PATENT SPECIFICATION

Application Date: March 30, 1942. No. 4219/42.

556,402

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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, 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 an optical objective for photographic or other purposes, corrected for spherical and chromatic aberrations, coma, astigmatism, field curvature and distortion. One well-known type of objective of this kind comprises two compound divergent meniscus components with their concave air-exposed surfaces facing one another and located between two outer simple convergent components. With such objectives a high degree of correction for the aberrations can be obtained with relatively high aperture, but even in the best objectives of this type there is usually a considerable residual over-correction for oblique spherical aberration.

The present invention has for its object to provide a modified form of objective of this known type wherein good correction is provided for oblique spherical aberration as well as for the other aberrations.

To this end according to the invention an additional divergent component is provided between the two inner compound components, so as to enable the dispersive power normally provided by the air-exposed concave surfaces of the two compound meniscus components, to be distributed amongst four surfaces.

Thus the objective according to the invention comprises five components in axial alignment, of which the first and fifth are simple convergent components, the second and fourth are compound components each consisting of a convergent element cemented to a divergent element, and the third is a simple divergent component, the difference between the curvatures of the rear surface of the third component and of the front surface of the fourth component (such difference being measured algebraically taking into account the signs of the curvatures in accordance with the usual convention) being greater than twice and less than four times the reciprocal of the equivalent focal length of the whole objective. The compound second component is preferably of meniscus form with its air-exposed surfaces convex to the front, whilst the fourth component may either be of meniscus form with its air-exposed surfaces concave to the front or may have its front surface plane or slightly convex to the front.

Usually the rear surface of the third component will be convex to the front and more strongly curved than the front surface of the fourth component, so that the air space between these surfaces has the form of a convergent lens. It is to be understood that the terms "front" and "rear" as herein used relate to the sides of the objective respectively nearer to and further from the longer conjugate in accordance with the usual convention.

The materials of which the four convergent elements of the objective are made preferably all have relatively high mean refractive indices, for example between 1.62 and 1.66.

The mean refractive index of the material used for the convergent elements of the second component preferably exceeds that for the divergent element cemented to it by less than .08. In a similar manner the mean refractive index of the material used for the convergent element of the fourth component preferably exceeds that for the divergent element cemented to it by more than .08. In general, the index difference in the fourth component will usually be of the order of twice that in the second component.

In order that a high relative aperture can be achieved for the objective it will usually be desirable for the mean refractive index of the material used for the simple third component to be greater than 1.65.

Numerical data for two convenient examples of objective according to the invention are given in the following tables, in which R_1 R_2 . . . designate the radii of curvature of the individual surfaces counting from the front (the positive sign indicating that the surface is convex to the front and the negative that it is concave thereto), D_1 D_2 . . . designate the axial thicknesses of the individual element, and S_1 S_2 . . . designate the axial air spaces between the components. The tables also give the mean refractive index for the D-line and the Abbé V number for the glasses of which the various elements are made.

EXAMPLE I.

Equivalent focal length 1.000		Relative aperture F/2	
Radius	Thickness or Air Separation	Refractive Index n_D	Abbé V Number
R_1 + .7970			
	D_1 .0698	1.644	48.3
R_2 ∞			
	S_1 .0031		
R_3 + .3874			
	D_2 .1037	1.644	48.3
R_4 −2.281			
	D_3 .0308	1.579	41.2
R_5 + .4107			
	S_2 .0770		
R_6 −1.081			
	D_4 .0308	1.749	27.8
R_7 + .3916			
	S_3 .0451		
R_8 −2.053			
	D_5 .0308	1.529	51.6
R_9 + .4667			
	D_6 .1037	1.644	48.3
R_{10} −1.466			
	S_4 .0031		
R_{11} +1.222			
	D_7 .0821	1.644	48.3
R_{12} − .6464			

EXAMPLE II.

Equivalent focal length 1.000		Relative aperture F/2	
Radius	Thickness or Air Separation	Refractive Index n_D	Abbé V Number
R_1 + .8661			
	D_1 .0700	1.644	48.3
R_2 ∞			
	S_1 .0031		
R_3 + .3883			
	D_2 .1039	1.644	48.3
R_4 − 2.286			
	D_3 .0308	1.579	41.2
R_5 + .4116			
	S_2 .0772		
R_6 − .9943			
	D_4 .0308	1.749	27.8
R_7 + .4065			
	S_3 .0452		
R_8 +18.202			
	D_5 .0308	1.529	51.6
R_9 + .5269			
	D_6 .1039	1.644	48.3
R_{10} − 2.935			
	S_4 .0133		
R_{11} + 1.192			
	D_7 .0823	1.644	48.3
R_{12} − .6089			

In both examples the compound second component is of meniscus form with both its surfaces strongly curved, but the examples differ in respect of the form of the compound fourth component. Thus in the first example the fourth component is of meniscus form but with its front surface much more weakly curved than the rear surface of the second component, whilst in the second example the front surface of the fourth component is slightly convex to the front, so that this component is biconvex.

In both examples the algebraic difference between the curvatures of the seventh and eighth surfaces is approximately three times the reciprocal of the equivalent focal length of the objective. The difference of mean refractive indices across the cemented surface R_4 of the second component amounts to .65 and is somewhat greater than half the corresponding index difference across the cemented surface R_9 in the fourth component, such difference amount to .115.

These examples give good correction for oblique spherical aberration, and in fact what is believed to be the highest degree of correction for this aberration ever yet obtained, at the aperture F/2. Thus in contrast with the known four-component objectives, from which the objective according to the invention has been developed, the oblique spherical aberration, instead of being strongly over-corrected, is in fact slightly under-corrected in these examples.

Dated this 30th day of March, 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, 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 an optical objective for photographic and other purposes, corrected for spherical and chromatic aberrations, coma, astigmatism, field curvature and distortion. One well-known type of objective of this kind comprises two compound divergent meniscus components with their concave air-exposed surfaces facing one another and located between two outer simple convergent components. With such objectives a high degree of correction for the aberrations can be obtained with relatively high aperture, but even in the best objectives of this type there is usually a considerable residual over-correction for oblique spherical aberration.

The present invention has for its object to provide a modified form of objective of this known type wherein good correction is provided for oblique spherical aberration as well as for the other aberrations.

To this end according to the invention an additional divergent component is provided between the two inner compound components, so as to enable the dispersive power normally provided by the air exposed concave surfaces of the two compound meniscus components, to be distributed amongst four surfaces.

Thus the objective according to the invention comprises five components in axial alignment, of which the first and fifth are simple convergent components, the second and fourth are compound components each consisting of a convergent element cemented to a divergent element, and the third is a simple divergent component, the difference between the curvatures of the rear surface of the third component and of the front surface of the fourth component (such difference being measured algebraically taking into account the signs of the curvatures in accordance with the usual convention) being greater than twice and less than four times the reciprocal of the equivalent focal length of the whole objective. The compound second component is preferably of meniscus form with its air-exposed surfaces convex to the front, whilst the fourth component may either be of meniscus form with its air-exposed surfaces to the front or may have its front surface plane or slightly convex to the front.

Usually the rear surface of the third component will be convex to the front and more strongly curved than the front surface of the fourth component, so that the air space between these surfaces has the form of a convergent lens. It is to be understood that the terms "front" and "rear" as herein used relate to the sides of the objective respectively nearer to and further from the longer conjugate in accordance with the usual convention.

The materials of which the four convergent elements of the objective are made preferably all have relatively high mean refractive indices, for example between 1.62 and 1.66.

The mean refractive index of the material used for the convergent elements of the second component preferably exceeds that for the divergent element cemented to it by less than .08. In a similar manner the mean refractive index of the material used for the convergent element of the fourth component preferably exceeds that for the divergent element cemented to it by more than .08. In general, the index difference in the fourth component will usually be of the order of twice that in the second component.

In order that a high relative aperture can be achieved for the objective it will usually be desirable for the mean refractive index of the material used for the simple third component to be greater than 1.65.

In the accompanying drawings,

Figures 1 and 2 respectively show two convenient practical examples of objective according to the new invention.

Numerical data for these two examples are given in the following tables, in which R_1 R_2 . . . designate the radii of curvature of the individual surfaces counting from the front (the positive sign indicating that the surface is convex to the front and the negative that it is concave thereto), D_1 D_2 . . . designate the axial thicknesses of the individual element, and S_1 S_2 . . . designate the axial air spaces between the components. The tables also give the mean refractive index for the D-line and the Abbe V number for the glasses of which the various elements are made.

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	D_6 .1039	1.644	48.3
R_{10} − 2.935			
	S_4 .0133		
R_{11} + 1.192			
	D_7 .0823	1.644	48.3
R_{12} − .6089			

In both examples the compound second component is of meniscus form with both its surfaces strongly curved, but the examples differ in respect of the form of the compound fourth component. Thus in the first example the fourth component is of meniscus form but with its front surface much more weakly curved than the rear surface of the second component, whilst in the second example the front surface of the fourth component is slightly convex to the front, so that this component is biconvex.

In both examples the algebraic difference between the curvatures of the seventh and eighth surfaces is approximately three times the reciprocal of the equivalent focal length of the objective. The difference of mean refractive indices across the cemented surfaces R_4 of the second component amounts to .065 and is somewhat greater than half the corresponding index difference across the cemented surface R_9 in the fourth component, such difference amounting to .115.

These examples give good correction for oblique spherical aberration, and in fact what is believed to be the highest degree of correction for this aberration ever yet obtained, at the aperture F/2. Thus in contrast with the known four-component objectives, from which the objective according to the invention has been developed, the oblique spherical aberration, instead of being strongly over-corrected, is in fact slightly under-corrected in these examples.

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 other purposes, corrected for spherical and chromatic aberrations, coma, astigmatism, field curvature and distortion, and comprising five components in axial alignment, of which the first and fifth are simple convergent components, the second and fourth are compound components each consisting of a convergent element cemented to a divergent element, and the third is a simple divergent component, the difference (measured algebraically) between the curvatures of the rear surface of the third component and of the front surface of the fourth component being greater than twice and less than four times the reciprocal of the equivalent focal length of the whole objective.

2. An optical objective as claimed in

Claim 1, in which the compound second component is of meniscus form with its air-exposed surfaces convex to the front.

3. An optical objective as claimed in Claim 1 or Claim 2, in which the rear surface of the third component is convex to the front and is more strongly curved than the front surface of the fourth component.

4. An optical objective as claimed in Claim 1 or Claim 2 or Claim 3, in which the materials of which the four convergent elements of the objective are made all have mean refractive indices lying between 1.62 and 1.66.

5. An optical objective as claimed in any one of Claims 1 to 4, in which the mean refractive index of the material used for the convergent element of the second component exceeds that for the divergent element cemented to it by less than .08.

6. An optical objective as claimed in any one of Claims 1 to 5, in which the mean refractive index of the material used for the convergent element of the fourth component exceeds that for the divergent element cemented to it by more than .08.

7. An optical objective as claimed in any one of Claims 1 to 6, in which the mean refractive index of the material used for the simple third component is greater than 1.65.

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

Dated this 25th day of February, 1943.

PULLINGER & MALET,
Agents for the Applicants.

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

FIG. 1.

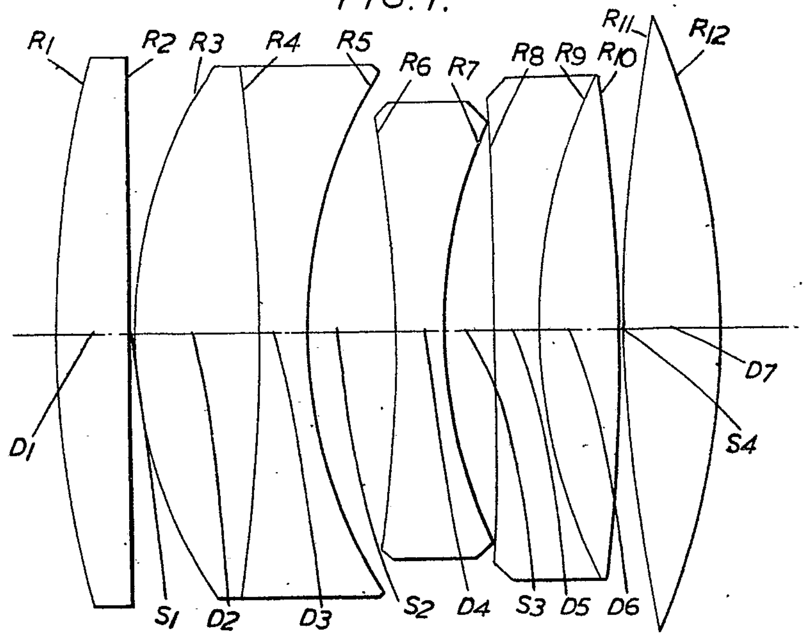

FIG. 2.