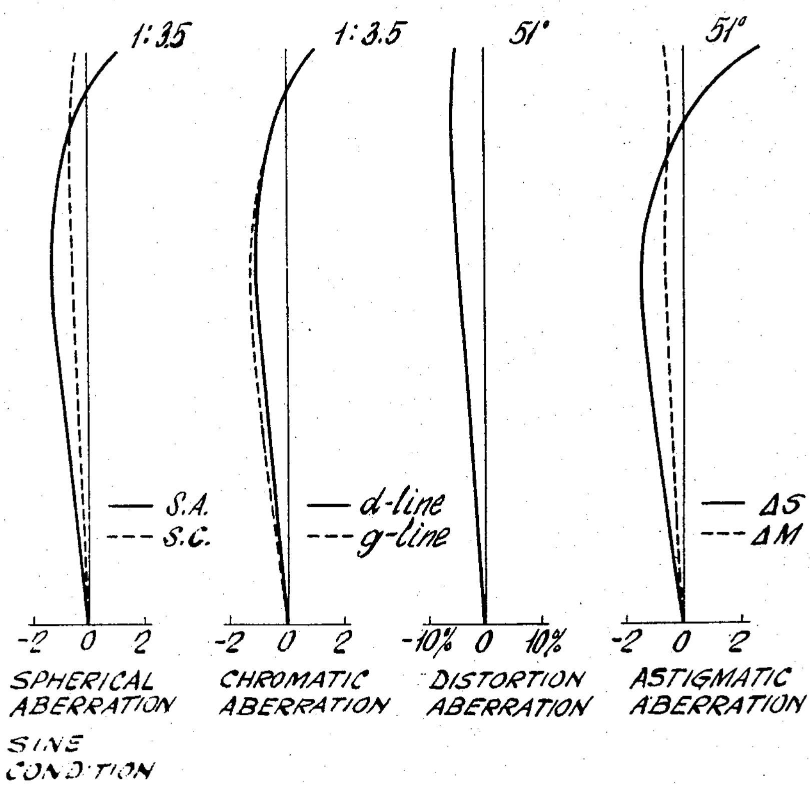
Fig - 4


1:3.5
1:3.5
51°
51°
S.A.
S.C.
d-line
g-line
ΔS
ΔM
-2 0 2
-2 0 2
-10% 0 10%
-2 0 2
SPHERICAL ABERRATION
SINE CONDITION
CHROMATIC ABERRATION
DISTORTION ABERRATION
ASTIGMATIC ABERRATION

WIDE ANGLE OBJECTIVE LENS SYSTEM WITH LARGE BACK FOCUS

BACKGROUND OF THE INVENTION

The present invention relates generally to improvements in optical lens systems and it relates particularly to an improved wide angle objective lens system.

The wide angle lens systems, particularly those of very wide angle of field and large aperture, heretofore available, possess numerous drawbacks and disadvantages. Among these drawbacks and disadvantages are the relatively small back focus, large bulk, limited aperture ratio and poor optical properties and efficiencies.

SUMMARY OF THE INVENTION

It is a principal lens of the present invention to provide an improved optical ens system.

Another object of the present invention is to provide an improved wide angle objective lens.

Still another object of the present invention is to provide an improved extra wide angle, high aperture ratio objective lens system having a large rear focus to focal length ratio.

A further object of the present invention is to provide an improved lens system of the above nature characterized by its high efficiency and resolution, low distortion and aberration, a back focus to focal length exceeding 1.85:1 and a large aperture ratio, of the order of 3.5:1 and a field angle exceeding 100°.

In a sense, the present invention contemplates the provision of a wide angle lens system comprising eleven consecutively designated lenses in which the seventh and eighth lenses form a cemented doublet with their mating surfaces defining a single face, the lenses being dimensioned and related to satisfy the following conditions or requirements:

$$F/2.3 < |F_{1.2.3.4}| < F/1.4,\ F_{1.2.3.4} < 0 \tag{1}$$

$$F/1.2 < F_{1.2.3.4.5.6} < F/0.6 \tag{2}$$

$$0.5F < |r_{14}| < 0.8F,\ r_{14} < 0 \tag{3}$$

$$0.25 < n_8 - n_7 < 0.35 \tag{4}$$

$$0.9F < r_{19} < 1.5F \tag{5}$$

$$0.8F < F_7 < 1.2F \tag{6}$$

$$1.2 < |F_7|/|F_8| < 2.0,\ F_8 < 0$$

wherein F is the focal length of the entire lens system, F_i is the focal length of the i-th lens, $F_{1.2\ldots i}$ is the focal length of the sub-system including the first to the i-th lens, N_i is the d-line refractive index of the i-th lens and r_j is the radius of curvature of the j-th lens face.

The first lens is a negative meniscus lens, the second lens is a positive lens, the third and fourth lenses are negative meniscus lenses, the fifth and sixth lenses are biconvex lenses, the seventh lens is positive and separated from the preceding lenses by a diaphragm, the eighth lens is negative, the ninth lens is positive, the tenth lens is negative and the eleventh lens is positive, the rear faces of the ninth, tenth and eleventh lenses being of greater curvature than the front faces thereof.

Considering the requirements as above enumerated, the requirement (**1**) functions to establish the powers of the negative lenses included in the front or object side lens group so that a back focus substantially twice the focal length of the lens system may be obtained. It is obvious that requirement (**1**) is also useful in reducing the incident angle, which is extremely wide with respect to the object side lens group, with respect to the fifth lens and the following lenses. When $F_{1.2.3.4}$ is negative and shorter than F/**2.3**, however, this requirement would be met but this requirement would be disadvantageous for the image side or rear lens group. The fact that a wide angle lens assembly requires an increased light quantity conflicts with the effective correction of aberration, particularly, of coma aberration while reduction of the Petzval's sum interferes with the achievement of a sufficiently wide incident angle. Furthermore, it will be difficult to accomplish the object of the second lens such that the chromatic aberration and the distortion are effectively prevented by the second lens from increasing in negative direction. When $F_{1.2.3.4}$ is longer than F/1.4, on the other hand, apart from a problem arising in the reverse direction, it would be difficult to achieve the present object unless a suitable counterplan is considered on the image side group.

The requirement (**2**) principally relates, in association with the previous requirement (**1**), to the correction of the chromatic aberration providing influence on magnification, which is highly important in the wide angle lens. A considerable difference is seen between the two embodiments, as hereinafter described in detail, with respect to the arrangement of glass material of various types. Both these embodiments are, however, similar in that the chromatic aberration in the range from the first to the twelfth surface is insufficiently corrected substantially to an equal extent. In the first, there is found a residual of the chromatic aberration larger than that in the second embodiment due to the value of ν_1, Abbe's number, selected at **40** while ν_2 is selected at 48.9 so that the chromatic aberration is corrected somewhat in the direction of insufficiency. In the second embodiment, on the other hand, ν_1 is selected approximately at **60** and ν_2 approximately at **64.** Both embodiments are attended with a residual of the chromatic aberration due to excessive correction. In view of the fact that the lens assembly of the present invention is adapted for a wide photographing angle, it will be reasonably expected from the fact as above mentioned in connection with the two embodiments that the chromatic aberration may be substantially corrected to a similar extent in the range ending at the twelfth surface. It is the object of the requirement (**2**) to achieve this. When $F_{1.2.3.4.5.6}$ is shorter than F/1.2, the object might be achieved by various combinations of the correction of the chromatic aberration, but this would result in reduced Petzval's sum, reduced efficiency of the object side group and, possibly, insufficiently corrected spherical aberration, so that the correction in the seventh lens and the following lenses would be difficult. When $F_{1.2.3.4.5.6}$ is longer than F/0.6, there would arise a problem also in the arrangement of glass materials of various types for the correction of the chromatic aberration. Correction of the astigmatic aberration would often be difficult, since the Petzval's sum would increase.

The requirement (3) functions in association with the requirement (4) to correct the spherical aberration still insufficiently corrected in the direction of excessive correction. Insufficiency of correction of the spherical aberration necessarily occurs in the image side group when a back focus longer than a certain length is required to satisfy the demand of the lens assembly according to the present invention. This is marked especially at the seventeenth and twenty-first surfaces. However, it is undesirable to face a convex surface of short curvature radius to the object side in order that no coma aberration occurs on the sixteenth surface, the twentieth surface and so on caused by light rays of relatively low incident heights. Thus, it is unavoidable that the seventeenth and twenty-first surfaces should bear burdens and this is true also from the view-point of distortion. This is the reason why the spherical aberration is corrected by making use of the refractive index at the fourteenth surface. When r_{14} assumes a negative value larger than 0.5F and $n_8 - n_7$ is larger than 0.35, insufficiency in correction of the spherical aberration occurring in the image side group would be possibly corrected in the direction of excessive correction. When r_{14} is larger than 0.8F and $n_8 - n_7$ is smaller than 0.25, on the other hand, the desired aberration balance could not be easily obtained unless the rest of the assembly is modified and some suitable countermeasures are employed.

The requirement (5) is to define the proper range within which the coma aberration principally with respect to the light rays of relatively low incident heights is effectively corrected. When r_{19} is smaller than 0.9F, the light rays vary in the direction along which the image height increases and possibly form a flare. When r_{19} is larger than 1.5F, the intention on which introduction of this negative lens is based would become less meaningful especially for the light rays of wide incident angles.

The requirement (6) is to give, also in association with the requirements (3) and (4), proper allotments of correction of chromatic, coma, spherical and the other aberrations depending upon the particular ratios $F_7 : F_8$ of the seventh and eighth lenses which are cemented together, forming a negative lens as a whole. When F_7/F_8 is smaller than 1.2, correction of the coma aberration would be difficult in the direction along which the image height increases with respect to the light rays of relatively low incident heights so far as an emphasis is put on an excessive correction of the spherical aberration, since F_8 would be too long compared to F_7. It is believed in this case that the correction of spherical aberration would be advantageously allotted to these cemented lenses since it would possibly be difficult to allot the correction of spherical aberration to any other lenses from the viewpoint of the manner in which the lens assembly according to the present invention is composed. When F_7/F_8 is larger than 2, it would be preferred to select n_8 of a higher value since the correction of coma aberration would be excessive in contrast to the previous case so far as correction of spherical aberration is sufficiently accomplished. Furthermore, in this case, the overall aberration balance would be lost as the requirement (4) is departed from since the influence upon the other kinds of aberration would vary.

Lens systems constructed in accordance with the present invention with an aperture ratio of 3.5:1 and an angle of field exceeding 100° are compact, possess back focus to focal length ratios exceeding 1.85:1 and have excellent optical properties and efficiencies.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a longitudinal view of a preferred embodiment of the present invention;

FIG. 2 is a set of aberration curves of an example of the lens system of FIG. 1;

FIG. 3 is a longitudinal view of another embodiment of the present invention; and FIG. 4 is a view similar to FIG. 2 as related to FIG. 3.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawings and particularly FIGS. 1 and 2 thereof which represent a preferred embodiment of the present invention, the reference numerals 1 to 11 generally consecutively designate the lenses forming the improved wide angle lens system, the first or front lens 1 being toward the object side and the eleventh or rear lens being toward the image side. The seventh and eighth lenses 7 and 8 are cemented at their mating confronting faces to form a doublet with the cemented surfaces defining a single face.

The first lens 1 is a negative meniscus lens of thickness d_1, refractive index N_1 and Abbe's number ν_1 and has a convex front face f_1 of radius of curvature r_1 and a concave rear face f_2 of radius of curvature r_2. The second lens is a positive lens of thickness d_3, refractive index N_2 and Abbe's number ν_2 and has a front face f_3 spaced a distance d_2 from face f_2 and of a radius of curvature r_3 and a rear face f_4 of radius of curvature r_4. The third lens 3 is a negative meniscus lens of thickness d_5, refractive index N_3 and Abbe's number ν_3 and has a front face f_5 of radius of curvature r_5 spaced from face f_4 a distance d_4 and a rear face f_6 of radius of curvature r_6. The fourth lens 4 is a negative meniscus lens of thickness d_7 refractive index N_4 and Abbe's number ν_4 and has a front face f_7 spaced a distance d_6 from face f_6 and a rear face f_8. The fifth lens is biconvex and of a thickness d_9, a refractive index N_5 and an Abbe's number ν_5 and has a front face f_9 of radius of curvature r_9 spaced a distance d_8 from face f_8 and a rear face f_{10}. The sixth lens 6 is biconvex and of a thickness d_{11}, refractive index N_6 and Abbe's number ν_6 and has a front face f_{11} spaced from face f_{10} a distance d_{10} and a rear face f_{12} of radius of curvature r_{12}.

The seventh lens 7 is positive with a thickness d_{13}, a refractive index N_7 and an Abbe's number ν_7 and has a front face f_{13} of radius of curvature r_{13} and spaced from face f_{12} a distance d_{12} and a rear face f_{14} of radius of curvature r_{14}. The eighth lens 8 is negative and cemented to seventh lens 7 and is of thickness d_{14}, refractive index N_8 and Abbe's number ν_8 and has its front face common with face f_{14} and a rear face f_{15}. The ninth lens 9 is positive, of thickness d_{16}, refractive index N_9

and Abbe's number ν_9 and has a front f_{16} of radius of curvature r_{16} spaced a distance d_{15} and a rear face f_{17} of radius of curvature r_{17}. The tenth lens **10** is negative and of thickness d_{18}, refractive index N_{10} and Abbe's number ν_{10} and has a front face f_{18} of radius of curvature r_{18} spaced from face f_{17} a distance d_{17} and a rear face f_{19} of radius of curvature r_{19}, and the eleventh lens **11** is positive with a thickness d_{20}, a refractive index N_{11} and an Abbe's number ν_{11} and has a front face f_{20} with a radius of curvature r_{20} spaced a distance d_{19} from face f_{19} and a rear face f_{21} of radius of curvature r_{21}.

The following Table I sets forth the numerical values of r_j, d_j, n_i and ν_i of a specific example of the lens system of FIG. **1** as well as other parameters, based on a focal length of the lens system F **100**, the refractive indices being in the d-line:

Table I

r_1	196.25	d_1	9.57	n_1/ν_1	1.80610/40.8
r_2	95.73	d_2	47.09		
r_3	3033.14	d_3	43.17	n_2/ν_2	1.53172/48.9
r_4	−342.39	d_4	0.65		
r_5	130.31	d_5	7.23	n_3/ν_3	1.69350/53.3
r_6	57.80	d_6	18.81		
r_7	246.94	d_7	7.45	n_4/ν_4	1.71300/54.0
r_8	72.22	d_8	14.74		
r_9	235.07	d_9	18.11	n_5/ν_5	1.74077/27.8
r_{10}	−357.57	d_{10}	18.97		
r_{11}	272.12	d_{11}	36.59	n_6/ν_6	1.60562/43.7
r_{12}	−86.37	d_{12}	13.70		
r_{13}	312.47	d_{13}	18.11	n_7/ν_7	1.51823/59.0
r_{14}	−52.41	d_{14}	5.76	n_8/ν_8	1.83400/37.2
r_{15}	894.12	d_{15}	8.43		
r_{16}	−1416.27	d_{16}	16.64	n_9/ν_9	1.69350/53.3
r_{17}	−110.97	d_{17}	0.49		
r_{18}	−887.30	d_{18}	5.27	n_{10}/ν_{10}	1.80518/25.4
r_{19}	118.00	d_{19}	10.71		
r_{20}	−1386.54	d_{20}	16.31	n_{11}/ν_{11}	1.64850/53.0
r_{21}	−98.62				

$F_7 = 102.06$ $\quad |F_{1.2.3.4}| = F/2.081 = 48.05$

$F_8 = -69.76$ $\quad F_{1.2.3.4.5.6} = F/0.992 = 100.8$

$F_7/|F_8| = 1.463$ $\quad F_B = 1.987F = 198.7$

In Table I, F_i is the focal length of the i-th lens, $F_{1.2\ldots i}$ is the focal length of the sub-system including the first to the i-th lens and F_B is the back focus.

The following Table II lists the Seidel's coefficients of the example of Table I.

TABLE II

	S_1	S_2	S_3	P	S_5
1	0.03	0.03	0.03	0.23	0.25
2	−1.09	0.24	−0.05	−0.47	0.11
3	0.06	0.08	0.11	0.01	0.17
4	−0.00	0.01	−0.02	0.10	−0.36
5	0.65	0.21	0.07	0.31	0.13
6	−15.60	0.91	−0.05	−0.71	0.04
7	3.12	0.69	0.15	0.17	0.07
8	−46.94	0.87	−0.02	−0.58	0.01
9	22.50	1.60	0.11	0.18	0.02
10	−0.37	−0.30	−0.25	0.12	−0.11
11	6.65	1.29	0.25	0.14	0.08
12	37.45	−4.67	0.58	0.44	−0.13
13	−0.08	0.12	−0.18	0.11	0.11
14	−37.38	1.14	−0.04	−0.18	0.01
15	0.00	0.00	0.03	0.05	−0.18
16	−0.02	0.04	−0.06	−0.03	0.15
17	23.38	−1.43	0.09	0.37	−0.03
18	−4.20	0.98	−0.23	−0.05	0.06
19	−3.69	−1.45	−0.57	−0.38	−0.04
20	0.00	0.01	0.05	−0.03	0.18
21	20.11	0.01	0.00	0.40	0.00
SUM	4.59	0.37	0.02	0.11	0.23

The ratio of the back focus F_B to the lens system focal length F in the above example is 1.987:1 and the various aberration characteristics of the lens system are excellent as illustrated by the graphs of FIG. **2** to an aperture ratio of 1.3:5 and a field exceeding 100°.

In FIG. **3** there is illustrated another embodiment of the present invention which is similar to that first described primarily in the specific dimensions and spatial relationships of the lenses and the two embodiments are otherwise alike, and similar designations are employed to identify the corresponding lenses, their thicknesses and spacings and their refractive indices and Abbe's numbers in the specific example thereof set forth in the following Table III which is likewise based on a lens system of focal length F = 100.

TABLE III

r_1	229.52	d_1	8.64	n_1/ν_1	1.64000/60.2
r_2	94.56	d_2	47.57		
r_3	∞	d_3	39.89	n_2/ν_2	1.51633/64.1
r_4	−312.73	d_4	1.62		
r_5	150.12	d_5	9.62	n_3/ν_3	1.64000/60.2
r_6	56.47	d_6	18.91		
r_7	167.82	d_7	9.62	n_4/ν_4	1.51633/64.1
r_8	65.37	d_8	16.22		
r_9	333.50	d_9	9.62	n_5/ν_5	1.64000/60.2
r_{10}	−1093.72	d_{10}	21.62		
r_{11}	181.10	d_{11}	25.40	n_6/ν_6	1.62588/35.7
r_{12}	−95.77	d_{12}	15.68		
r_{13}	424.27	d_{13}	23.24	n_7/ν_7	1.51633/64.1
r_{14}	−58.17	d_{14}	6.40	n_8/ν_8	1.83400/37.2
r_{15}	253.87	d_{15}	8.11		
r_{16}	−1502.70	d_{16}	14.59	n_9/ν_9	1.48749/70.1
r_{17}	−72.53	d_{17}	0.54		
r_{18}	324.32	d_{18}	5.78	n_{10}/ν_{10}	1.80518/25.4
r_{19}	121.74	d_{19}	10.81		
r_{20}	1043.14	d_{20}	18.92	n_{11}/ν_{11}	1.51633/64.1
r_{21}	−106.74				

$F_7 = 100.70$ $\quad |F_{1.2.3.4}| = F/1.786 = 55.99$

$F_8 = -56.22$ $\quad F_{1.2.3.4.5.6} = F/0.878 = 113.90$

$F_7/|F_8| = 1.791$ $\quad F_B = 1.997F = 199.7$

The following Table IV lists Seidel's coefficients for the lens system of Table I:

Table IV

	S_1	S_2	S_3	P	S_5
1	0.20	0.03	0.03	0.17	0.26
2	−0.99	0.23	−0.06	−0.41	0.11
3	0.04	0.07	0.11	0.00	0.18
4	0.00	0.00	−0.01	0.11	−0.38
5	0.42	0.18	0.07	0.26	0.14
6	−16.00	1.04	−0.07	−0.69	0.05
7	4.24	0.65	0.10	0.20	0.05
8	−37.55	0.41	−0.00	−0.52	0.01
9	11.98	1.53	0.19	0.12	0.04
10	−2.02	−0.73	−0.27	0.04	−0.08
11	15.27	2.15	0.30	0.21	0.07
12	25.72	−3.83	0.57	0.40	−0.15
13	−0.12	0.14	−0.18	0.08	0.12
14	−34.75	0.83	−0.02	−0.20	0.01
15	−1.95	−0.90	−0.42	−0.18	−0.27
16	0.10	0.13	0.16	−0.02	0.18
17	26.60	−0.61	0.01	0.45	−0.01
18	−0.01	0.04	−0.17	0.14	0.12
19	−2.60	−1.09	−0.46	−0.37	−0.34
20	0.01	0.02	0.05	0.03	0.17
21	16.22	0.13	0.00	0.32	0.00
Sum	4.61	0.40	−0.03	0.14	0.26

The ratio of the back focus F_B to the lens system focal length F is 199.7:1 and the optical characteristics of the lens system are excellent demonstrated by the set of graphs in FIG. **4**.

While there have been described and illustrated preferred embodiments of the present invention, it is apparent that numerous alterations, omissions and additions may be made without departure from the spirit thereof. It should be noted that the radii of curvatures r_i and the interface distances d_i are not based on any particular system of linear dimensions so that they represent relative values among themselves, bearing relationships corresponding to the values given in the specific examples.

The ratio of the back focus F_B to the lens system focal length F is 199.7:1 and the optical characteristics of the lens system are excellent demonstrated by the set of graphs in FIG. 4.

While there have been described and illustrated preferred embodiments of the present invention it is apparent that numerous alterations, omissions and additions may be made without departing from the spirit thereof. It should be noted that the radii of curvatures r_j and the interface distances d_i are not based on any particular system of linear dimensions so that they represent relative values among themselves, bearing relationships corresponding to the values given in the specific examples.

We claim:

1. A wide angle lens system comprising eleven lenses consecutively designated from the front lens on the object side to the rear lens on the image side as the first to the eleventh lens, the seventh and eighth lenses being joined at their confronting mating faces to define a singly designated face and form a doublet, said lenses having the following dimensions and relationships:

r_1	196.25	d_1	9.57	n_1/ν_1	1.80610/40.8
r_2	95.73	d_2	47.09		
r_3	3033.14	d_3	43.17	n_2/ν_2	1.53172/48.9
r_4	−342.39	d_4	0.65		
r_5	130.31	d_5	7.23	n_3/ν_3	1.69350/53.3
r_6	57.80	d_6	18.81		
r_7	246.94	d_7	7.45	n_4/ν_4	1.71300/54.0
r_8	72.22	d_8	14.74		
r_9	235.07	d_9	18.11	n_5/ν_5	1.74077/27.8
r_{10}	−357.57	d_{10}	18.97		
r_{11}	272.12	d_{11}	36.59	n_6/ν_6	1.60562/43.7
r_{12}	−86.37	d_{12}	13.70		
r_{13}	312.47	d_{13}	18.11	n_7/ν_7	1.51823/59.0
r_{14}	−52.41	d_{14}	5.76	n_8/ν_8	1.83400/37.2
r_{15}	894.12	d_{15}	8.43		
r_{16}	−1416.27	d_{16}	16.64	m_9/ν_9	1.69350/53.3
r_{17}	−110.97	d_{17}	0.49		
r_{18}	−887.30	d_{18}	5.27	$n_{10}/\nu 10$	1.80518/25.4
r_{19}	118.00	d_{19}	10.71		
r_{20}	−1386.54	d_{20}	16.31	$n_{11}/\nu 11$	1.64850/53.0
r_{21}	−98.62				

wherein r_j is the radius of curvature of the j-th lens face, d_j is the axial distance between the j-th face and the next rearwardly succeeding face, N_i is the d-line refractive index of the i-th lens and ν_i is the Abbe's number of the i-th lens.

2. A wide angle lens system comprising eleven lenses consecutively designated from the front lens on the object side to the rear lens on the image side as the first to the eleventh lens, the seventh and cighth lenses being joined at their confronting mating faces to define a singly designated face and form a doublet, said lenses having the following dimensions and relationships:

r_1	229.52	d_1	8.64	n_1/ν_1	1.64000/60.2
r_2	94.56	d_2	47.57		
r_3	∞	d_3	39.89	n_2/ν_2	1.51633/64.1
r_4	−312.73	d_4	1.62		
r_5	150.12	d_5	9.62	n_3/ν_3	1.64000/60.2
r_6	56.47	d_6	18.91		
r_7	167.82	d_7	9.62	n_4/ν_4	1.51633/64.1
r_8	65.37	d_8	16.22		
r_9	333.50	d_9	9.62	n_5/ν_5	1.64000/60.2
r_{10}	−1093.72	d_{10}	21.62		
r_{11}	181.10	d_{11}	25.40	n_6/ν_6	1.62588/35.7
r_{12}	−95.77	d_{12}	15.68		
r_{13}	424.27	d_{13}	23.24	n_7/ν_7	1.51633/64.1
r_{14}	−58.17	d_{14}	6.40	n_8/ν_8	1.83400/37.2

-Continued

r_{15}	253.87	d_{15}	8.11		
r_{16}	−1502.70	d_{16}	14.59	n_9/ν_9	1.48749/70.1
r_{17}	−72.53	d_{17}	0.54		
r_{18}	324.32	d_{18}	5.78	n_{10}/ν_{10}	1.80518/25.4
r_{19}	121.74	d_{19}	10.81		
r_{20}	1043.14	d_{20}	18.92	n_{11}/ν_{11}	1.51633/64.1
r_{21}	−106.74				

wherein r_j is the radius of curvature of the j-th lens face, d_j is the axial distance between the j-th lens face and the next rearwardly succeeding lens face N_i is the d-line refractive index of the i-th lens and ν_i is the Abbe's number of the i-th lens.

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