PATENT SPECIFICATION

Application Date: Oct. 6, 1942. No. 14033/42.

560,608

Complete Specification Left: Oct. 5, 1943.

Complete Specification Accepted: April 12, 1944.

PROVISIONAL SPECIFICATION

Improvements in or relating to Optical Objectives

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

This invention relates to an optical objective corrected for spherical and chromatic aberrations, coma, astigmatism, field curvature and distortion, and comprising a simple divergent component located between two simple convergent components, and has for its primary object to provide a higher aperture or a higher degree of correction than in existing objectives of this kind.

In the objective according to the invention the numerical sum of the radii of curvature of the front surface of the front component and of the rear surface of the rear component lies between 90% and 130% of the equivalent focal length of the objective, whilst the axial distance between such two surfaces lies between 40% and 50% of the equivalent focal length.

Conveniently at least one of the convergent outer components is made of a material having a mean refractive index between 1.70 and 1.80 and Abbé V number greater than 50.0 and preferably less than 58.0. The materials used for both outer components may have refractive index and Abbé V number within such limits, or alternatively one only may be within these limits the other conveniently having mean refractive index between 1.56 and 1.62 and Abbé V number between 55.0 and 61.0. Thus for example both outer components may be made of crystalline magnesium-oxide in the form known as β-magnesium-oxide, or one may be of magnesium oxide crystal and the other of crown glass.

The divergent middle component is preferably made of a material having mean refractive index between 1.64 and 1.75 and Abbé V number between 34.0 and 27.0, and, although dense flint glass may be used, it is especially convenient to make the middle component of an alkaline halide crystal, for example sodium bromide crystal.

By choosing materials for the three elements all having substantially the same relative partial dispersion, it is possible to obtain a much higher degree of correction for secondary spectrum than hitherto without sacrificing the corrections for astigmatism, field curvature and distortion. The relative partial dispersion, usually represented by θ, may be defined by the mathematical expression $\frac{n_g - n_e}{n_F - n_C}$, where n_C, n_e, n_F and n_g are respectively the refractive indices for the spectrum lines C, *e*, F and *g*. Thus sodium bromide crystal has relative partial dispersion .985, and good secondary spectrum correction can be obtained with the use of this crystal for the divergent component in conjunction with magnesium-oxide crystal for the two convergent components, the relative partial dispersion of magnesium oxide crystal being .989.

Numerical data for three convenient practical examples of objective according to the invention are given in the following tables, in which R_1 R_2 . . . . represent thte radii of curvature of the individual lens surfaces counting from the front (that is from the side of the longer conjugate) 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 D_3 represent the axial thicknesses of the individual elements, and S_1 S_2 represent the axial air spaces between the components. The tables also give the mean refractive indices n_D for the D line, the Abbé V numbers and the relative partial dispersions θ of the materials used for the various elements.

[Price 1/-]

EXAMPLE I.

Equivalent focal length 1.000 Relative aperture F/2.5

Radius	Thickness or Air Separation	Refractive Index n_D	Abbé V Number	Relative Partial Dispersion
R_1 + .3531				
	D_1 .1112	1.574	57.3	1.006
R_2 ∞				
	S_1 .1122			
R_3 − .6154				
	D_2 .0306	1.652	33.5	1.060
R_4 + .3409				
	S_2 .1122			
R_5 + 1.007				
	D_3 .0796	1.738	53.5	.989
R_6 − .6031				

EXAMPLE II.

Equivalent focal length 1.000 Relative aperture F/2.5

Radius	Thickness or Air Separation	Refractive Index n_D	Abbé V Number	Relative Partial Dispersion
R_1 + .5412				
	D_1 .1475	1.738	53.5	.989
R_2 − 7.612				
	S_1 .0913			
R_3 − .4905				
	D_2 .0076	1.675	32.2	1.063
R_4 + .5260				
	S_2 .0971			
R_5 + 4.326				
	D_3 .0990	1.738	53.5	.989
R_6 − .4324				

EXAMPLE III.

Equivalent focal length 1.000 Relative aperture F/2.5

Radius	Thickness or Air Separation	Refractive Index n_D	Abbé V Number	Relative Partial Dispersion
R_1 + .5217				
	D_1 .1422	1.738	53.5	.989
R_2 − 7.336				
	S_1 .0880			
R_3 − .5543				
	D_2 .0058	1.641	30.0	.985
R_4 + .4984				
	S_2 .1234			
R_5 + 4.820				
	D_3 .0954	1.738	53.5	.989
R_6 − .4893				

In Example I the convergent rear component is made of magnesium oxide crystal and the convergent front component of crown glass, dense flint glass being used for the divergent middle component. In Examples II and III the convergent outer components are both made of magnesium oxide crystal, the divergent middle component being made of dense flint glass in Example II and of sodium bromide crystal in Example III.

The numerical sum of the radii R_1 and R_6 and the overall length of the objective are respectively .9562 and .4458 in Example I and .9736 and .4425 in Example II, and 1.0110 and .4548 in Example III.

Example III gives good correction for secondary spectrum and has the further advantage that it can be used not only with visible light but also over a wide range of the ultra violet down to 2000 Å. Since the relative partial dispersion of sodium bromide crystal used for the divergent component is slightly less than that of the magnesium oxide crystal used for the convergent components, the combination gives a small residual secondary spectrum which is the reverse of the usual shape, for the paraxial focussing distance thereby established for the central wavelength chosen for colour correction is a maximum and other wavelengths both longer and shorter give smaller focussing distances. This is favourable for use with violet and ultraviolet rays, for as the wavelength decreases, the secondary spherical aberration becomes increasingly relatively over-corrected and the shortening of the paraxial focussing distance thus makes it possible to arrange a compromise such that the position of the focal plane can remain constant for all wavelengths with slightly softer definition for the shorter wavelengths.

Dated this 6th day of October, 1942.

PULLINGER & MALET,
Agents for the Applicants.

COMPLETE SPECIFICATION

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We, TAYLOR, TAYLOR & HOBSON LIMITED, a Company registered under the Laws of Great Britain, ARTHUR WARMISHAM, British Subject, and CHARLES GORRIE WYNNE, British Subject, all of 104, Stoughton Street, Leicester, 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 an optical objective corrected for spherical and chromatic aberrations, coma, astigmatism, field curvature and distortion, and comprising a simple divergent component located between two simple convergent components, and has for its primary object to provide a higher aperture or a higher degree of correction than in existing objectives of this kind.

In the objective according to the invention the numerical sum of the radii of curvature of the front surface of the front component and of the rear surface of the rear component lies between 90% and 130% of the equivalent focal length of the objective, whilst the axial distance between such two surfaces lies between 40% and 50% of the equivalent focal length, at least one of the convergent outer components being made of a material having a mean refractive index between 1.70 and 1.80 and Abbé V number greater than 50.0 and preferably less than 58.0. The materials used for both outer components may have refractive index and Abbé V number within such limits, or alternatively one only may be within these limits the other conveniently having mean refractive index between 1.56 and 1.62 and Abbé V number between 55.0 and 61.0. Thus for example both outer components may be made of crystalline magnesium-oxide in the form known as β-magnesium-oxide, or one may be of magnesium oxide crystal and the other of crown glass.

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By choosing materials for the three elements all having substantially the same relative partial dispersion, it is possible to obtain a much higher degree of correction for secondary spectrum than hitherto without sacrificing the corrections for astigmatism, field curvature and distortion. The relative partial dispersion, usually represented by θ, may be defined by the mathematical expression $\frac{n_g - n_e}{n_F - n_C}$, where n_C, n_e, n_F and n_g are respectively the refractive indices for the spectrum lines C, e, F and g. Thus sodium bromide crystal has relative partial dispersion .985, and good secondary spectrum correction can be obtained with the use of this crystal for the divergent component in conjunction with magnesium-oxide crystal for the two convergent components, the relative partial dispersion of magnesium oxide crystal being .989.

One arrangement of objective according to the invention is illustrated in the accompanying drawing, and numerical data for three convenient examples are given in the following tables, in which R_1 R_2 . . . . represent the radii of curvature of the individual lens surfaces counting from the front (that is from the side of the longer conjugate) 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 D_3 represent the axial thicknesses of the individual elements, and S_1 S_2 represent the axial air spaces between the components. The tables also give the mean refractive indices n_D for the D line, the Abbé V numbers and the relative partial dispersions θ of the materials used for the various elements.

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The numerical sum of the radii R_1 and R_6 and the overall length of the objective are respectively .9562 and .4458 in Example I and .9736 and .4425 in Example II, and 1.0110 and .4548 in Example III.

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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 corrected for spherical and chromatic aberrations, coma, astigmatism, field curvature and distortion, and comprising a simple divergent component located between two simple convergent components, in which the numerical sum of the radii of curvature of the front surface of the front component and of the rear surface of the rear component lies between 90% and 130% of the equivalent focal length of the objective, whilst the axial distance between such two surfaces lies between 40% and 50% of such equivalent focal length, at least one of the convergent outer components being made of material having mean refractive index between 1.70 and 1.80 and Abbé V number greater than 50.0.

2. An optical objective as claimed in Claim 1, in which the Abbé V number of the material used for the said convergent outer component is less than 58.0.

3. An optical objective as claimed in Claim 2, in which the convergent outer components are made of crystalline magnesium oxide in the form known as β-magnesium-oxide.

4. An optical objective as claimed in Claim 1 or Claim 2, in which one of the convergent outer components is made of material having mean refractive index between 1.56 and 1.62 and Abbé V number between 55.0 and 61.0.

5. An optical objective as claimed in any one of Claims 1 to 3 in which the

materials of which all three components are made have substantially the same relative partial dispersion.

6. An optical objective as claimed in any one of Claims 1 to 5, in which the divergent middle component is made of a material having mean refractive index between 1.64 and 1.75 and Abbé V number between 34.0 and 27.0.

7. An optical objective as claimed in any one of Claims 1 to 6, in which the divergent middle component is made of an alkaline halide crystal.

8. An optical objective as claimed in Claim 7, in which the divergent middle component is made of sodium bromide crystal.

9. An optical objective as claimed in Claim 6, in which dense flint glass is used for the divergent middle component.

10. An optical objective having numerical data substantially in accordance with one or other of the tables herein set forth.

Dated this 5th day of October, 1943.
PULLINGER & MALET,
Agents for the Applicants.

Leamington Spa: Printed for His Majesty's Stationery Office, by the Courier Press.—1944.

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