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PATENT SPECIFICATION



Application Date: Dec. 12, 1939. No. 32051/39. ,, Nov. 4, 1940. No. 16050/40.

537,237

One Complete Specification Left: Nov. 8, 1940.

(Under Section 16 of the Patents and Designs Acts, 1907 to 1939.)

Specification Accepted: June 13, 1941.

PROVISIONAL SPECIFICATION No. 32051 A.D. 1939.

Improvements in or relating to Optical Objectives

We, TAYLOR, TAYLOR & HOBSON LIMITED, a Company registered under the Laws of Great Britain, and Arthur Warmisham, British Subject, both of 5 104, Stoughton Street, Leicester, do hereby declare the nature of this invention to be as follows:—

This invention relates to optical objectives for photographic or like purposes, of 10 the kind comprising five simple components separated by air spaces, the front component and the rear two components being convergent whilst the second and third components are divergent. It is 15 to be understood that the terms "front" and "rear" as used herein relate respectively to the sides of the objective nearer to and further from the longer conjugate.

The present invention has for its object 20 to reduce the spherical zonal aberration in such an objective or alternatively to increase the aperture without undue increase of zonal spherical aberration.

In the objective according to the n 25 present invention the second air space (i.e. rethe air space between the two divergent components) has an axial length less than that of either the first or the third air space, and preferably less than 45% of the experiment focal length 1 000

sum of those of the first and third air 30 spaces.

Conveniently the front divergent component has its shallower side turned towards the front. The numerical sum of the radii of curvature of the front surface of the front divergent component and of the rear surface of the rear divergent component preferably exceeds the equivalent focal length of the objective. It is preferable to employ for all three convergent components glasses having mean refractive indices greater than 1.6.

Numerical data for one convenient example of objective according to the invention are given in the following table, in which $R_1 R_2 \ldots$ represent the radii of curvature of the individual lens surfaces counting from the front (the positive sign indicating that the surface is convex towards the front and the negative sign that it is concave thereto), $D_1 D_2 \ldots$ represent the axial thicknesses of the lens elements, and $S_1 S_2 \ldots$ represent the axial air spaces between the components. The table also gives the mean refractive index n_p and the Abbé V number for the glass used for each element.

space, and	Equivalent				Relative aper	ture F /3.5
60	Radius		Thick	ness or ration	$egin{array}{c} ext{Refractive} \ ext{Index} \ n_{ exttt{D}} \end{array}$	$f Abb\'e V \ f number$
	$\overline{R_i + .3188}$		$\mathbf{D}_{\scriptscriptstyle{1}}$.0663	1.613	59.4
65	$R_2 - 3.347$		S_1	.0502		
	R_36694 $R_4 + .5862$		\mathbf{D}_2	.0131	1.579	40.4
70	$R_{5} - 5.020$.0291		40.4
	$R_{\epsilon} + .4016$.0131	1.579	40.4
75	$R_{\tau} + 1.435$.0603	1.613	59.4
75	$R_s - 1.435$	-	S_4			
	$ m R_{\scriptscriptstyle 9} \infty$.0301	1.613	59.4
80 [Price	R ₁₀ 5466	s 6 d				

It will be noticed that in this example S₂ is less than S₁ and S₃ and is less than a third of the sum of S₁ and S₃, whilst S4 is zero, the fourth and fifth components 5 touching one another at the axis. Also, R_3 is numerically greater than R_4 and the numerical sum of R_3 and R_6 is greater than 1. Two glasses only are used, one for the three convergent components having a mean refractive index 10 1.613 and the other for the two divergent components with a lower index.

Dated this 12th day of December, 1939. A. F. PULLINGER, Agent for the Applicants.

PROVISIONAL SPECIFICATION No. 16050 A.D. 1940.

Improvements in or relating to Optical Objectives

TAYLOR, TAYLOR & HOBSON LIMITED, a Company registered under the 15 Laws of Great Britain, and ARTHUR WARMISHAM, British Subject, both of 104, Stoughton Street, Leicester, do hereby declare the nature of this invention to be as follows:—

This invention relates to optical objectives for photographic or like purposes, corrected for spherical and chromatic aberrations, coma, astigmatism, field curvature and distortion, and of the kind

25 comprising five simple components separated by air spaces, two of the components being divergent and next to one another, whilst the other three are convergent and are disposed one on one side

30 and two on the other side of the divergent components. It is to be understood that the terms "front" and "rear" as used herein relate respectively to the sides of the objective nearer to and further from 35 the longer conjugate in accordance with the usual convention.

The present applicants' copending British Patent Application No. 32051 of

1939 relates to an objective of this kind, 40 wherein the convergent components consist of the front component and the rear two components, and like the present invention has for its object to reduce the zonal spherical aberration or alternatively

45 to increase the aperture without undue increase of zonal spherical aberration. According to the present invention, as

also according to the invention of such copending application, the air space 50 between the two divergent components has an axial length less than that of either of the immediately adjacent air spaces, and preferably less than 45% of the sum of those of such air spaces. 55 veniently the front divergent component is double-concave and has its shallower

side turned towards the front. The numerical sum of the radii of curvature of the front surface of the front diver-60 gent component and the rear surface of

the rear divergent component preferably exceeds the equivalent focal length of the objective. It is preferable to employ for all three convergent components glasses having mean refractive indices 65 greater than 1.6. The same glass may be used for these three components, and the two divergent components may also be made of the same glass so that only two different glasses are required for the 70

objective. The present invention is concerned with a modification of the arrangement of the above-mentioned copending application, wherein the three convergent components consist of the front two components and the rear component. this case, when improved zonal spherical aberration correction is desired, it is preferable for the front surface of the rear 80 divergent component to be flat or slightly concave towards the front, its radius of curvature being not less than four times the equivalent focal length of the objec-For higher aperture objectives, however, such surface is preferably either flat or slightly convex towards the front, its radius of curvature being not less than twice the equivalent focal length of the objective. In some instances the glasses 90 used for the five components each have a mean refractive index greater than 1.64.

Numerical data for four convenient examples of objective according to the invention are given in the following tables, in which $R_1 R_2 \dots$ represent the radii of curvature of the individual lens surfaces counting from the front (the positive sign indicating that the surface is convex to the front and the negative 100 that it is concave thereto), D₁, D₂ represent the axial thicknesses of the lens elements, and S₁ S₂ represent the axial air spaces between the components. The tables also give the 105 mean refractive index $n_{\rm p}$ and the Abbé V number for the glass used for each

element.

Example I.

	Equivalent focal length 1.000		Relative aperture F/3.5	
	Radius	Thickness or Separation	Refractive Index $n_{\scriptscriptstyle m D}$	Abbé V number
5	$R_1 + .3555$	$D_1 .0416$	1.613	59.4
	$R_2 + 1.101$	$S_1 = 0$		
10	$ m R_{a} + .5505 \\ m R_{4} + 2.477 \\$	$D_2 .0416$	1.613	59.4
	$R_4 + z.477$ $R_5 - 1.125$	S_2 .0396		
15	$R_{\rm s} + .4972$	D_a .0129	1.579	40.4
	$R_{7} - 9.908$	S ₃ .0297	1 570	40.4
20	$\rm R_s ~+~ .3644$	$egin{array}{ccc} {f D_4} & .0129 \\ {f S_4} & .0565 \end{array}$	1.579	40.4
&U	R_{ν} + .7926	${ m D_5} .0694$	1.613	59.4
	R ₁₀ 5096		<u></u>	

EXAMPLE II.

25	Equivalent foca	l length 1.000	Relative aper	ture F/2.5
	Radius	Thickness or Separation	$\begin{array}{c} \text{Refractive} \\ \text{Index } n_{\scriptscriptstyle \rm D} \end{array}$	Abbé V number
-	R ₁ + .7262	$D_{1} .057$	1.613	59.3
30	$R_2 + 2.174$ $R_3 + .4219$	S001		
35	$R_4 + 2.500$	$D_2 .084$ $S_2 .041$	1.613	59.3
00	$R_{s} = 1.220$	\mathbf{D}_{a} .015	1.621	36.2
40	$egin{array}{lll} m R_{\scriptscriptstyle 6} & + & .5214 \ m R_{\scriptscriptstyle 7} & \infty \end{array}$	S_3 .035		22.5
	$R_{*} + .5087$	\mathbf{D}_{4} .031 \mathbf{S}_{4} .050	1.621	36.2
45	$R_{19} + .9901$ $R_{19}5066$	\mathbf{D}_{z} .080	1.644	48.3
_	1110			

EXAMPLE III.

	Equivalent focal length 1.000		Relative aperture F/2.5		
	Radius	Thickness or Separation	Refractive Index n_{D}	Abbé V number	-
5	$R_1 + .6553$	D 057	1 044	40.9	_
	$R_2 + 1.667$	$D_1 .057$	1,644	48.3	
10	$R_3 + .3945$	S_{i} .001		.	
10	$R_4 + 1.449$	$\mathbf{D_2}$.084	1.613	59.3	
	$ m R_{5}$ -2.000	S_2 .041			
15	$R_{c} + .4815$	$\mathbf{D_{s}}$.015	1.652	33.5	
	$R_{\tau} + 3.086$	S_{s} .040			
	$ m R_s + .4464$	\mathbf{D}_{4} .015	1.652	33.5	
20	$R_v + .8403$	S_4 .065			
	$R_{10}5590$	D_{5} .080	1.644	48.3	

EXAMPLE IV.

25	Equivalent foca	l length 1.000	Relative aper	ture $F/2.5$
•	Radius	Thickness or Separation	$\begin{array}{c} \text{Refractive} \\ \text{Index } n_{\scriptscriptstyle \text{D}} \end{array}$	Abbé V number
•	$R_{i} + .5208$	T) 057	1.044	10.6
30	$R_2 + 1.587$	D ₁ .057	1.644	48.3
	$R_s + .3656$	S_i 0		·
	$R_4 + 1.449$	D_2 .073	1.644	48.3
35	$ m R_{\scriptscriptstyle 5}$ -11.76	S_2 .0365		
	$R_6 + .3390$	$\mathbf{D}_{\mathfrak{s}}$.02	1.697	30.5
40		S_{s} .03		
40	$R_7 + 2.841$	D_4 .02	1.652	33.5
	$R_s + .4458$	S ₄ .08		
45	$R_{\text{\tiny 9}}$ + $.8696$	$\mathrm{D}_{\mathfrak{s}}$.084	1.644	48.3
	R ₁₀ 6349	25.001	I.OII	10.0

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It will be noticed in these four examples that S₃ is less than S₂ and S₄ and less than 45% of the sum of S₂ and S₄, and that R₅ is negative and is 5 numerically greater than R₅, whilst the numerical sum of R₅ and R₈ is considerably greater than the equivalent focal length. In Example I R₇ is slightly concave to the front, and in 10 Example II R₇ is flat. In Examples III and IV the fourth element is slightly meniscus shaped, with surface R₇ convex to the front. In Examples I and IV the

same glass is used for all three convergent components, and in Example IV all five 15 components are made of glasses having mean refractive index greater than 1.64. With such an arrangement it is possible to obtain good spherical aberration correction up to an aperture F/2.5 with useful 20 definition over a field having a semi-angle of 25 degrees.

Dated this 4th day of November, 1940. PULLINGER & MALET-VEALE, Agents for the Applicants.

COMPLETE SPECIFICATION

Improvements in or relating to Optical Objectives

We, Taylor, Taylor & Hobson Limited, a Company registered under the 25 Laws of Great Britain, and Arthur Warmisham, British Subject, both of 104, Stoughton Street, Leicester, do hereby declare the nature of this invention and in what manner the same is to 30 be performed, to be particularly described and ascertained in and by the following statement:—

This invention relates to optical objectives for photographic or like purposes, corrected for spherical and chromatic aberrations, coma, astigmatism, field curvature and distortion, and of the kind comprising five simple components separated by air spaces, two of the components being divergent and next to one another, whilst the other three are convergent and are disposed one on one side and two on the other side of the divergent components. It is to be understood that the terms "front" and "rear" as used herein relate respectively to the sides of the objective nearer to and further from the longer conjugate in accordance with the usual convention.

The present invention has for its object to reduce the zonal spherical aberration in such an objective or alternatively to increase the aperture without undue increase of zonal spherical aberration.

55 In the objective according to the present invention, the air space between the two divergent components has an axial length less than that of either of the immediately adjacent air spaces, and pre-60 ferably less than 45% of the sum of those of such air spaces. Conveniently the front divergent component is double-concave and has its shallower side turned towards the front. The numerical sum of the radii of curvature of the front surface of the front divergent component and the rear surface of the rear divergent component preferably exceeds the equivalent

focal length of the objective.

It is preferable to employ for all three convergent components glasses having mean refractive indices greater than 1.6. The same glass may be used for these three components, and the two divergent components may also be made of the same glass, so that only two different glasses are required for the objective. In some instances the glasses used for the five components each have a mean refractive index greater than 1.64.

In one arrangement according to the invention the front component and the rear two components are convergent and the second and third components are divergent, whilst in another arrangement 85 the front two components and the rear component are convergent and the third and fourth components divergent. the latter case, when improved zonal spherical aberration correction is desired, 90 it is preferable for the front surface of the rear divergent component to be flat or slightly concave towards the front, its radius of curvature being not less than four times the equivalent focal length of 95 the objective. For higher aperture objectives, however, such surface is preferably either flat or slightly convex towards the front, its radius of curvature being not less than twice the equivalent focal length 100 of the objective.

Numerical data for five convenient examples of objective according to the invention are given in the following tables, in which $R_1 R_2 \ldots$ represent the 105 radii of curvature of the individual lens surfaces counting from the front (the positive sign indicating that the surface is convex to the front and the negative sign that it is concave thereto), 110 $D_1, D_2 \ldots$ represent the axial thicknesses of the lens elements, and $S_1 S_2 \ldots$ represent the axial air spaces between the components. The tables also

give the mean refractive index $n_{\rm D}$ and the Abbé V number for the glass used for each element.

The first example has its second and 5 third components divergent and is illus-

trated in Figure 1 of the accompanying drawings, whilst Figure 2 illustrates the alternative arrangement (Examples II, III, IV and V) in which the third and tourth components are divergent.

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Example I.

	Equivalent focal length 1.000		Relative aperture F/3.5		
	Radius	Thickness or Separation	Refractive Index $n_{ t D}$	Abbé V number	
15	$R_1 + .3188$	D occa	1 619	50.4	_
	$R_2 - 3.347$	D ₁ .0663	1.613	59.4	
	R_{3} - $.6694$	S ₁ .0502			
2 0	$R_4 + .5862$	D_2 .0131	1.579	40.4	
	$R_{s} - 5.020$	S_2 .0291			٠.
25	$R_{\rm c} + .4016$	D_3 .0131	1.579	40.4	
£,∪		S _s .0603	•		
	$R_7 + 1.435$	D_4 .0301	1.613	59.4	
30	$R_{s} - 1.435$	$S_4 = 0$			
	$R_{\mathfrak{g}}$ ∞	$\mathbf{D}_{\mathfrak{s}}$.0301	1.613	59.4	
	$R_{10}5466$	223 .0001	1.010	00.1	

It will be noticed that in this example S₂ is less than S₁ and S₃ and is less than a third of the sum of S₁ and S₃, whilst S₄ is zero, the fourth and fifth components touching one another at the axis. Also, R₃ is numerically greater than R₄ and

the numerical sum of R_3 and R_6 is 40 greater than 1. Two glasses only are used, one for the three convergent components having a mean refractive index 1.613 and the other for the two divergent components with a lower index. 45

Example II.

	Equivalent focal length 1.000 Relative aperture		ture $F/3.5$	
	Radius	Thickness or Separation	Refractive Index $n_{\scriptscriptstyle D}$	Abbé V number
50	$ m R_{1} + .3555 m \ R_{2} + 1.101 m \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ $	D0416	1.613	59.4
er	$R_3 + .5505$	$S_1 = 0$ $D_2 = .0416$	1.613	50.4
55	$ m R_{_{5}} + 2.477 \ m R_{_{5}} - 1.125 \ m$	$S_2 .0396$	1.013	59.4
60	$R_{6} + .4972$	${ m D_{s}}$.0129 ${ m S_{s}}$.0297	1.579	40.4
i	$ m R_{7} - 9.908$ $ m R_{8} + .3644$	D_4 .0129	- 1.579	40.4
65	$R_{s} + .3044$ $R_{s} + .7926$	S ₄ .0565		
	$R_{10}5096$	D_{s} .0694	1.613	- 59.4

Example III.

	Equivalent focal length 1.000		Relative aperture F/2.5	
	Radius	Thickness or Separation	$\begin{array}{c} \text{Refractive} \\ \text{Index} \ n_{\scriptscriptstyle \mathrm{D}} \end{array}$	Abbé V number
5	$R_1 + .7262$	D ₁ .057	1.613	59.3
	$R_2 + 2.174$ $R_3 + .4219$	S ₁ .001		
10	$ m R_{_4} + 2.500$	D_2 .084	1.613	59.3
	$R_5 - 1.220$	S_2 .041 D_3 .015	1.621	36.2
15	$R_{\rm c}$ + .5214	S_{3} .035	2000-	
	$R_{7} \infty$ $R_{8} + .5087$	D_{4} .031	1.621	36.2
20	$R_{s} + .9901$	S ₄ .050	1 044	40 B
	R ₁₀ 5066	D ₅ .080	1.644	48.3

EXAMPLE IV.

25	Equivalent focal	length 1.000	Relative aper	ture F/2.5
•	Radius	Thickness or Separation	$egin{array}{c} ext{Refractive} \ ext{Index} \ n_{ ext{ in}} \end{array}$	Abbé V number
30	$R_1 + .6553$ $R_2 + 1.667$	$D_1 .057$	1.644	48.3
00	$R_3 + .3945$	S_1 .001 D_2 .084	1.613	59.3 .
35	$ m R_4 + 1.449 \ m R_5 - 2.000 \ m$	S_2 .041		
	$R_{\text{\tiny G}} + .4815$	${ m D_{s}} .015$ ${ m S_{s}} .040$	1.652	33.5
40	$ m R_{7} + 3.086 m \ R_{8} + .4464 m \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ $	D015	1.652	33.5
45	$R_9 + .8403$	S_4 .065 D_5 .080	1.644	48.3
	R ₁₀ 5590			

EXAMPLE V.

	Equivalent focal length 1.000		Relative aperture F/2.5		
	Radius	Thickness or Separation	Refractive Index $n_{\scriptscriptstyle m D}$	Abbé V number	
5	$R_1 + .5208$	D 057	1 644	40.9	
	$R_2 + 1.587$	D ₁ .057	1.644	48.3	
	$R_{\rm a}$ + $.3656$	S ₁ 0	1 644	40.9	
.0	$R_4 + 1.449$	D_2 .073	1.644	48.3	
	$R_5 - 11.76$	S ₂ .0365	4 00W		
.5	R_{6} ,+ .3390	D_{s} .02	1.697	30.5	
	$R_7 + 2.841$	S_s .03			
	$R_s + .4458$	D_{4} .02	1.652	33.5	
0	$R_{2} + .8696$	S_4 .08			
	$R_{10}6349$	D_s .084	1.644	48.3	

It will be noticed in these last four 25 examples that S₃ is less than S₂ and S₄ and less than 45% of the sum of S₂ and S4, and that R5 is negative and is numerically greater than R₆, whilst the numerical sum of R₅ and R₈ is con30 siderably greater than the equivalent focal length. In Example II R7 is slightly concave to the front, and in Example III R_7 is flat. In Examples IV and V the fourth element is slightly 35 meniscus shaped, with surface R, convex to the front. In Examples II and V the same glass is used for all three convergent components, and in Example V all five components are made of glasses hav-40 ing mean refractive index greater than With such an arrangment it is possible to obtain good spherical aberration correction up to an aperture F/2.5 with useful definition over a field having 45 a semi-angle of 25 degrees.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what we

50 claim is:—
1. An optical objective, comprising five

simple components separated by air spaces, of which two are divergent and next to one another, whilst the other 55 three are convergent and are disposed one on one side and two on the other side of the pain of divergent components wherein the air space between the two divergent components has an axial length less than

that of either of the immediately adjacent

2. An optical objective as claimed in Claim 1, in which axial length of the air space between the divergent components is less than 45% of the sum of those of the immediately adjacent air spaces.

3. An optical objective as claimed in Claim 1 or Claim 2, in which the front divergent component is double-concave and has its shallower side turned towards the front.

4. An optical objective as claimed in Claim 1 or Claim 2 or Claim 3, in which the numerical sum of the radii of curvature of the front surface of the front divergent component and of the rear surface of the rear divergent component exceeds the equivalent focal length of the objective.

5. An optical objective as claimed in any one of the preceding Claims, in which the glasses used for the three convergent components each have a mean refractive index greater than 1.6.

6. An optical objective as claimed in any one of the preceding Claims, in which the same glass is used for all three convergent components.

7. An optical objective as claimed in Claim 6, in which the same glass is used for the two divergent components such glass being different from that used for the convergent components.

8. An optical objective as claimed in any one of the preceding Claims, in

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which the glasses used for the five components each have a mean refractive index greater than 1.64.

9. An optical objective as claimed in 5 any one of the preceding Claims, in which the convergent components consist of the front two components and the rear component.

10. An optical objective as claimed in 10 Claim 9, in which the front surface of the rear divergent component is concave towards the front and has a radius of curvature not less than four times the equivalent focal length of the objective.

11. An optical objective as claimed in 15 Claim 9, in which the front surface of the rear divergent component is convex towards the front and has a radius of curvature not less than twice the equivalent focal length of the objective.

12. An optical objective having numerical data substantially as set forth

in any one of the tables herein.

Dated this 8th day of November, 1940.

PULLINGER & MALET, Agents for the Applicants.

Learnington Spa: Printed for His Majesty's Stationery Office, by the Courier Press.—1941.

[This Drawing is a full-size reproduction of the Original.]

Fig. 1.

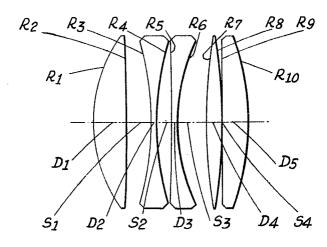


Fig. 2.

