SPECIFICATION PATENT



No. 10965 43. Application Date: July 6, 1943.

566,963

Complete Specification Left: Aug. 4, 1944.

Complete Specification Accepted: Jan. 22, 1945.

PROVISIONAL SPECIFICATION

Improvements in or relating to Optical Objectives

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, England, do hereby declare the nature of this invention to be as follows:-

This invention relates to optical objectives for photographic or projection or like 10 purposes, of the kind corrected for spherical and chromatic aberrations, coma, astigmatism, field curvature and distortion and comprising two compound dispersive meniscus components having 15 their concave air-exposed surfaces facing one another disposed between a front collective component and a pair of rear collective components. It is to be understood the term "front" as herein used 20 refers to the side of the objective nearer to the longer conjugate and the term "rear" to the side nearer the shorter conjugate.

The present applicants British Patent 25 Specification No. 522,651 relates to an objective of this kind wherein the mean refractive indices of the materials used for the front element of the front dispersive component, for the rear element 30 of the rear dispersive component, and for the front member of the pair of collective rear components are greater than 1.63, the two rear components both having their shallower surfaces facing the front.

The present invention has for its object still further to improve the correction of the aberrations in an objective of the above mentioned kind.

In the objective according to the inven-40 tion the mean refractive index of the material used for the rear element of the rear dispersive component lies between 1.70 and 1.80, whilst the collective fourth component is simple and is made of a 45 material having mean refractive index less than 1.70, at least one of the two collective rear components having its shallower surface facing the front.

The power (that is the reciprocal of the 50 focal length) of the collective rear com-

ponent preferably lies between 30% and 70% of the power of the whole objective. Conveniently the sum of the numerical values of the radii of curvature of the concave air-exposed surfaces of the two com- 55 pound dispersive components is greater than .5 and less than .7 times the equivalent focal length of the whole objective. The three collective components are preferably all in the form of simple ele-60 ments.

Usually, both rear collective components will have their shallower surfaces facing the front, and in such case the radii of curvature of the rear surfaces of 65 these components lie between 1.5 and 4.0 times the equivalent focal length of the whole objective. This, however, is not essential to the invention, and one of these components, for example the rear com-70 ponent, may have its shallower surface facing the rear. In such case the radii of curvature of the rear surfaces of the two components preferably lie between 1.3 and 6.0 times the equivalent focal length of 75 the whole objective.

The rear element of the rear dispersive component may be made of optical glass having the appropriate refractive index or alternatively it is sometimes convenient to 80 use crystalline magnesium oxide in the form known as β -magnesium-oxide for this element. Such crystal may also be used for the collective rear component.

Numerical data for five convenient 85 examples of objective according to the invention are given in the following tables, in which R₁ R₂ represent the radii of curvature of the various surfaces counting from the front (the positive 90 sign indicating that the surface is convex to the front and the negative sign that it is concave thereto), $D_1 D_2 \dots$ represent the axial thicknesses of the individual elements, and S_1 S_2 represent the 95 axial air separations between the components. The tables also give the mean refractive indices n_D for the D-line and the Abbé V numbers of the materials used for the elements.

Ex.	4 3 FT	T T	

	Equivalent focal length 1.000		Relative Aperture F/	
	Radius	Thickness or Air Separation	$\begin{array}{c} \stackrel{\cdot}{\text{Refractive}} \\ \text{Index} \ n_{\scriptscriptstyle \rm D} \end{array}$	Abbé V Number.
5	$R_1 + .8084$ $R_2 + 6.166$	D_1 .1086 S_1 .0020	1.6135	59.3
10	$R_3 + .3972$ $R_4 + 4.471$	$egin{array}{ccc} D_{2} & .1693 \\ D_{3} & .0313 \end{array}$	1.6431 1.67605	48.3 32.3
15	$ m R_{_{5}} + .2736 m \ R_{_{6}}3568 m \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ $	S_2 .2006 D_4 .0414	1.621	36.2
20	$R_7 + 1.263$ R_85351 $R_9 + 4.210$	D_{5} .1409 S_{3} .0020	1.7445	45.8
25	$R_{10} - 1.683$ $R_{11} + 3.886$	$egin{array}{lll} & D_6 & .0576 \\ & S_4 & .0020 \\ & D_7 & .0495 \end{array}$	1.613 1.6135	59.3 59.3
	$R_{12} - 2.321$	D ₇ .0±33	1.0199	

EXAMPLE II.

	Equivalent focal	length 1.000	Relative Aperture F/1.5	
30	Radius	Thickness or Air Separation	$egin{array}{c} ext{Refractive} \ ext{Index} \ n_{ ext{ in}} \end{array}$	Abbé V Number.
35	$R_1 + .8074$ $R_2 + 6.157$	D_1 .1085 S_1 .0020	1.6135	53.5
	$R_3 + .3966$ $R_4 + 7.991$	D_2 .1691 D_3 .0313	1.6431 1.67605	48.3 32.3
40	$R_{s} + .2735$ $R_{s}3639$	S_2 .2003 D_4 .0414	1.608	38.2
45	$egin{array}{lll} { m R_{7}} & + & 1.261 \\ { m \dot{R}_{8}} & - & .5434 \end{array}$	$egin{array}{ccc} {f D_5} & .1504 \\ {f S_3} & .0020 \end{array}$	1.7385	53.5
50	$R_{i0} + 3.480$ $R_{i0} - 2.029$	$egin{array}{ccc} {f D_6} & .0575 \ {f S_4} & .0020 \end{array}$	1.613	53.5
	$R_{11} + 3.364$ $R_{12} - 2.545$	D_7 .0494	1.6135	59.3

EXAMPLE III.

	Equivalent focal length 1.000		Relative Aperture F/1.5	
	Radius	Thickness or Air Separation	$\begin{array}{c} \text{Refractive} \\ \text{Index} \ \ n_{\scriptscriptstyle \text{D}} \end{array}$	Abbé V Number.
5	$R_1 + .8073$ $R_2 + 6.157$	D ₁ .1085	1.6135	53.5
10	$R_3 + .3966$	S_1 .0020 D_2 .1690	1.6431	48.3
	$R_4 + 7.990$ $R_5 + .2735$	D_3 .0313 S_2 .2003	1.67605	32.3
15	$ m R_{6}3638 \\ m R_{7} + 1.2613 \\$	$\mathbf{D_4}$.0414	1.608	38.2
20	R_s5433 $R_s + 4.204$	${ m D_5} .1504 \ { m S_3} .0020 \$	1.7385	· 53.5
	$R_{10} - 1.841$	${ m D_6} = .0576$ ${ m S_4} = .0020$	1.613	53.5
25	$R_{11} + 3.927$ $R_{12} - 3.157$	$\mathrm{D_7}$.0494	1.7385	53.5

EXAMPLE IV.

	Equivalent focal	Equivalent focal length 1.000		erture $F/1.5$
30	Radius	Thickness or Air Separation	$egin{array}{c} ext{Refractive} \ ext{Index} \ n_{ ext{\tiny D}} \end{array}$	Abbé V Number.
35	$R_1 + .8091$ $R_2 + 6.171$ $R_3 + .3975$	D_1 .1087 S_1 .0020	1.6135	53.5
40	$R_4 + 8.008$ $R_5 + .2741$ R_63646	D_2 .1694 D_3 .0314 S_2 .2008	1.6431 1.67605	48.3 32.3
45	$R_7 + 1.264$ R_85445	$\mathbf{D_4}$.0415 $\mathbf{D_5}$.1507 $\mathbf{S_3}$.0020	1.608 1.7385	38.2 53.5
50	$R_0 + 2.984$ $R_{10} - 1.728$ $R_{11} + 3.935$	${f D}_6 .0536$ ${f S}_4 .0020$ ${f D}_7 .0496$	1.525 1.7385	59.0 53.5
	$R_{12} - 3.147$			

EXAMPLE V.

Equivalent focal length 1.000		Relative Aperture F/1.5	
Radius	Thickness or Air Separation	$egin{array}{c} ext{Refractive} \ ext{Index} \ n_{ exttt{D}} \end{array}$	Abbé V Number.
$R_1 + .8091$ $R_2 + 6.171$	D ₁ .1087	1.6135	53.5
$R_3 + .3975$ $R_4 + 8.008$	D_2 .1694	1.6431	48.3
$ m R_{5} + .2741 \ m R_{6}3646 \ m$	S_2 .2008		32.3
$R_7 + 1.264$ R_85445	$egin{array}{ccc} {f D}_{4} & .0415 \ {f D}_{5} & .1507 \end{array}$	1.608 1.7385	38.2 53.5
$\rm R_{\rm s}~+~2.984$	$egin{array}{ll} \mathbf{S_{3}} & .0020 \\ \mathbf{D_{6}} & .0536 \end{array}$	1.525	59.0
$R_{11} + 3.371$	S_4 .0020 D_7 .0496	1.7385	53.5
	$egin{array}{lll} & & & & & & & & & & & & & & & & & &$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$

The back focal lengths in these five examples are respectively .5731, .5692, 30 .5717, .5714 and .5705 times the equivalent focal length of the objective. The ratio of the power of the rear component to that of the whole objective is 42.3% in Example I, 42.3% in Example II, 42.2% 35 in Example III, 42.2% in Example IV and 38.5% in Example V. The numerical sum of R₅ and R₆ lies between .63 and .64 in all five examples. In the first four examples the two rear collective components have their shallower surfaces facing the front, whilst in Example V the rear component has its shallower surface facing the rear.

In Example I the rear element of the

rear dispersive component is made of optical glass, whilst in the other four examples magnesium oxide crystal is used for this element. This crystal is also used for the rear component in Examples III, IV and V, this component being made of dense barium crown glass in Examples I and II. Examples IV and V (which are substantially the same except for the curvatures of the last three surfaces) differ from the first three examples primarily in 55 the use of a low index glass for the collective fourth component.

Dated this 6th day of July, 1943.
PULLINGER & MALET,
Agents for the Applicants.

566,963

COMPLETE SPECIFICATION

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 104, Stoughton Street, Leicester, England, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the 10 following statement:—

This invention relates to optical objectives for photographic or projection or like purposes, of the kind corrected for spherical and chromatic aberrations, coma, astigmatism, field curvature and distortion and comprising two compound dispersive meniscus components having one another disposed between a front collective components. It is to be understood the term "front" as herein used refers to the side of the objective nearer to the longer conjugate and the term "rear" to the side nearer the shorter

conjugate.

The present applicants' British Patent Specification No. 522,651 relates to an objective of this kind wherein the mean refractive indices of the materials used for the front element of the front dispersive component, for the rear element of the rear dispersive component, and for the front member of the pair of collective rear components are greater than 1.63, the two rear components both having their shallower surfaces facing the front.

The present invention has for its object still further to improve the correction of the aberrations in an objective of the above mentioned kind.

In the objective according to the invention the mean refractive index of the material used for the rear element of the 45 rear dispersive component lies between 1.70 and 1.80, whilst the collective fourth component is simple and is made of a material having mean refractive index less than 1.70, at least one of the two 50 collective rear components having its shallower surface facing the front.

The power (that is the reciprocal of the focal length) of the collective rear com-

ponent preferably lies between 30% and 70% of the power of the whole objective. 55 Conveniently the sum of the numerical values of the radii of curvature of the concave air-exposed surfaces of the two compound dispersive components is greater than .5 and less than .7 times the 60 equivalent focal length of the whole objective. The three collective components are preferably all in the form of simple elements.

Usually, both rear collective components 65 will have their shallower surfaces facing the front, and in such case the radii of curvature of the rear surfaces of these components lie between 1.5 and 4.0 times the equivalent focal length of the whole 70 objective. This, however, is not essential to the invention, and one of these components, for example the rear component, may have its shallower surface facing the rear. In such case the radii of curvature 75 of the rear surfaces of the two components preferably lie between 1.3 and 6.0 times the equivalent focal length of the whole objective.

The rear element of the rear dispersive 80 component may be made of optical glass having the appropriate refractive index or alternatively it is sometimes convenient to use crystalline magnesium oxide in the form known as β -magnesium-oxide for this element. Such crystal may also be used for the collective rear component.

A typical construction of objective according to the invention is shown in the 90 accompanying drawing, and numerical data for five convenient examples thereof are given in the following tables, in which $R_1 R_2 \dots$ represent the radii of curvature of the various surfaces counting from 95 the front (the positive sign indicating that the surface is convex to the front and the negative sign that it is concave thereto), D_{1} , D_{2} , ... represent the axial thicknesses of the individual elements, and S_{1} , S_{2} , ... represent the axial air separations between the components. The tables also give the mean refractive indices n_D for the D-line and the Abbé V numbers of the materials used for the 105 elements.

EXAMPLE I.

	Equivalent focal length 1.000		Relative Aperture F/1.	
	Radius	Thickness or Air Separation	$\begin{array}{c} \text{Refractive} \\ \text{Index} \ n_{\scriptscriptstyle \mathbf{D}} \end{array}$	Abbé V Number.
5	$R_1 + .8084$ $R_2 + 6.166$	D ₁ .1086	1.6135	59.3
10	$R_3 + .3972$	$S_1 = .0020$ $D_2 = .1693$	1.6431	48.3
10	$R_4 + 4.471$ $R_5 + .2736$	$\mathbf{D}_{\scriptscriptstyle{3}}$.0313	1.67605	32.3
15	R_63568	S_2 .2006 D_4 .0414	1.621	36.2
	$ m R_{z} + 1.263 \ m R_{s} - .5351 \ m$	${ m D_5}$.1409 ${ m S_3}$.0020	1.7445	45.8
20	$R_9 + 4.210$ $R_{10} - 1.683$	$egin{array}{ccc} S_{s} & .0020 \ D_{c} & .0576 \ \end{array}$	1.613	59.3
25	$R_{10} - 1.085$ $R_{11} + 3.886$	S_40020 D_70495	1.6135	59.3
	$R_{12} - 2.321$			

EXAMPLE II.

	Equivalent focal	Equivalent focal length 1.000		erture $F/1.5$
30 .	Radius	Thickness or Air Separation	$\begin{array}{c} \text{Refractive} \\ \text{Index} \ \ n_{\scriptscriptstyle D} \end{array}$	Abbé V Number.
35	$R_1 + .8074$ $R_2 + 6.157$ $R_3 + .3966$ $R_4 + 7.991$	D ₁ .1085 S ₁ .0020 D ₂ .1691	1.6135	53.5
4 0	$R_5 + .2735$ R_63639	$egin{array}{ccc} D_{3} & .0313 \\ S_{2} & .2003 \\ D_{4} & .0414 \end{array}$	1.67605 1.608	32.3 38.2
4 5	$R_7 + 1.261$ R_85434 $R_9 + 3.480$	$egin{array}{cccc} D_5 & .1504 & & & \\ S_3 & .0020 & & & \\ D_6 & .0575 & & & \\ \end{array}$	1.7385 1.613	53.5 53.5
50	$R_{10} - 2.029$ $R_{11} + 3.364$ $R_{12} - 2.545$	$S_4 = .0020$ $D_7 = .0494$	1.6135	59.3

EXAMPLE III.

	Equivalent focal length 1.000		Relative Ap	erture F/1.5
•	Radius	Thickness or Air Separation	$egin{array}{ccc} ext{Refractive} \ ext{Index} & n_{ extsf{D}} \end{array}$	Abbé V Number.
5	$R_1 + .8073$	D_1 .1085	1.6135	53.5
	$R_2 + 6.157$	S_1 .0020		-
10	$R_3 + .3966$	$\mathbf{D_z}$.1690	1.6431	48.3
	$R_4 + 7.990$	D_{a} .0313	1.67605	32.3
	$R_s + .2735$	$S_2 = .2003$	•	
15	$R_{\rm G}$ – $.3638$	D_4 .0414	- 1.608	38.2
	$R_7 + 1.2613$	\mathbf{D}_{s} .3504	1.7385	53.5
20	R_s5433	S_3 .0020		
	$R_{\mathfrak{g}} + 4.204$	$\mathbf{D}_{\mathfrak{s}}$.0575	1.613	53.5
	$R_{10} - 1.841$	S ₄ .0020		
25	$R_{11} + 3.927$	$\mathbf{D}_{\mathbf{r}}$.0494	1.7385	53.5
	$R_{12} - 3.157$	_ 7 .0.20.2		

EXAMPLE IV.

	Equivalent focal length 1.000		Relative Aperture F/1.5	
30	Radius	Thickness or Air Separation	$\begin{array}{c} \text{Refractive} \\ \text{Index} \ \textit{n}_{\scriptscriptstyle D} \end{array}$	Abbé V Number.
	$R_1 + .8091$ $R_2 + 6.171$	D ₁ .1087	1.6135	53.5
25	$R_3 + .3975$ $R_4 + 8.008$	S_1 .0020 D_2 .1694	1.6431	48.3
40	$R_s \div .2741$	${ m D_3}$.0314 ${ m S_2}$.2008	1.67605	32.3
45	$R_{\rm c}3646$ $R_{\rm r} + 1.264$	$egin{array}{ccc} D_4 & .0415 \ D_5 & .1507 \end{array}$	1.608 1.7385	38.2 53.5
20	$ m R_{8}5445 \\ m R_{9} + 2.984 \\$	S ₃ .0020		
50	$R_{z0} = 1.728$ $R_{11} + 3.935$	D ₆ .0536 S ₄ .0020	1.525	59.0
	$R_{12} - 3.147$	D ₇ .0496	1.7385	53.5

EXAMPLE V.

	Equivalent focal length 1.000		Relative Aperture F/1.5	
·	Radius	Thickness or Air Separation	$egin{array}{c} ext{Refractive} \ ext{Index} \ n_{ ext{\tiny D}} \ \end{array}$	Abbé V Number.
5	$R_1 + .8091$ $R_2 + 6.171$	D ₁ .1087	1.6135	58.5
10	$R_3 + .3975$	$S_1 = .0020$ $D_2 = .1694$	1.6431	48.3
	$R_4 + 8.008$ $R_5 + .2741$	D_{s} .0314 S_{s} .2008	1.67605	32.3
15	$R_{\rm s}3646$ $R_{\rm 7} + 1.264$	$egin{array}{cccc} D_4 & .0415 \\ D_5 & .1507 \end{array}$	1.608	38.2
20	$ m R_{8}5445 \ m R_{9} + 2.984 \ m$	S_3 .0020	1.7385	53.5
25	$R_{10} - 1.555$ $R_{11} + 3.371$	$\mathrm{D_6}$.0536 $\mathrm{S_4}$.0020	1.525	59.0
-	$R_{12} - 4.445$	D ₇ .0496	1.7385	53.5

The back focal lengths in these five examples are respectively .5731, .5692, 30 .5717, .5714 and .5705 times the equivalent focal length of the objective. The ratio of the power of the rear component to that of the whole objective is 42.3% in Example I, 42.3% in Example II, 42.2% in Example III, 42.2% in Example IV and 38.5% in Example V. The numerical sum of R₅ and R₆ lies between .63 and .64 in all five examples. In the first four examples the two rear collective com-40 ponents have their shallower surfaces fac-

ing the front, whilst in Example V the rear component has its shallower surface facing the rear.

In Example I the rear element of the 45 rear dispersive component is made of optical glass, whilst in the other four examples magnesium oxide crystal is used for this element. This crystal is also used for the rear component in Examples III. 50 IV and V, this component being made of

dense barium crown glass in Examples I and II. Examples IV and V (which are substantially the same except for the curvatures of the last three surfaces)

55 differ from the first three examples primarily in the use of a low index glass for the collective fourth component.

Having now particularly described and ascertained the nature of our said invention, and in what manner the same is to 60 be performed, we declare that what we claim is:-

1. An optical objective for photographic or projection or like purposes, comprising two compound dispersive meniscus com- 65 ponents with their concave air-exposed surfaces facing one another disposed between a front collective component and a pair of rear collective components, wherein the mean refractive index of the 70 material used for the rear element of the rear compound dispersive component lies between 1.70 and 1.80, whilst the collective fourth component is simple and is made of a material having mean refractive 75 index less than 1.70, at least one of the pair of rear collective components having its shallower surface facing the front.

2. An optical objective as claimed in Claim 1, in which the power of the rear 80 collective component lies between 30% and 70% of the power of the whole objec-

tive.

3. An optical objective as claimed in Claim 1 or Claim 2, in which the sum of 85 the numerical values of the radii of curvature of the concave air-exposed surfaces

of the two compound dispersive components is greater than .5 and less than .7 times the equivalent focal length of the whole objective.

4. An optical objective as claimed in any one of Claims 1 to 3, in which both rear collective components have their shallower surfaces facing the front.

5. An optical objective as claimed in 10 Claim 4, in which the radii of curvature of the rear surfaces of the two rear collective components lie between 1.5 and 4.0 times the equivalent focal length of the whole objective.

5 6. An optical objective as claimed in any one of Claims 1 to 3, in which the collective rear component has its shallower

surface facing the rear.

7. An optical objective as claimed in 20 Claim 6, in which the radii of curvature of the rear surfaces of the two rear collective components lie between 1.3 and 6.0 times the equivalent local length of the whole objective.

5 8. An optical objective as claimed in

any one of Claims 1 to 7, in which the rear element of the rear dispersive component is made of crystalline magnesium oxide in the form known as β -magnesium-oxide

9. An optical objective as claimed in any one of Claims 1 to 8, in which all three collective components are in the

form of simple elements.

10. An optical objective as claimed in 35 Claim 9, in which the collective rear component is made of material having mean refractive index between 1.70 and 1.80.

11. An optical objective as claimed in Claim 10, in which the collective rear component is made of crystalline magnesium oxide in the form known as β -magnesium-oxide.

12. An optical objective having numerical data substantially in accord-45 ance with any one of the tables herein set forth.

Dated this 4th day of August, 1944. PULLINGER & MALET, Agents for the Applicants.

Learnington Spa: Printed for His Majesty's Stationery Office, by the Courier Press.—1945.

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