PATENT SPECIFICATION

Application Date: Oct. 6, 1942. No. 14035/42.

560,609

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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 for photographic or other purposes of the kind corrected for spherical and chromatic aberrations, coma, astigmatism, field curvature and distortion, and comprising two compound divergent components located between two simple convergent components, each divergent component consisting of a divergent element made of a material having relatively low Abbé V number and compounded with a second element made of a material having relatively high Abbé V number, such second element usually (but not necessarily) being convergent.

In the objective according to the invention the materials used for the two divergent elements of low Abbé V number have mean refractive index between 1.62 and 1.68 and Abbé V number between 21.0 and 31.0, whilst those used for the other four elements have mean refractive index between 1.70 and 1.80 and Abbé V number greater than 50.0 and preferably less than 58.0. Each of the two divergent elements preferably has mean refractive index at least .05 less than that of the element cemented to it.

Various combinations of materials may be employed and it is especially convenient to make each of the two divergent elements of an alkaline halide crystal. For example potassium iodide or sodium bromide crystal may be used for these divergent elements.

By choosing materials for all the elements 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. Such an arrangement, using alkaline halide crystal for the divergent elements, in itself forms the subject of the present applicants' British Patent Application No. 13957 of 1942 (Serial No. 560,540. The relative partial dispersion usually represented by the symbol 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 potassium iodide crystal and sodium bromide crystal respectively have relative partial dispersions .987 and .985, and good secondary spectrum correction can be obtained with the use of either of these crystals for the two divergent elements in conjunction with magnesium oxide crystal in the form known as β-magnesium-oxide for the other four elements, such crystal having relative partial dispersion .989.

The cemented surfaces in the two divergent components are preferably such that (regarding a cemented surface as having positive curvature if concave to the diaphragm and negative curvature if convex thereto) the algebraic sum of the curvatures of the two cemented surfaces is positive. When the overall axial length of the objective lies between .51 and .65 times the equivalent focal length of the objective, such algebraic sum preferably lies between 5.0 and 1.8 times the reciprocal of such equivalent focal length, whilst when the overall length is between .65 and .80 times the equivalent focal length, the algebraic sum preferably lies between 4.0 and 1.0 times the reciprocal of the equivalent focal length.

Numerical data for two convenient practical 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 individual lens surface 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 . . . . represent the axial thicknesses of the various elements, and S_1 S_2 S_3 the axial air separations between the components. The tables also give the mean refractive indices n_D and the Abbé V numbers and also the relative partial dispersions of the materials of which the individual elements are made.

EXAMPLE I.

Equivalent focal length 1.000 — Relative aperture F/2.0

Radius	Thickness or Air Separation	Refractive Index n_D	Abbé V Number	Relative Partial Dispersion
R_1 + .7356				
	D_1 .0684	1.7378	53.5	.989
R_2 +1.6278				
	S_1 .0049			
R_2 + .3455				
	D_2 .0922	1.7378	53.5	.989
R_4 + .5448				
	D_3 .0195	1.641	29.9	.985
R_5 + .2607				
	S_2 .1563			
R_6 − .3637				
	D_4 .0195	1.641	29.9	.985
R_7 −1.0722				
	D_5 .1319	1.7378	53.5	.989
R_8 − .4966				
	S_3 .0049			
R_9 +6.5113				
	D_6 .0342	1.7378	53.5	.989
R_{10} −1.0335				

EXAMPLE II.

Equivalent focal length 1.000 — Relative aperture F/2.0

Radius	Thickness or Air Separation	Refractive Index n_D	Abbé V Number	Relative Partial Dispersion
R_1 +1.0058				
	D_1 .8070	1.7378	53.5	.989
R_2 +8.333				
	S_1 0.0			
R_3 + .4237				
	D_2 .1474	1.7378	53.5	.989
R_4 + .4237				
	D_3 .0440	1.6634	21.4	.987
R_5 + .2730				
	S_2 .1960			
R_6 − .3127				
	D_4 .0450	1.6634	21.4	.987
R_7 − .7010				
	D_5 .1603	1.7378	53.5	.989
R_8 − .4268				
	S_3 0.0			
R_9 +2.130				
	D_6 .1040	1.7378	53.5	.989
R_{10} −1.247				

In each of these examples the two cemented surfaces R_4 and R_7 are both concave to the diaphragm. In Example I the curvatures of these two surfaces are respectively about 1.84 and 0.93 and the overall length of the objective is .5318, whilst in Example I the two curvatures are respectively about 2.36 and 1.43, the overall length being .7837.

The use of sodium bromide crystal in Example I or of potassium iodide crystal in Example II in conjunction with magnesium oxide crystal, for all the elements of the objective, has the important further advantage that the objective can be employed not only for visible light but also for a wide range of ultra violet wavelengths down to 2000 Angstrom units. Since the relative partial dispersions of the alkaline halide crystals which may be used for the divergent components are slightly less than that of the magnesium oxide crystal of the convergent components, such crystal combinations give 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 ultra violet rays, for as the wavelength decreases, the secondary spherical abberration 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.

It will be appreciated that the foregoing arrangements have been described by way of example only and that the invention can be carried into practice in other ways.

Dated this 6th day of October, 1942.
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, 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 for photographic or other purposes of the kind corrected for spherical and chromatic aberration, coma, astigmatism, field curvature and distortion, and comprising two compound divergent components located between two simple convergent components, each divergent component consisting of a divergent element made of a material having relatively low Abbé V number and compounded with a second element made of a material having a relatively high Abbé V number such second element usually (but not necessarily) being convergent.

In the objective according to the invention the materials used for the two divergent elements of low Abbé V number have mean refractive index between 1.62 and 1.68 and Abbé V number between 21.0 and 31.0, whilst those used for the other four elements have mean refractive index between 1.70 and 1.80 and Abbé V number greater than 50.0, and preferably less than 58.0. The material used for each of the two divergent elements preferably has mean refractive index at least .05 less than that of the material used for the element cemented to it.

Various combinations of materials may be employed and it is especially convenient to make each of the two divergent elements of an alkaline halide crystal. For example potassium iodide or sodium bromide crystal may be used for these divergent elements.

By choosing materials for all the elements 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. Such an arrangement, using alkaline halide crystal for the divergent elements, in itself forms the subject of the present applicants' British Patent Application No. 13957 of 1942 (Serial No. 560,540). The relative partial dispersion, usually represented by the symbol 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 potassium iodide crystal and sodium bromide crystal respectively have relative partial dispersions .987 and .985, and good secondary spectrum correction can be obtained with the use of either of these crystals for the two divergent elements in conjunction with magnesium oxide crystal in the form known as β-magnesium-oxide for the other four elements, such crystal having relative partial dispersion .989.

The cemented surfaces in the two divergent components are preferably such that (regarding a cemented surface as having positive curvature if concave to the diaphragm and negative curvature if convex thereto) the algebraic sum of the curvatures of the two cemented surfaces is positive. When the overall axial length of the objective lies between .51 and .65 times the equivalent focal length of the objective, such algebraic sum preferably lies between 5.0 and 1.8 times the reciprocal of such equivalent focal length, whilst when the overall length is between .65 and .80 times the equivalent focal length, the algebraic sum preferably lies between 4.0 and 1.0 times the reciprocal of the equivalent focal length.

The accompanying drawing illustrates a preferred practical arrangement of objective according to the invention and numerical data for two convenient examples of this arrangement are given in the following tables, in which R_1 and 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. . . . represent the axial thicknesses of the various elements, and S_1 S_2 S_3 the axial air separations between the components. The tables also give the mean refractive indices n_D and the Abbé V numbers and also the relative partial dispersions of the materials of which the individual elements are made.

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EXAMPLE II.

Equivalent focal length 1.000 Relative aperture F/2.0

Radius	Thickness or Air Separation	Refractive Index n_D	Abbé V Number	Relative Partial Dispersion
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R_4 + .4237				
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R_5 + .2730				
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R_6 − .3127				
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R_7 − .7010				
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R_8 − .4268				
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R_9 + 2.130				
	D_6 .1040	1.7378	53.5	.989
R_{10} − 1.247				

In each of these examples the two cemented surfaces R_4 and R_7 are both concave to the diaphragm. In Example I the curvatures of these two surfaces are respectively 1.84 and 0.93 and the overall length of the objective is .5318, whilst in Example I the two curvatures are respectively about 2.36 and 1.43, the overall length being .7837.

The use of sodium bromide crystal in Example I or of potassium iodide crystal in Example II in conjunction with magnesium oxide crystal, for all the elements of the objective, has the important further advantage that the objective can be employed not only for visible light but also for a wide range of ultra violet wavelengths down to 2000 Angstrom units. Since the relative partial dispersions of the alkaline halide crystals which may be usesd for the divergent components are slightly less than that of the magnesium oxide crystal of the convergent components, such crystal combinations give 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 ultra violet rays, for as the wavelength decreases, the secondary spherical aberration becomes increasingly relatively overcorrected 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.

It will be appreciated that the foregoing arrangements have been described by way of example only and that the invention can be carried into practice in other ways.

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 two divergent components located between two simple convergent components and each consisting of a divergent element made of a material having relatively low Abbé V number and compounded with a second element made of a material having relatively high Abbé V number, wherein the materials used for the two divergent elements of low Abbé V number have mean refractive index lying between 1.62 and 1.68 and Abbé V number lying between

21.0 and 31.0 whilst those used for the other four elements have mean refractive index lying 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 numbers of the materials used for the said other four elements are less than 58.0.

3. An optical objective as claimed in Claim 1 or Claim 2, in which the materials used for all the elements have substantially the same relative partial dispersion.

4. An optical objective as claimed in Claim 1 or Claim 2 or Claim 3, in which the material used for each of the two divergent elements has mean refractive index at least .05 less than that of the material used for the element cemented to it.

5. An optical objective as claimed in any one of Claims 1 to 4, in which the two divergent elements are each made of an alkaline halide crystal.

6. An optical objective as claimed in Claim 5, in which sodium bromide crystal is used for the two divergent elements, whilst the other four elements are all made of magnesium oxide crystal.

7. An optical objective as claimed in Claim 5, in which potassium iodide crystal is used for the two divergent elements, whilst the other four elements are all made of magnesium oxide crystal.

8. An optical objective as claimed in any one of Claims 1 to 7, in which the algebraic sum of the curvatures of the cemented surfaces in the two divergent components (regarding such curvature as positive if the surface is concave to the diaphragm position and negative if the surface is convex thereto) is positive.

9. An optical objective as claimed in Claim 8, in which the overall axial length of the objective lies between .51 and .65 times the equivalent focal length of the objective, and the algebraic sum of the curvatures (as defined in Claim 8) of the two cemented surfaces lies between 5.0 and 1.8 times the reciprocal of such equivalent focal length.

10. An optical objective as claimed in Claim 8, in which the overall axial length of the objective lies between .65 and .80 times the equivalent focal length of the objective, and the algebraic sum of the curvatures (as defined in Claim 8) of the two cemented surfaces lies between 4.0 and 1.0 times the reciprocal of such equivalent focal length.

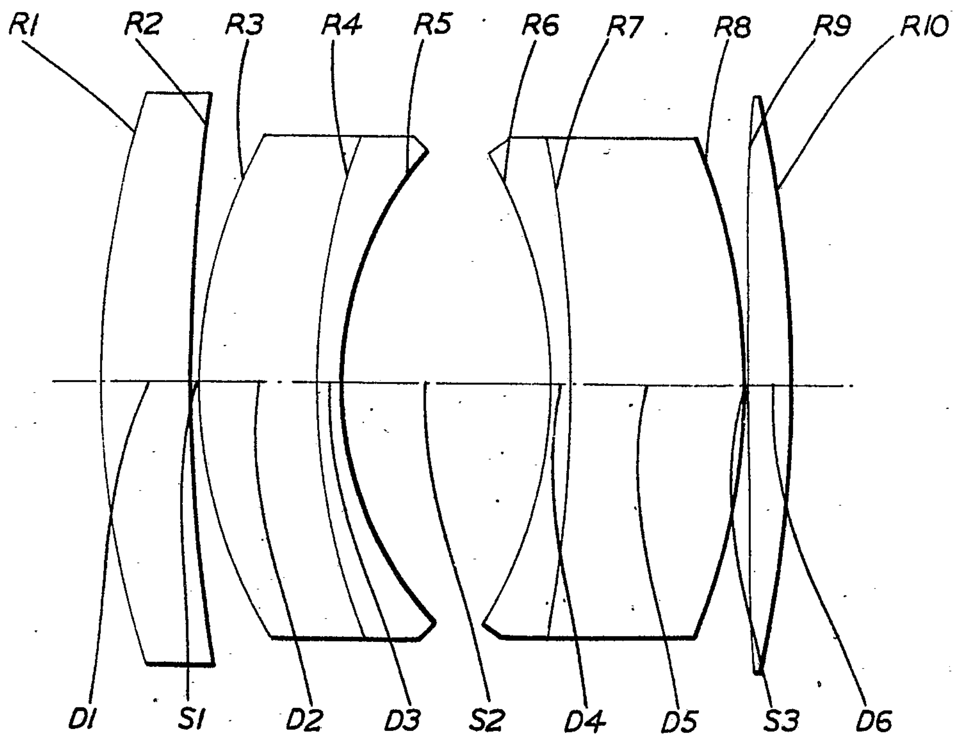
11. An optical objective having numerical data substantially in accordance with one or other of the tables herein set forth.

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 reproduction of the Original on a reduced scale.]



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