PATENT SPECIFICATION

Application Date: March 6, 1941. No. 3063/41.

547,739

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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 optical objectives for photographic or projection or other purposes of the kind, corrected for spherical and chromatic aberrations, coma, astigmatism, field curvature and distortion, and comprising two convergent meniscus components disposed one on either side of the diaphragm position between two compound divergent miniscus components each consisting of a double concave divergent element cemented to a double convex convergent element, all the air-exposed surfaces of the objective being concave towards the diaphragm.

Hitherto most objectives of this kind have been symmetrical about the diaphragm position, but it has also been proposed, in order to improve the aperture and the angular field, to make the objective slightly asymmetrical as regards curvatures and axial spacings whilst retaining symmetry as regards the types of glass used.

The present invention has for its object to improve the zonal spherical aberration correction in such objectives. and thereby to give an increased relative aperture or alternatively better correction at the same aperture, without materially reducing the angular field.

In the objective according to the invention the difference between the mean refractive indices (for the D-line) of the two elements of each compound divergent component lies between .04 and .09, the mean refractive index of the convex element lying between 1.63 and 1.75, whilst that of the concave element lies between 1.56 and 1.68, and the ratio of the radius of curvature of the concave air-exposed surface of the rear compound divergent component to that of the concave air-exposed surface of the front compound divergent component lies between 1.1 and 1.8. The sum of the radii of curvature of these two concave surfaces is preferably greater than .38 times the equivalent focal length of the objective.

It is to be understood that the terms "front" and "rear" as herein used relates respectively to the sides of the objective nearer to and further from the longer conjugate in accordance with the usual convention.

In order to obtain the most satisfactory combination of zonal spherical aberration correction and wide angular extent of correction for astigmatism and distortion, it is preferable for the two inner convergent components, each consisting of a simple element, to have different means refractive indices, one of them being not greater than and the other not less than the mean refractive index of the adjacent double-concave element in the compound component.

In one convenient arrangement the mean refractive indices of all the elements of the objective are greater than 1.62.

The invention may be carried into practice in various ways but numerical data are given in the tables below for three convenient practical arrangements of objective according thereto.

In these tables R_1 R_2 . . . represent the radii of curvature of the individual surfaces of the objective 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 various components. The tables also give the mean refractive indices n_D and the Abbé V numbers of the glasses used for the elements of the objective.

EXAMPLE I.

Equivalent focal length 1.000. Relative aperture F/4.5.

Radius	Thickness or Separation	Refractive Index n_D	Abbé V Number.
R_1 + .2460			
	D_1 .0617	1.644	48.3
R_2 − .9940			
	D_2 .0189	1.579	41.2
R_3 + .1791			
	S_1 .0099		
R_4 + .2400			
	D_3 .0345	1.518	60.3
R_5 + .3601			
	S_2 .0418		
R_6 − .6039			
	D_4 .0368	1.613	59.4
R_7 − .3458			
	S_3 .0099		
R_8 − .2238			
	D_5 .0318	1.579	41.2
R_9 + .7952			
	D_6 .0626	1.644	48.3
R_{10} − .2990			

EXAMPLE II.

Equivalent focal length 1.000. Relative aperture F/4.5.

Radius	Thickness or Separation	Refractive Index n_D	Abbé V Number.
R_1 + .2455			
	D_1 .0610	1.644	48.3
R_2 −1.000			
	D_2 .0190	1.579	41.2
R_3 + .1802			
	S_1 .0100		
R_4 + .2857			
	D_3 .0350	1.613	59.4
R_5 + .4445			
	S_2 .0460		
R_6 − .4587			
	D_4 .0350	1.518	60.3
R_7 − .2838			
	S_3 .0100		
R_8 − .2232			
	D_5 .0320	1.579	41.2
R_9 + .8475			
	D_6 .0670	1.644	48.3
R_{10} − .2994			

EXAMPLE III.

Equivalent focal length 1.000. Relative aperture F/4.5.

Radius	Thickness or Separation	Refractive Index n_D	Abbé V Number.
R_1 + .2418			
	D_1 .0616	1.702	41.2
R_2 − .9627			
	D_2 .0183	1.653	33.5
R_3 + .1821			
	S_1 .0096		
R_4 + .3157			
	D_3 .0434	1.622	36.2
R_5 + .5899			
	S_2 .0366		
R_6 − .5799			
	D_4 .0549	1.653	46.2
R_7 − .4123			
	S_3 .0096		
R_8 − .2629			
	D_5 .0183	1.653	33.5
R_9 + .8022			
	D_6 .0838	1.702	41.2
R_{10} − .3201			

These three examples all give better correction for the aberrations, and especially for zonal spherical aberration, than the known objectives of the same type for aperture F/4.5, and give good correction over a semi-angular field of 35° for coma, astigmatism and distortion, and generally the examples employ higher mean refractive indices than the known objectives.

In all three examples the same glasses are used in the two halves for the elements of the compound divergent components, but different glasses are used for the two simple convergent components, the rear convergent component having the greater index in the first and third examples, whilst the front convergent component has the greater index in the second example. Fairly good correction can however be obtained if the two convergent components have the same refractive index. For example, Examples I and II can readily be modified to suit the use of an index, say, 1.572 for both convergent components. The preferred average index for these two components depends on the indices used in the compound components, and generally an increase in such indices will call for an increase in the average index for the inner components.

Dated this 6th day of March, 1941.

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 projection or other purposes of the kind, corrected for spherical and chromatic aberrations, coma, astigmatism, field curvature and distortion, and comprising two convergent meniscus components disposed one on either side of the diaphragm position between two compound divergent meniscus components each consisting of a double concave divergent element cemented to a double convex convergent element, all the air-exposed surfaces of the objective being concave towards the diaphragm.

Hitherto most objectives of this kind have been symmetrical about the diaphragm position, but it has also been proposed, in order to improve the aperture and the angular field, to make the objective slightly asymmetrical as regards curvatures and axial spacings whilst retaining symmetry as regards the types of glass used.

The present invention has for its object to improve the zonal spherical aberration correction in such objectives, and thereby to give an increased relative aperture or alternatively better correction at the same aperture, without materially reducing the angular field.

In the objective according to the invention the difference between the mean refractive indices (for the D-line) of the two elements of each compound divergent component lies between .04 and .09, the mean refractive index of the convex element lying between 1.63 and 1.75, whilst that of the concave element lies between 1.56 and 1.68, and the ratio of the radius of curvature of the concave air-exposed surface of the rear compound divergent component to that of the concave air-exposed surface of the front compound divergent component lies between 1.1 and 1.8. The numerical sum of the radii of curvature of these two concave surfaces is preferably greater than .38 times the equivalent focal length of the objective.

It is to be understood that the terms "front" and "rear" as herein used relate respectively to the sides of the objective nearer to and further from the longer conjugate in accordance with the usual convention.

In order to obtain the most satisfactory combination of zonal spherical aberration correction and wide angular extent of correction for astigmatism and distortion, it is preferable for the two inner convergent components, each consisting of a simple element, to have different mean refractive indices, one of them being not greater than and the other not less than the mean refractive index of the adjacent double-concave element in the compound component.

In one convenient arrangement the mean refractive indices of all the elements of the objective are greater than 1.62.

The invention may be carried into practice in various ways but numerical data are given in the tables below for three convenient practical arrangements of objective according thereto, the first of such examples being illustrated in the accompanying drawings.

In these tables R_1 R_2 . . . represent the radii of curvature of the individual surfaces of the objective 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 various components. The tables also give the mean refractive indices n_D and the Abbé V numbers of the glasses used for the elements of the objective.

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Equivalent focal length 1.000. Relative aperture F/4.5.

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In all three examples the same glasses are used in the two halves for the elements of the compound divergent components, but different glasses are used for the two simple convergent components, the rear convergent component having the greater index in the first and third examples, whilst the front convergent component has the greater index in the second example. Fairly good correction can however be obtained if the two convergent components have the same refractive index. For example, Examples I and II can readily be modified to suit the use of an index, say, 1.572 for both convergent components. The preferred average index for these two components depends on the indices used in the compound components, and generally an increase in such indices will call for an increase in the average index for the inner components.

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 of the kind described, in which the difference between the mean refractive indices of the two elements of each compound divergent component lies between .04 and .09, the mean refractive index of the convex element lying between 1.63 and 1.75 whilst that of the concave element lies betwen 1.56 and 1.68, and in which the ratio of the radius of curvature of the concave air-exposed surface of the rear compound divergent component to that of the concave air-exposed surface of the front compound divergent component lies between 1.1 and 1.8.

2. An optical objective as claimed in Claim 1, in which the numerical sum of the radii of curvature of the air-exposed concave surfaces of the two compound divergent components is greater than .38 times the equivalent focal length of the objective.

3. An optical objective as claimed in Claim 1, or Claim 2, in which the two inner convergent components each consist of a simple element and have different mean refractive indices, one of them being not greater than and the other not less than the mean refractive index of the adjacent double-concave element in the compound component.

4. An optical objective as claimed in Claim 1 or Claim 2 or Claim 3, in which the mean refractive indices of all the elements of the objective are greater than 1.62.

5. An optical objective having numerical data substantially in accordance with any one of the tables herein set forth.

Dated this 6th day of March, 1942.

PULLINGER & MALET,
Agents for the Applicants.

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