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 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 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 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 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 present invention the second air space (i.e. the 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 sum of those of the first and third air 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 . . . . 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 . . . . represent the axial thicknesses of the lens elements, and S_1 S_2 . . . . represent the axial air spaces between the components. The table also gives the mean refractive index n_D and the Abbé V number for the glass used for each element.

Equivalent focal length 1.000 Relative aperture F/3.5

Radius	Thickness or Separation	Refractive Index n_D	Abbé V number
R_1 + .3188			
	D_1 .0663	1.613	59.4
R_2 −3.347			
	S_1 .0502		
R_3 − .6694			
	D_2 .0131	1.579	40.4
R_4 + .5862			
	S_2 .0291		
R_5 −5.020			
	D_3 .0131	1.579	40.4
R_6 + .4016			
	S_3 .0603		
R_7 +1.435			
	D_4 .0301	1.613	59.4
R_8 −1.435			
	S_4 0		
R_9 ∞			
	D_5 .0301	1.613	59.4
R_{10} − .5466			

[*Price* 1/-]

4s 6d

It will be noticed that in this example S_2 is less than S_1 and S_3 and is less than a third of the sum of S_1 and S_3, whilst S_4 is zero, the fourth and fifth components 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 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

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, 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 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 applicants' copending British Patent Application No. 32051 of 1939 relates to an objective of this kind, 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 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 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. 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.

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. In this case, when improved zonal spherical aberration correction is desired, 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 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 of the objective. In some instances the glasses 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 . . . . 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 sign that it is concave thereto), D_1, D_2 . . . . represent the axial thicknesses of the lens elements, and S_1 S_2 represent the axial air spaces between the components. The tables also give the mean refractive index n_D 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_D	Abbé V number
R_1 + .3555			
	D_1 .0416	1.613	59.4
R_2 +1.101			
	S_1 0		
R_3 + .5505			
	D_2 .0416	1.613	59.4
R_4 +2.477			
	S_2 .0396		
R_5 −1.125			
	D_3 .0129	1.579	40.4
R_6 + .4972			
	S_3 .0297		
R_7 −9.908			
	D_4 .0129	1.579	40.4
R_8 + .3644			
	S_4 .0565		
R_9 + .7926			
	D_5 .0694	1.613	59.4
R_{10} − .5096			

EXAMPLE II.

Equivalent focal length 1.000 Relative aperture F/2.5

Radius	Thickness or Separation	Refractive Index n_D	Abbé V number
R_1 + .7262			
	D_1 .057	1.613	59.3
R_2 +2.174			
	S_1 .001		
R_3 + .4219			
	D_2 .084	1.613	59.3
R_4 +2.500			
	S_2 .041		
R_5 −1.220			
	D_3 .015	1.621	36.2
R_6 + .5214			
	S_3 .035		
R_7 ∞			
	D_4 .031	1.621	36.2
R_8 + .5087			
	S_4 .050		
R_9 + .9901			
	D_5 .080	1.644	48.3
R_{10} − .5066			

EXAMPLE III.

Equivalent focal length 1.000 Relative aperture F/2.5

Radius	Thickness or Separation	Refractive Index n_D	Abbé V number
R_1 + .6553			
	D_1 .057	1.644	48.3
R_2 +1.667			
	S_1 .001		
R_3 + .3945			
	D_2 .084	1.613	59.3
R_4 +1.449			
	S_2 .041		
R_5 −2.000			
	D_3 .015	1.652	33.5
R_6 + .4815			
	S_3 .040		
R_7 +3.086			
	D_4 .015	1.652	33.5
R_8 + .4464			
	S_4 .065		
R_9 + .8403			
	D_5 .080	1.644	48.3
R_{10} − .5590			

EXAMPLE IV.

Equivalent focal length 1.000 Relative aperture F/2.5

Radius	Thickness or Separation	Refractive Index n_D	Abbé V number
R_1 + .5208			
	D_1 .057	1.644	48.3
R_2 +1.587			
	S_1 0		
R_3 + .3656			
	D_2 .073	1.644	48.3
R_4 +1.449			
	S_2 .0365		
R_5 −11.76			
	D_3 .02	1.697	30.5
R_6 + .3390			
	S_3 .03		
R_7 +2.841			
	D_4 .02	1.652	33.5
R_8 + .4458			
	S_4 .08		
R_9 + .8696			
	D_5 .084	1.644	48.3
R_{10} − .6349			

It will be noticed in these four examples that S_3 is less than S_2 and S_4 and less than 45% of the sum of S_2 and S_4, and that R_5 is negative and is numerically greater than R_6, whilst the numerical sum of R_5 and R_8 is considerably greater than the equivalent focal length. In Example I R_7 is slightly concave to the front, and in Example II R_7 is flat. In Examples III and IV the fourth element is slightly meniscus shaped, with surface R_7 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 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 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 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 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.

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 preferably 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 the front two components and the rear component are convergent and the third and fourth components divergent. In the latter case, when improved zonal spherical aberration correction is desired, 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 lengh of 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 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 . . . . 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 sign that it is concave thereto), D_1, D_2 . . . . represent the axial thicknesses of the lens elements, and S_1 S_2 . . . . represent the axial air spaces between the components. The tables also give the mean refractive index n_D and the Abbé V number for the glass used for each element.

The first example has its second and third components divergent and is illustrated 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 fourth components are divergent.

EXAMPLE I.

Equivalent focal length 1.000 Relative aperture F/3.5

Radius	Thickness or Separation	Refractive Index n_D	Abbé V number
R_1 + .3188			
	D_1 .0663	1.613	59.4
R_2 −3.347			
	S_1 .0502		
R_3 − .6694			
	D_2 .0131	1.579	40.4
R_4 + .5862			
	S_2 .0291		
R_5 −5.020			
	D_3 .0131	1.579	40.4
R_6 + .4016			
	S_3 .0603		
R_7 +1.435			
	D_4 .0301	1.613	59.4
R_8 −1.435			
	S_4 0		
R_9 ∞			
	D_5 .0301	1.613	59.4
R_{10} − .5466			

It will be noticed that in this example S_2 is less than S_1 and S_3 and is less than a third of the sum of S_1 and S_3, whilst S_4 is zero, the fourth and fifth components 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 1.613 and the other for the two divergent components with a lower index.

EXAMPLE II.

Equivalent focal length 1.000 Relative aperture F/3.5

Radius	Thickness or Separation	Refractive Index n_D	Abbé V number
R_1 + .3555			
	D_1 .0416	1.613	59.4
R_2 +1.101			
	S_1 0		
R_3 + .5505			
	D_2 .0416	1.613	59.4
R_4 +2.477			
	S_2 .0396		
R_5 −1.125			
	D_3 .0129	1.579	40.4
R_6 + .4972			
	S_3 .0297		
R_7 −9.908			
	D_4 .0129	1.579	40.4
R_8 + .3644			
	S_4 .0565		
R_9 + .7926			
	D_5 .0694	1.613	59.4
R_{10} − .5096			

Example III.

Equivalent focal length 1.000 Relative aperture F/2.5

Radius	Thickness or Separation	Refractive Index n_D	Abbé V number
R_1 + .7262			
	D_1 .057	1.613	59.3
R_2 +2.174			
	S_1 .001		
R_3 + .4219			
	D_2 .084	1.613	59.3
R_4 +2.500			
	S_2 .041		
R_5 −1.220			
	D_3 .015	1.621	36.2
R_6 + .5214			
	S_3 .035		
R_7 ∞			
	D_4 .031	1.621	36.2
R_8 + .5087			
	S_4 .050		
R_9 + .9901			
	D_5 .080	1.644	48.3
R_{10} − .5066			

Example IV.

Equivalent focal length 1.000 Relative aperture F/2.5

Radius	Thickness or Separation	Refractive Index n_D	Abbé V number
R_1 + .6553			
	D_1 .057	1.644	48.3
R_2 +1.667			
	S_1 .001		
R_3 + .3945			
	D_2 .084	1.613	59.3
R_4 +1.449			
	S_2 .041		
R_5 −2.000			
	D_3 .015	1.652	33.5
R_6 + .4815			
	S_3 .040		
R_7 +3.086			
	D_4 .015	1.652	33.5
R_8 + .4464			
	S_4 .065		
R_9 + .8403			
	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_D	Abbé V number
R_1 + .5208			
	D_1 .057	1.644	48.3
R_2 +1.587			
	S_1 0		
R_3 + .3656			
	D_2 .073	1.644	48.3
R_4 +1.449			
	S_2 .0365		
R_5 −11.76			
	D_3 .02	1.697	30.5
R_6 + .3390			
	S_3 .03		
R_7 +2.841			
	D_4 .02	1.652	33.5
R_8 + .4458			
	S_4 .08		
R_9 + .8696			
	D_5 .084	1.644	48.3
R_{10} − .6349			

It will be noticed in these last four examples that S_3 is less than S_2 and S_4 and less than 45% of the sum of S_2 and S_4, and that R_5 is negative and is numerically greater than R_6, whilst the numerical sum of R_5 and R_8 is considerably greater than the equivalent focal length. In Example II R_7 is slightly concave to the front, and in Example III R_7 is flat. In Examples IV and V the fourth element is slightly meniscus shaped, with surface R_7 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 having mean refractive index greater than 1.64. 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 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 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 three are convergent and are disposed one on one side and two on the other side of the pair 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 air spaces.

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

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 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 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 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.

Leamington 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.

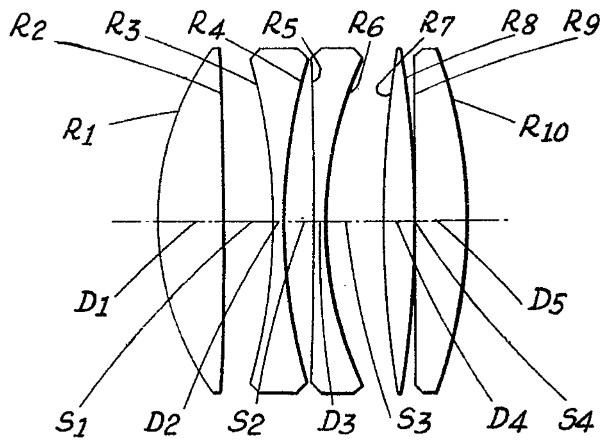

Fig. 2.