# PATENT SPECIFICATION

Application Date: July 12, 1940. No. 11603/40. 542,508

Complete Specification Left: June 19, 1941.

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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 and like purposes, corrected for spherical abberation, coma, astigmatism and distortion, of the kind comprising an asymmetrical divergent component disposed behind two convergent components and in front of a third convergent component, each of the components consisting of a single element. It should be made clear that the side of the longer conjugate is hereinafter referred to as the "front" of the objective in accordance with the usual convention.

The present applicants' British Patent No. 477,424 relates to an objective of the above kind, wherein glass having a mean refractive index $n_D$ substantially greater than 1.65 is employed for the divergent component, which is double-concave, and the radius of curvature of the front surface of such component is at least ten times that of the rear surface thereof, the glass used for the rear component preferably having a mean refractive index $n_D$ greater than 1.62 and an Abbé V number less than 50. Such objective was primarily intended for very short focal lengths, such as 12½ millimetres, and it has been found that, if the objective is employed for longer focal lengths, such as 2½ inches, it is not wholly satisfactory in respect of zonal spherical aberration.

The present invention has for its primary object to effect improvements in an objective of the above-mentioned kind, whereby the aberrations are satisfactorily corrected over a semi-field of at least 10 degrees.

To this end according to the invention the rear surface of the second convergent component is convex towards the front and has a radius of curvature less than five times the equivalent focal length of the objective, while the front surface of the divergent component is either concave to the front with a radius of curvature greater than ten times the equivalent focal length or is slightly convex towards the front. The radius of curvature of the rear surface of the second convergent component is preferably greater than the equivalent focal length, and that of the rear surface of the divergent component is preferably less than one-tenth of that of the front surface of the divergent component. As in the objective of the prior patent above mentioned, the mean refractive index of the glass used for the divergent component is preferably greater than 1.65, and the glass used for the rear convergent component preferably has a mean refractive index greater than 1.62 and an Abbé V number less than 50.

Numerical data for two convenient practical examples of objective according to the invention are given in the tables below, in which $R_1$, $R_2$ . . . . . designate the successive radii of curvature of the surfaces counting from the front (the positive sign indicating that the surface is convex towards the front and the negative that it is concave thereto), $D_1$, $D_2$ . . . . . designate the axial thicknesses of the lens elements, and $S_1$, $S_2$, $S_3$ the axial air separations between the components. The glass of which each element is made is defined in terms of its mean refractive index $n_D$ and its Abbé V number.

[Price 1/-]

EXAMPLE I.

Equivalent Focal Length 1.000 Relative Aperture F/1.4.

| Radius | Thickness or Separation | Refractive Index $n_D$ | Abbé V Number |
|---|---|---|---|
| $R_1$ + 1.070 | | | |
| | $D_1$ .110 | 1.613 | 59.4 |
| $R_2$ + 10.0 | | | |
| | $S_1$ .010 | | |
| $R_3$ + .5263 | | | |
| | $D_2$ .252 | 1.613 | 59.4 |
| $R_4$ + 3.509 | | | |
| | $S_2$ .011 | | |
| $R_5$ − 26.32 | | | |
| | $D_3$ .210 | 1.749 | 27.8 |
| $R_6$ + .3194 | | | |
| | $S_3$ .196 | | |
| $R_7$ + .5814 | | | |
| | $D_4$ .110 | 1.644 | 48.3 |
| $R_8$ − 1.253 | | | |

It will be noticed that in this example the radius $R^4$ is approximately 3½ times the equivalent focal length, the surface being convex to the front, whilst the fifth surface is concave to the front and has a radius over 26 times the equivalent focal length. With this example, at a focal length of 2½ inches, the residual aberrations are very satisfactory over a semi-field of 12 degrees.

EXAMPLE II.

Equivalent Focal Length 1.000 Relative Aperture F/1.4.

| Radius | Thickness or Separation | Refractive Index $n_D$ | Abbé V Number |
|---|---|---|---|
| $R_1$ + 1.011 | | | |
| | $D_1$ .110 | 1.613 | 59.4 |
| $R_2$ + 6.667 | | | |
| | $S_1$ .010 | | |
| $R_3$ + .5102 | | | |
| | $D_2$ .240 | 1.613 | 59.4 |
| $R_4$ + 2.857 | | | |
| | $S_2$ .011 | | |
| $R_5$ + 26.29 | | | |
| | $D_3$ .210 | 1.749 | 27.8 |
| $R_6$ + .2976 | | | |
| | $S_3$ .196 | | |
| $R_7$ + .5263 | | | |
| | $D_4$ .110 | 1.644 | 48.3 |
| $R_8$ − 1.305 | | | |

This example differs from the first primarily in that the fifth surface is slightly convex towards the front and has a radius substantially greater than ten times the equivalent focal length, the convexity of the fourth surface to the front being somewhat reduced.

Dated this 12th day of July, 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 an optical objective for photographic and like purposes, corrected for spherical aberration, coma, astigmatism and distortion, of the kind comprising an asymmetrical divergent component disposed behind two convergent components and in front of a third convergent component, each of the components consisting of a simple element. It should be made clear that the side of the longer conjugate is herein referred to as the "front" of the objective in accordance with the usual convention.

The present applicants' British Patent No. 477,424 relates to an objective of the above kind, wherein glass having a mean refractive index $n_D$ substantially greater than 1.65 is employed for the divergent component, which is double-concave, and the radius of curvature of the front surface of such component is at least ten times that of the rear surface thereof, the glass used for the rear component preferably having a mean refractive index $n_D$ greater than 1.62 and an Abbé V number less than 50. Such objective was primarily intended for very short focal lengths, such as 12½ millimetres, and it has been found that, if the objective is employed for longer focal lengths, such as 2½ inches, it is not wholly satisfactory in respect of zonal spherical aberration.

The present invention has for its primary object to effect improvements in an objective of the above-mentioned kind, whereby the aberrations are satisfactorily corrected over a semi-field of at least 10 degrees.

To this end according to the invention the rear surface of the second convergent component is convex towards the front and has a radius of curvature less than five times the equivalent focal length of the objective whilst the front surface of the divergent component has a radius of curvature greater than ten times the equivalent focal length, whether such surface be convex or concave to the front. The radius of curvature of the rear surface of the second convergent component is preferably greater than the equivalent focal length, and that of the rear surface of the divergent component is preferably less than one-tenth of that of the front surface of the divergent component. As in the objective of the prior patent above mentioned, the mean refractive index of the glass used for the divergent component is preferably greater than 1.65, and the glass used for the rear convergent component preferably has a mean refractive index greater than 1.62 and an Abbé V number less than 50.

A preferred construction of objective according to the invention is illustrated in the accompanying drawing, and numerical data for two convenient practical examples thereof are given in the tables below, in which $R_1$, $R_2$ ..... designate the successive radii of curvature of the surfaces counting from the front (the positive sign indicating that the surface is convex towards the front and the negative that it is concave thereto), $D_1$, $D_2$ ..... designate the axial thicknesses of the lens elements, and $S_1$, $S_2$, $S_3$ the axial air separations between the components. The glass of which each element is made is defined in terms of its mean refractive index $n_D$ and its Abbé V number.

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It will be noticed that in this example the radius $R^4$ is approximately 3½ times the equivalent focal length, the surface being convex to the front, whilst the fifth surface is concave to the front and has a radius over 26 times the equivalent focal length. With this example, at a focal length of 2½ inches, the residual aberrations are very satisfactory over a semi-field of 12 degrees.

EXAMPLE II.

Equivalent Focal Length 1.000 Relative Aperture F/1.4.

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| | $D_4$ .110 | 1.644 | 48.3 |
| $R_8$ − 1.305 | | | |

This example differs from the first primarily in that the fifth surface is slightly convex towards the front and the convexity of the fourth surface to the front is somewhat reduced. As in the first example, the radius of the fifth surface is substantially greater than ten times the equivalent focal length.

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 rear surface of the second convergent component is convex towards the front and has a radius of curvature less than five times the equivalent focal length of the objective, whilst the radius of curvature of the front surface of the divergent component is numerically greater than ten times the equivalent focal length.

2. An optical objective as claimed in Claim 1, in which the radius of curvature of the rear surface of the second convergent component is greater than the equivalent focal length of the objective.

3. An optical objective as claimed in Claim 1 or Claim 2 in which the radius of curvature of the rear surface of the divergent component is less than one-tenth of that of the front surface thereof.

4. An optical objective as claimed in Claim 1 or Claim 2 or Claim 3, in which the mean refractive index of the glass used for the divergent component is greater than 1.65.

5. An optical objective as claimed in Claim 4, in which the glass used for the rear component has a mean refractive index greater than 1.62 and an Abbé V number less than 50.

6. An optical objective as claimed in any one of Claims 1 to 5, in which the front surface of the divergent component is convex to the front and has a radius of curvature greater than ten times the equivalent focal length.

7. An optical objective substantially as shown in the accompanying drawing and having numerical data substantially as set forth in one or other of the tables herein.

Dated this 19th day of June, 1941.

PULLINGER & MALET,
Agents for the Applicants.

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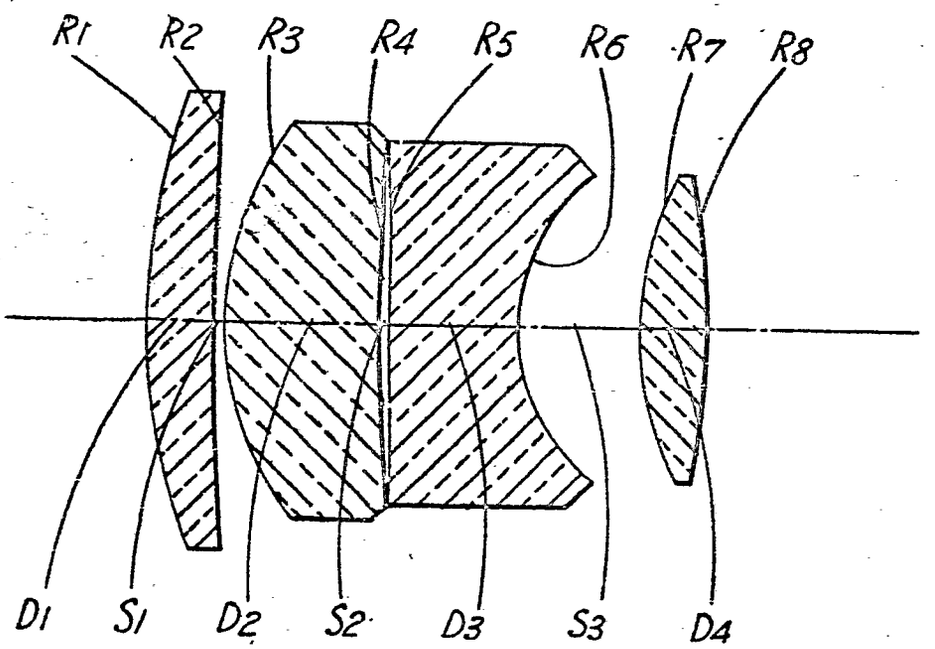


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