PATENT SPECIFICATION

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

566,963

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Complete Specification Accepted: Jan. 22, 1945.

PROVISIONAL 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 to be as follows:—

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 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 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 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 collective rear components having its shallower surface facing the front.

The power (that is the reciprocal of the focal length) of the collective rear component 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 compound 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 elements.

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 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 component, 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 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 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 examples of objective according to the invention are given in the following tables, in which R_1 R_2 . . . . . represent the radii of curvature of the various 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), 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 elements.

[Price 1/-]

EXAMPLE I.

Equivalent focal length 1.000 Relative Aperture F/1.5

Radius	Thickness or Air Separation	Refractive Index n_D	Abbé V Number.
R_1 + .8084			
	D_1 .1086	1.6135	59.3
R_2 + 6.166			
	S_1 .0020		
R_3 + .3972			
	D_2 .1693	1.6431	48.3
R_4 + 4.471			
	D_3 .0313	1.67605	32.3
R_5 + .2736			
	S_2 .2006		
R_6 − .3568			
	D_4 .0414	1.621	36.2
R_7 + 1.263			
	D_5 .1409	1.7445	45.8
R_8 − .5351			
	S_3 .0020		
R_9 + 4.210			
	D_6 .0576	1.613	59.3
R_{10} − 1.683			
	S_4 .0020		
R_{11} + 3.886			
	D_7 .0495	1.6135	59.3
R_{12} − 2.321			

EXAMPLE II.

Equivalent focal length 1.000 Relative Aperture F/1.5

Radius	Thickness or Air Separation	Refractive Index n_D	Abbé V Number.
R_1 + .8074			
	D_1 .1085	1.6135	53.5
R_2 + 6.157			
	S_1 .0020		
R_3 + .3966			
	D_2 .1691	1.6431	48.3
R_4 + 7.991			
	D_3 .0313	1.67605	32.3
R_5 + .2735			
	S_2 .2003		
R_6 − .3639			
	D_4 .0414	1.608	38.2
R_7 + 1.261			
	D_5 .1504	1.7385	53.5
R_8 − .5434			
	S_3 .0020		
R_9 + 3.480			
	D_6 .0575	1.613	53.5
R_{10} − 2.029			
	S_4 .0020		
R_{11} + 3.364			
	D_7 .0494	1.6135	59.3
R_{12} − 2.545			

EXAMPLE III.

Equivalent focal length 1.000 Relative Aperture F/1.5

Radius	Thickness or Air Separation	Refractive Index n_D	Abbé V Number.
R_1 + .8073			
	D_1 .1085	1.6135	53.5
R_2 + 6.157			
	S_1 .0020		
R_3 + .3966			
	D_2 .1690	1.6431	48.3
R_4 + 7.990			
	D_3 .0313	1.67605	32.3
R_5 + .2735			
	S_2 .2003		
R_6 − .3638			
	D_4 .0414	1.608	38.2
R_7 + 1.2613			
	D_5 .1504	1.7385	53.5
R_8 − .5433			
	S_3 .0020		
R_9 + 4.204			
	D_6 .0575	1.613	53.5
R_{10} − 1.841			
	S_4 .0020		
R_{11} + 3.927			
	D_7 .0494	1.7385	53.5
R_{12} − 3.157			

EXAMPLE IV.

Equivalent focal length 1.000 Relative Aperture F/1.5

Radius	Thickness or Air Separation	Refractive Index n_D	Abbé V Number.
R_1 + .8091			
	D_1 .1087	1.6135	53.5
R_2 + 6.171			
	S_1 .0020		
R_3 + .3975			
	D_2 .1694	1.6431	48.3
R_4 + 8.008			
	D_3 .0314	1.67605	32.3
R_5 + .2741			
	S_2 .2008		
R_6 − .3646			
	D_4 .0415	1.608	38.2
R_7 + 1.264			
	D_5 .1507	1.7385	53.5
R_8 − .5445			
	S_3 .0020		
R_9 + 2.984			
	D_6 .0536	1.525	59.0
R_{10} − 1.728			
	S_4 .0020		
R_{11} + 3.935			
	D_7 .0496	1.7385	53.5
R_{12} − 3.147			

EXAMPLE V.

Equivalent focal length 1.000 Relative Aperture F/1.5

Radius	Thickness or Air Separation	Refractive Index n_D	Abbé V Number.
R_1 + .8091			
	D_1 .1087	1.6135	53.5
R_2 + 6.171			
	S_1 .0020		
R_3 + .3975			
	D_2 .1694	1.6431	48.3
R_4 + 8.008			
	D_3 .0314	1.67605	32.3
R_5 + .2741			
	S_2 .2008		
R_6 − .3646			
	D_4 .0415	1.608	38.2
R_7 + 1.264			
	D_5 .1507	1.7385	53.5
R_8 − .5445			
	S_3 .0020		
R_9 + 2.984			
	D_6 .0536	1.525	59.0
R_{10} − 1.555			
	S_4 .0020		
R_{11} + 3.371			
	D_7 .0496	1.7385	53.5
R_{12} − 4.445			

The back focal lengths in these five examples are respectively .5731, .5692, .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 R_5 and R_6 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 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.

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 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 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 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 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 collective rear components having its shallower surface facing the front.

The power (that is the reciprocal of the focal length) of the collective rear component 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 compound 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 elements.

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 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 component, 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 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 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 accompanying drawing, and numerical data for five convenient examples thereof are given in the following tables, in which R_1 R_2 . . . . . represent the radii of curvature of the various 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), 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 elements.

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Equivalent focal length 1.000 Relative Aperture F/1.5

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	D_3 .0313	1.67605	32.3
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	S_2 .2003		
R_6 − .3638			
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R_{10} − 1.841			
	S_4 .0020		
R_{11} + 3.927			
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R_{12} − 3.157			

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Equivalent focal length 1.000 Relative Aperture F/1.5

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R_7 + 1.264			
	D_5 .1507	1.7385	53.5
R_8 − .5445			
	S_3 .0020		
R_9 + 2.984			
	D_6 .0536	1.525	59.0
R_{10} − 1.728			
	S_4 .0020		
R_{11} + 3.935			
	D_7 .0496	1.7385	53.5
R_{12} − 3.147			

EXAMPLE V.

Equivalent focal length 1.000 Relative Aperture F/1.5

Radius	Thickness or Air Separation	Refractive Index n_D	Abbé V Number.
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	D_1 .1087	1.6135	53.5
R_2 + 6.171			
	S_1 .0020		
R_3 + .3975			
	D_2 .1694	1.6431	48.3
R_4 + 8.008			
	D_3 .0314	1.67605	32.3
R_5 + .2741			
	S_2 .2008		
R_6 − .3646			
	D_4 .0415	1.608	38.2
R_7 + 1.264			
	D_5 .1507	1.7385	53.5
R_8 − .5445			
	S_3 .0020		
R_9 + 2.984			
	D_6 .0536	1.525	59.0
R_{10} − 1.555			
	S_4 .0020		
R_{11} + 3.371			
	D_7 .0496	1.7385	53.5
R_{12} − 4.445			

The back focal lengths in these five examples are respectively .5731, .5692, .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 R_5 and R_6 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 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 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 components 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 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 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 collective component lies between 30% and 70% of the power of the whole objective.

3. An optical objective as claimed in Claim 1 or Claim 2, in which 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 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 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.

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 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.

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 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 accordance with any one of the tables herein set forth.

Dated this 4th day of August, 1944.

PULLINGER & MALET,
Agents for the Applicants.

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

[This Drawing is a reproduction of the Original on a reduced scale.]