Application Date: May 31, 1946.   No. 16650/46.

Complete Specification Left: April 14, 1947.

Complete Specification Accepted: Nov. 17, 1948.

Index at acceptance:—Class 97(i), J7c.

PROVISIONAL SPECIFICATION

Improvements relating to Optical Objectives

We, THE PULLIN OPTICAL COMPANY LIMITED, a Company organised under the laws of Great Britain, of Phœnix Works, Great West Road, Brentford, in the
5 County of Middlesex, and HORACE WILLIAM LEE, a British subject, of Solar Works, Lane End Road, Sands, High Wycombe, in the County of Buckingham, do hereby declare the nature of this inven-
10 tion to be as follows:—

This invention relates to optical objectives and particularly to photographic lenses corrected for chromatic and spherical aberration, coma, astigmatism, dis-
15 tortion and field curvature and comprising three co-axial single glass elements—two outer collective elements and an intermediate dispersive element. The object of the invention is to provide an improved
20 form of objective in which only stable and homogeneous glasses of high transparency are employed and which provide a larger aperture or alternatively, a higher degree of correction than is obtained in lenses
25 hitherto constructed.

Hitherto in lenses of the kind described above, an aperture of F/2.5 has been attained only with large zonal spherical aberration resulting in impaired definition
30 or by using crystals or glasses having extremely high refractive indices of 1.75 or higher. Such highly refractive glasses are expensive and the crystals are difficult and expensive to produce.

35 According to the present invention, all three of the elements are formed of glasses having refractive indices greater than 1.65 and less than 1.75 and Abbé V numbers less than 55—24 $(n.d. -1.691)^{1}/_{s}$.
40 where $n.d.$ is the refractive index for the helium d line. This condition may be complied with by using the glass S.B.F.

717,477 of Chance Bros. Ltd. for the two collective elements and the glass E.D.F. 700,302 of the same Company for the dis- 45 persive element but all glasses within the above limits are stable and easily produced and are of suitable hardness for optical working. Preferably the dispersive element has a refractive index less 50 than that of either of the collective elements but not more than 0.05 less than that of either collective element.

In a lens according to this invention, having a sufficiently small zone to work 55 at an aperture of F/2.5 and having a field of 40 degrees without excessive astigmatism or zonal curvature of field, the arithmetic sum of the powers of the three elements lies between 5 and 7 times the 60 power of the system, the overall length between 0.4 and 0.5 times the focal length of the system and the separation of either collective element from the dispersive element—measured from the respective 65 nodal planes—does not differ by more than 20 per cent. from their mean value.

The numerical data for an actual example of a lens according to this invention is set out in the following table in which a 70 refers to the front collective element facing the longer conjugate, b refers to the dispersive element and c to the rear collective element. The radius is shown positive when the surface is convex to light 75 incident on the first surface and negative when concave. Thickness and separation are measured on the axis. Equivalent focal length $=1.00$.

Relative aperture F/2.5. Angle of field 80 40°.

The glasses of Chance Bros. Ltd. mentioned above are used.

Element	Radius	Thickness or Separation	Refractive Index	Abbé V Number
a	$r_1 + 0.4624$ $r_2\ \infty$	t, a 0.0886	1.717	47.7
		S_1 0.0929		
b	$r_3 - 0.7010$ $r_4 + 0.4269$	t, b 0.0175	1.70035	30.3
		S_2 0.1135		
c	$r_5 + 2.030$ $r_6 - 0.5038$	t, c 0.1418	1.717	47.7

Dated this 31st day of May, 1946.

For the Applicants:
GILL, JENNINGS & EVERY,
Chartered Patent Agents,
51/52, Chancery Lane, London, W.C.2.

COMPLETE SPECIFICATION

Improvements relating to Optical Objectives

We, THE PULLIN OPTICAL COMPANY LIMITED, a Company organised under the laws of Great Britain, of Phœnix Works, Great West Road, Brentford, Middlesex, England, and HORACE WILLIAM LEE, a British subject, of Solar Works, Lane End Road, Sands, High Wycombe, in the County of Buckingham, 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 and particularly to photographic lenses corrected for chromatic and spherical aberration, coma, astigmatism, distortion and field curvature and comprising three co-axial single glass elements—two outer collective elements and an intermediate dispersive element. The object of the invention is to provide an improved form of objective in which only stable and homogeneous glasses of high transparency are employed and which provides a larger aperture or alternatively, a higher degree of correction than is obtained in lenses hitherto constructed.

Hitherto in lenses of the kind described above, an aperture of F/2.5 has been attained only with large zonal spherical aberration resulting in impaired definition or by using crystals or glasses having extremely high refractive indices of 1.75 or higher. Such highly refractive glasses are expensive and the crystals are difficult and expensive to produce.

According to the present invention, all three of the elements are of glasses having refractive indices greater than 1.65 and less than 1.75 and Abbé V numbers less than $55 - 24_3 \sqrt{(n.d. - 1.691)}$, where $n.d$ is the refractive index for the helium d line. This condition may be complied with by using the glass S.B.F. 717,477 of Chance Bros. Ltd. for the two collective elements and the glass E.D.F. 700,302 of the same Company for the dispersive element or by using that Company's glass S.B.F. 691,548 for the collective elements and their glass E.D.F. 653,336 for the dispersive element. However, all glasses within the above limits are stable and easily produced and re-produced and are of suitable hardness for optical working. Preferably, the dispersive element has a refractive index less than that of either of the collective elements but not more than 0.05 less than that of either collective element.

In a lens according to this invention, having a sufficiently small zone to work at an aperture of F/2.5 and having a field of 40 degrees, without excessive astigmatism or zonal curvature of field, the arithmetical sum of the powers of the three elements lies between five and seven times the power of the system, the overall length between 0.4 and 0.5 times the focal length of the system and the separation of either collective element from the dispersive element—measured from the nodal planes—does not differ by more than 20 per cent. from their mean value.

In order that the invention may be clearly understood and readily carried into effect, two examples of the novel lens will now be more fully described with re-

ference to the accompanying drawings, in which:—

Figures 1 and 2 are the usual diagrams of the two examples.

The numerical data for the two examples of lenses according to this invention are set out in the following tables, in which a refers to the front collective element, b refers to the dispersive element and c to the rear collective element. In this connection, the front element is that on the side of the long conjugate for which the system is corrected and the rear element that on the side of the short conjugate. The radius R is shown positive when the surface is convex to light incident on the first surface and negative when concave. Thickness d and separation s are measured on the axis.

For the example shown in Figure 1:—
Equivalent focal length = 1.00. Relative aperture F/2.5.
Angle of field 40°.

| | | | | Glass | |
Component	Radius of Curvature	Thickness or separation	Refractive Index	Abbé V number	Chance number
a	$R_1 + 0.4624$ $R_2 \quad \infty$	d a 0.0886	1.717	47.7	S.B.F. 717477
		S_1 0.0929			
b	$R_3 - 0.7010$ $R_4 + 0.4269$	d b 0.0175	1.70035	30.3 ·	E.D.F. 700302
		s_2 0.1135			
c	$R_5 + 2.030$ $R_6 - 0.5038$	d c 0.1418	1.717	47.7	S.B.F. 717477

For the example shown in Figure 2:—
Equivalent focal length = 1.00. Relative aperture F/2.5
Angle of field 40°.

| | | | | Glass | |
Component	Radius of Curvature	Thickness or separation	Refractive Index	Abbé V number	Chance number
a	$R_1 + 0.440$ $R_2 \quad \infty$	d a 0.086	1.6910	54.8	S.B.F. 691548
		s_1 0.100			
b	$R_3 - 0.691$ $R_4 + 0.408$	d b 0.017	1.6534	33.6	E.D.F. 653336
		s_2 0.125			
c	$R_5 + 1.949$ $R_6 - 0.519$	d c 0.135	1.6910	54.8	S.B.F. 691548

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 two

outer collective elements and an intermediate dispersive element, in which all three of those elements are formed of glasses having refractive indices greater than 1.65 and less than 1.75 and Abbé V numbers less than $55-24_3\sqrt{(nd-1.691)}$, where nd is the refractive index for the helium d line.

2. An optical objective according to claim 1, in which the dispersive element has a refractive index less than that of either of the two collective elements but not more than 0.05 less than that of either collective element.

3. An optical objective according to claim 2, in which the arithmetical sum of the powers of the three elements lies between five and seven times the power of the system, the overall length lies between 0.4 and 0.5 times the focal length of the objective and the separation of either collective element from the dispersive element, measured from the respective nodal planes, does not differ by more than 20 per cent. from their mean valve.

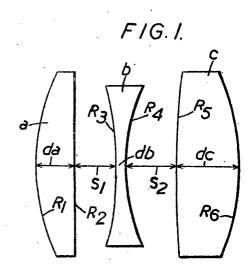4. An optical objective according to claim 3, constructed with the numerical data set forth in either of the tables herein.

Dated this 14th day of April, 1947.
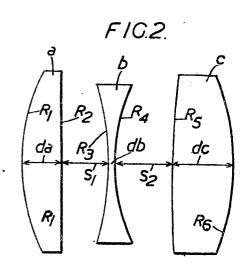For the Applicants:
GILL, JENNINGS & EVERY,
Chartered Patent Agents,
51/52, Chancery Lane, London, W.C.2.

FIG. 1.

FIG. 2.