

1531025

PATENT SPECIFICATION

(11) 1 531 525

- (21) Application No. 32783/76
- (22) Filed 6 Aug. 1976
- (31) Convention Application Nos. 6079/75 and 6078/75
- (32) Filed 6 Aug. 1975
- (31) Convention Application No. 474/76
- (32) Filed 23 Jan. 1976
- (31) Convention Application No. 2334/76
- (32) Filed 31 March 1976
- (31) Convention Application No. 3398/76
- (32) Filed 10 May 1976
- (31) Convention Application No. 4995/76
- (32) Filed 8 July 1976 in
- (33) Austria (AT)
- (44) Complete Specification published 8 Nov. 1978
- (51) INT CL² G02B 15/14
- (52) Index at acceptance G2J 23C B7C8



(54) OPTICAL SYSTEM

(71) We, BOLEX INTERNATIONAL SA, of 18 Avenue des Alpes, Ste-Croix, Switzerland, a Swiss company, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to an optical system and is more specifically concerned with a camera optical system incorporating a varifocal objective, preferably one having a zoom facility, able to be used in conjunction with a removable supplementary lens which can be fitted to the front of the camera.

In accordance with one aspect of the invention there is provided a combination of a camera having a varifocal objective incorporating movable lens means to shift the position of an object plane in front of the camera over macro and normal ranges, and a supplementary lens of negative refractivity removably mounted in front of the objective and having a focal length less than the distance between the front lens of the varifocal objective and the far limit of the macro range.

The combination of the invention has the advantage that it is able to provide a portable camera with an unusually large wide-angle effect and with focal lengths as short as 3 mm. or even less in some circumstances.

In accordance with a second aspect of the invention there is provided a camera for use in the inventive combination mentioned above, such camera having a varifocal objective incorporating movable lens means to shift the object plane in front of the camera over macro and normal ranges, a mount for positioning a supplementary lens of negative refractivity in front of the varifocal objective so that the varifocal objective can focus in the macro range on the focal plane of the supplementary lens, and additional marker or mechanical means which are correlated to the mount and which provide the correct setting for the varifocal objective to suit the supplementary lens when it correctly is positioned on the mount.

The additional marker or mechanical means of the second aspect of the invention may comprise simply a special indicating device for the particular focus setting of the varifocal objective which is associated with the fitted supplementary element. The indicating device can for example comprise a special Vernier on the focusing ring of the lens. A visible signal provided on the camera case or in the finder is however also feasible for the above-mentioned focus setting. A special kind of indicating device is the use of a reflex finder with a focus indicator. The object rays would in this case of course have to be reflected in the reflex finder as seen in the incident light direction — behind the lens elements which set the varifocal objective to the "macro" range. The focus indicator can be constructed as a ground glass screen, split-image rangefinder or the like. To relieve the user of the need for any adjustment of the lens it is also feasible that fitting the supplementary lens on the lens actuates an adjusting means for the lens element which sets the lens to the "macro" range. Other forms of such means are mentioned later in the text.

In accordance with a third aspect of the invention there is provided a supplementary lens for use in the inventive combination mentioned above, such lens having a negative refractivity and containing a lens element having back and front facing surfaces at least one of which is aspherical and is provided with radially inner and outer surface portions coaxially arranged with respect to the optical axis of the lens, the radius of curvature of the inner surface portion being different from the radius of curvature of the outer surface portion.

The lens element of the supplementary lens may have its front-facing surface aspherical, its back-facing surface aspherical, or both its front and back facing surfaces aspherical. It may also be constituted by several individual lens elements. The surface of the lens which is front-facing or back-facing is immediately apparent from examining the lens mounting fixture used to attach the supplementary lens in front of the camera's varifocal objective.

For a supplementary lens having a back-facing aspherical surface, it is preferred to have the radius of curvature of the inner portion of such surfaces through which the optical axis of varifocal objective passes, less than that of the front-facing surface adjacent the axis, the ratio A between the focal length of the supplementary lens at a distance M from the optical axis and for a numerical aperture M being expressed by:

$$A \leq 1 - \frac{1.7}{(1+M)^2}$$

to ensure that an error-free image at a different focal length can be taken with the varifocal objective, which is corrected for itself, even after removal of the supplementary lens, for example after a wide-angle exposure.

One embodiment for the supplementary lens with special correction of the image errors in conjunction with the zoom lens set to "macro" is obtained if the curvature of the lens element, constructed as an individual lens, is defined by the following condition for the axial radius of curvature r_{02} of the lens curvature surface which is distal with respect to the object:

$$r_{02} < 1.5 \cdot h_f$$

$$r_{02} < f_f \cdot (n_d - 1)$$

In this expression f_f refers to the focal length of the lens, n_d the refractive index of the lens material and h_f the free height of the said curvature surface — measured from the optical axis.

The special curvature of the curvature surface nearest to the image substantially defines the construction of the lens, and the deflection of the rays from the object and emerging from the lens can be controlled under the best possible conditions, a feature with a beneficial effect on correction.

A special advantage in eliminating image errors is obtained if one of the curvature surfaces or even both are constructed in aspherical form. The deformation Δg of the aspherical configuration from an imaginary spherical surface with a radius of curvature corresponding to the vertex curvature radius R_0 of the aspherical configuration, in each case at a height h from the optical axis, is to be defined by the following condition:

$$\Delta g = \frac{h^2}{R_0 \cdot (2h_f)^2} \pm 20\%$$

where h_f refers to the free height of the lens curvature surface which is distal with respect to the object.

As already mentioned, it is advantageous for optimum correction of the lens if both curvature surfaces are aspherical. In this case the following conditions will have to be satisfied:

$$|\Delta g_1| > \Delta g > |\Delta g_2|$$

where Δg_1 refers to the deformation of the aspherical lens curvature surface nearest to the object Δg_2 refers to the deformation of the aspherical lens curvature surface which is distal with respect to the object and Δg refers to the sum of the two deformations.

The curvature surface which is distal with respect to the object will be aspherically constructed so as to limit the steeply rising cost of constructing two aspherical surfaces

while maintaining a good state of correction, the aspherical configuration, being conveniently defined by the formula:

$$g_A = \frac{c \cdot h^2}{1 + 1 - c^2 h^2 (K+1)} + \sum_{i=2}^n a_{2i} h^{2i}$$

where g_A is the curvature of the aspherical configuration at the relevant distance h from the optical axis referred to a reference plane, c is the reciprocal of the vertex curvature radius R_0 of the aspherical configuration and K is a constant deformation factor so that r_0 and h_F , the free height of the lens curvature surface which is distal with respect to the object, being subject to the following condition:

$$R_0 > 0,9 h_F$$

It is advantageous when using the supplementary lens with a fixed-focus or zoom macro lens if f_0 , the focal length of the entire optical system, and f_{G-F} , the focal length of the system reduced by the negative supplementary lens, is subject to the following condition:

$$r_{02} < 0,375 \cdot h_F \cdot f_0, \text{ where} \\ 0,5 f_{G-F} < f_0 < 0,8 d_{G-F}$$

The invention will now be described in more detail, by way of examples, with reference to the accompanying diagrammatic drawings, in which:

Figure 1 shows a zoom lens with a wide-angle supplementary lens;

Figures 2 to 4 show three different embodiments of wide-angle supplementary lens units each with a different zoom lens;

Figures 5 to 9 show details of constructions of locking means for mounting the wide-angle supplementary lens units in front of a varifocal objective lens locking means for an adjusting device of the lenses of the varifocal objective which are movable when focusing in the macro range;

Figure 10 shows in detail a wide-angle supplementary lens unit with an aspherical surface nearest to the object;

Figure 11 is a graph showing possible refractive power distributions of the lens illustrated in Figure 10;

Figures 12 and 13 show further embodiments of the aspherical refractive surface nearest to the object;

Figure 14 shows another supplementary lens unit in conjunction with a zoom lens; Figures 15 to 17 show possible embodiments of negative supplementary lenses with an aspherical surface on the curved surface nearest to the object (Figure 15); on the curved surface which is distal with respect to the object (Figure 16); and, on both curved surfaces (Figure 17);

Figures 18A to D show a modification of an anamorphic lens;

Figures 19A to D show a second modification in diagrammatic form;

Figures 20 and 21 show a camera having a zoom lens in the form of an anamorphic lens;

Figures 22 to 25 show two possible embodiments of lenses in which the focal length can be adjusted for two different object distances;

Figure 26 shows a basic embodiment for a sliding device provided for different object distance adjustment;

Figures 27, 28A and 28B show possible arrangements of focal length adjustment cams on cam supports;

Figures 29A and B show in detail a focal length adjusting device for the two slidable elements of a zoom lens;

Figures 30A and 30B show a non-positive version for transmitting motion;

Figures 31A to C show a positive version permitting focal length adjustment in several planes in the macro range, this facility being also offered by the device illustrated in Figure 32 but with a different locking device or cam system;

Figures 33A, 33B show positive means of guiding the cam follower, with cam supports situated in different planes;

Figures 34A and 34B shown an embodiment with cam followers for the second focal length adjustment cam or for different macro zoom ranges; and,

Figures 35 and 36 show a camera with a supplementary unit such as a transparency holder on wide-angle supplementary unit mounted on the lens, the focal length adjustment being controlled in dependence on the supplementary device.

The varifocal zoom lens 1 illustrated in Figure 1 by infinitely thin lens elements comprises a positive front element 2, negative elements 3,4 which can be slid along

the optical axis 0 in the course of adjusting the focal length, a stationary positive element 5 and a positive base lens 6. The lens 1 can be adjusted to a plane 7 situated in the extreme close-up range by moving the negative element 4 into the position 4' shown in broken lines. A lens having this facility is already described in the Austrian Patent Specification 317 576.

In front of the varifocal lens 1 is a removable wide-angle supplementary lens unit 8. The supplementary unit 8 has a focal point situated in the plane 7. If the lens 1 is focused on the plane 7 in the macro range the lens combination can achieve an extreme wide-angle effect.

Figure 2 shows the physical optical construction of such a lens combination or system, the wide-angle supplementary unit 8' being formed by the first lens element. Without the wide-angle supplementary unit 8', lens 1' has five times the focal length range with a relative aperture of 1:1.2. A total image angle of 90° can be achieved when the wide-angle supplementary unit is fitted. In the Table below, r refers to the radii, d or l to the vertex distances, n_d to the refractive indices and v_d to the Abbe numbers of the kinds of glass employed.

		n_d	v_d
$r_1' + 2.33$			
$r_2' + 1.14$	$d_1' = 0.12$	1.805	25.4
$r_3' + 9.929$	$l_1' = 0.34$		
$r_4' + 2.044$	$d_2' = 0.10$	/ 1.805	/ 25.4
r_5' plan	$d_3' = 0.38$	/ 1.606	/ 43.9
$r_6' + 2.482$	$l_2' = 0.01$		
$r_7' + 7.189$	$d_4' = 0.21$	/ 1.620	/ 60.3
$r_8' + 1.947$	$l_3' = 0.01$		
$r_9' + 8.453$	$d_5' = 0.28$	/ 1.691	/ 54.7
	$l_4' = \begin{matrix} 0.038 \dots f_{\min} \\ 0.763 \dots f_M \\ 1.097 \dots f_{\max} \end{matrix}$		
$r_{10}' + 6.210$	$d_6' = 0.05$	/ 1.691	/ 54.7
$r_{11}' + 0.629$	$l_5' = 0.21$		
$r_{12}' - 1.112$	$d_7' = 0.05$	/ 1.620	/ 60.3
$r_{13}' + 0.888$	$d_8' = 0.14$	/ 1.805	/ 25.4
$r_{14}' + 5.048$	$l_6' = \begin{matrix} 1.204 \dots f_{\min} \\ 0.368 \dots f_M \\ 0.145 \dots f_{\max} \end{matrix}$		
$r_{15}' - 0.782$	$d_9' = 0.06$	/ 1.744	/ 44.8
$r_{16}' - 1.899$	$l_7' = \begin{matrix} 0.024 \dots f_{\min} \\ 0.135 \dots f_M \\ 0.024 \dots f_{\max} \end{matrix}$		
r_{17}' plan	$d_{10}' =$	/ 1.620	/ 60.3
$r_{18}' - 1.131$	$l_8' = 0.01$		
$r_{19}' + 2.659$	$d_{11}' = 0.12$	/ 1.620	/ 60.3

(17)

5

1,531,525

5

		n_d	v_d
$r_{20}' = 4.235$	$l_9' = 0.04$		
r_{p}' plan	$d_{p}' = 0.25$	/ 1.517	/ 64.2
r_{p}' plan			
Diaphragm space $0.09 + 0.05$			
$r_{21}' + 3.948$	$d_{12}' = 0.16$	/ 1.720	/ 50.4
$r_{22}' - 2.475$	$l_{10}' = 0.01$		
$r_{23}' + 0.676$	$d_{13}' = 0.30$	/ 1.664	/ 35.8
$r_{24}' - 0.835$	$d_{14}' = 0.05$	/ 1.805	/ 25.4
$r_{25}' + 2.399$	$l_{11}' = 0.07$		
$r_{26}' + 1.295$	$d_{15}' = 0.11$	/ 1.847	/ 23.8
$r_{27}' + 0.522$	$l_{12}' = 0.19$		
$r_{28}' + 2.482$	$d_{16}' = 0.17$	/ 1.713	/ 53.8
$r_{29}' - 0.576$	$l_{13}' = 0.01$		
$r_{30}' + 0.700$	$d_{17}' = 0.12$	/ 1.641	/ 60.1
$r_{31}' + 1.440$			

Focal length with wide angle supplementary unit $f_{GW} = 0.22$.

Another combination of a wide-angle supplementary lens unit in conjunction with a zoom lens is shown in Figure 3, the image angle obtained thereby being approximately 90° as for the above example. In this modification, the supplementary unit 8" comprises two lenses of the same lens radius and the same lens thickness. The zoom lens 1" has five times the zoom range and a relative aperture of 1:1.9 and is characterized more particularly by a low loss of brightness towards the image edge compared with lenses of comparable power and kind. Technical specifications of the zoom lens and of the supplementary unit are disclosed in the Table below.

		n_d	v_d
$r_1'' + 2.14$	$d_1'' = 0.13$	1.805	25.4
$r_2'' + 1.47$	$l_1'' = 0.28$		
$r_3'' + 2.14$	$d_2'' = 0.13$	1.805	25.4
$r_4'' + 1.47$	$l_2'' = 0.36$		
$r_5'' + 6.308$	$d_3'' = 0.07$	1.805	/ 25.4
$r_6'' + 1.976$	$l_3'' = 0.06$		
$r_7'' + 2.082$	$d_4'' = 0.26$	1.620	/ 60.3
r_8'' plan	$l_4'' = 0.01$		
$r_9'' + 2.341$	$d_5'' = 0.15$	1.623	/ 58.1
$r_{10}'' + 4.961$	$l_5'' = 0.01$		

(15)

6

1,531,525

6

		n_d	v_d
$r_{11}'' + 1.005$	$d_6'' = 0.22$	1.623	/ 58.1
$r_{12}'' + 12.664$	$l_6'' = \begin{matrix} 0.04 \cdot \cdot \cdot f_{Gmin} \\ 0.69 \cdot \cdot \cdot f_{GM} \\ 1.03 \cdot \cdot \cdot f_{Gmax} \end{matrix}$		
$r_{13}'' + 5.981$	$d_7'' = 0.05$	1.658	/ 50.9
$r_{14}'' + 0.567$	$l_7'' = 0.16$		
$r_{15}'' - 1.086$	$d_8'' = 0.05$	1.669	/ 57.4
$r_{16}'' + 0.652$	$d_9'' = 0.15$	1.805	/ 25.4
$r_{17}'' + 7.039$	$l_8'' = \begin{matrix} 1.09 \cdot \cdot \cdot f_{Gmin} \\ 0.32 \cdot \cdot \cdot f_{GM} \\ 0.14 \cdot \cdot \cdot f_{Gmax} \end{matrix}$		
$r_{18}'' - 0.639$	$d_{10}'' = 0.05$	1.624	/ 47.0
$r_{19}'' - 1.288$	$l_9'' = \begin{matrix} 0.10 \cdot \cdot \cdot f_{Gmin} \\ 0.22 \cdot \cdot \cdot f_{GM} \\ 0.06 \cdot \cdot \cdot f_{Gmax} \end{matrix}$		
$r_{20}'' + 1.097$	$d_{11}'' = 0.10$	1.691	/ 54.7
$r_{21}'' - 3.661$	$l_{10}'' = 0.46$		
$r_{22}'' + 2.052$	$d_{12}'' = 0.10$	1.620	/ 60.3
$r_{23}'' - 2.052$	$l_{11}'' = 0.01$		
$r_{24}'' + 0.686$	$d_{13}'' = 0.13$	1.717	/ 48.0
$r_{25}'' + 26.527$	$l_{12}'' = 0.04$		
$r_{26}'' + 0.848$	$d_{14}'' = 0.16$	1.785	/ 26.1
$r_{27}'' + 0.535$	$l_{13}'' = 0.18$		
$r_{28}'' + 1.614$	$d_{15}'' = 0.19$	1.720	/ 50.4
$r_{29}'' - 0.639$			

Focal length with wide-angle supplementary unit $f_{GW} = 0.22$.

Figure 4 finally shows a third variation of a wide-angle supplementary unit in combination with a further zoom lens $1'''$. As in the example of Figure 3, the wide-angle supplementary unit $8'''$ comprises two lenses. The zoom lens has a focal length range covering a factor of 8 and a relatively aperture of 1:1.8. A "fish eye" effect with an image angle of nearly 180° can be achieved with this wide-angle lens. One possible modification of the embodiment for this lens is disclosed in the Table below.

5

5

	n_d	v_d
$r_1''' + 5.64$		
$r_2''' + 1.35$	$d_1''' = 0.10$	1.805 25.4
$r_3''' + 5.64$	$l_1''' = 0.29$	
$r_4''' + 1.35$	$d_2''' = 0.10$	1.805 25.4
$r_5''' + 5.279$	$l_2''' = 0.21$	
$r_6''' + 1.670$	$d_3''' = 0.084$	1.805 25.4
$r_7''' + 1.670$		
$r_8''' \text{ plan}$	$d_4''' = 0.276$	1.620 60.3
$r_9''' + 2.339$	$l_3''' = 0.004$	
$r_{10}''' + 4.191$	$d_5''' = 0.100$	1.658 50.9
$r_{11}''' + 1.583$	$l_4''' = 0.004$	
$r_{12}''' + 7.391$	$d_6''' = 0.221$	1.658 50.9
	$l_5''' = 0.029$	
$r_{13}''' + 5.201$	0.821	f_{Gmin}
$r_{14}''' + 0.459$	1.112	f_{GM}
$r_{15}''' - 0.877$	$d_7''' = 0.038$	1.691 54.7
$r_{16}''' + 0.639$	$l_6''' = 0.153$	
$r_{17}''' + 7.187$	$d_8''' = 0.038$	1.669 57.4
	$d_9''' = 0.113$	1.805 25.4
$r_{18}''' + 0.576$	$l_7''' = 1.198 \cdot f_{Gmin}$	
$r_{19}''' - 1.459$	$0.249 \cdot f_{GM}$	
	$0.114 \cdot f_{Gmax}$	
	$d_{10}''' = 0.042$	1.624 47.0
	$l_8''' = 0.016$	
$r_{20}''' + 1.055$	0.172	f_{Gmin}
$r_{21}''' - 1.682$	0.016	f_{GM}
$r_p''' \text{ plan}$	$d_{11}''' = 0.102$	1.689 49.5
$r_p''' \text{ plan}$	$l_9''' = 0.038$	
	$d_p''' = 0.209$	1.517 64.2
Diaphragm space = 0.084 + 0.104		
$r_{22}''' + 1.785$	$d_{12}''' = 0.088$	1.620 60.3
$r_{23}''' - 1.785$	$l_{10}''' = 0.004$	
$r_{24}''' + 0.614$	$d_{13}''' = 0.109$	1.717 48.0
$r_{25}''' + 15.718$	$l_{11}''' = 0.031$	

17

1,531,525

8

8

	n_d	v_d
$r_{26}''' = 0.826$	$d_{14}''' = 0.251$	1.785 / 26.1
$r_{27}''' = 0.468$	$l_{12}''' = 0.107$	
$r_{28}''' = 0.967$	$d_{15}''' = 0.163$	1.720 / 50.4
$r_{29}''' = 0.618$		

Focal length with wide-angle supplementary unit $f_{aw} = 0.11$.

The wide-angle supplementary units of Figures 2, 3 and 4 can be combined with each of the lens 1', 1'' or 1'''. The supplementary unit according to Figure 2 consists of an individual element 8', but the supplementary units 8'' and 8''' in Figures 3 and 4 each comprise two individual lens elements. It is possible to support each of the individual elements of Figures 3 and 4 in a mount which can be coupled to the lens 1'' or 1''' or to the second individual lens element. The user is therefore able to achieve a wide-angle effect of greater or lesser extremity depending on whether he has coupled one or both individual lens elements to the lens. Basically, it would be possible to increase the wide-angle effect with a further lens 8' in accordance with Figure 2, but because of the high refractive power of this individual lens element it is not possible to ensure that an aberration-free image can be obtained with a second such lens. Another embodiment of an individual lens element which can be optionally used by itself, in duplex configuration or in a larger number as a supplementary lens in conjunction with a lens 1''' in accordance with Figure 4, is disclosed in the following Table:

	d	n_d	v
r_1 2.18	0.18	1.5168	64.17
r_2 1.25			

The distance between this lens elements and the lens 1''' is 0.40 and it has a focal length of 5.01. If only one lens element is coupled to the lens 1''', there will be an overall focal length of 0.22, while two such lenses will provide an overall focal length of 0.17. This overall focal length can be reduced still further by the addition of further lens elements.

The zoom lens illustrated in Figure 5 has mounts 9, 10 for the elements 3 and 4 which are adjustable in the course of focal length adjustment over the normal distance range. These mounts can slide on guide columns 11, 12 along the optical axis 0. The sliding motion is controlled by a disc cam 13 which can be rotated about an axis 14 by means of a focal length adjusting knob, not shown. The disc cam 13 supports two cam lobes 15, 16 in which cam followers 17, 18 are guided which are connected to the mounts 9, 10. Each of the cams has a section α which controls the motion of the lens elements 3, 4 when adjusting the focal length over the normal distance range and a section β for controlling the focussing motion of the said elements in the macro range.

A receiving device 20 for a mount 19 of a wide-angle supplementary lens unit 8 is situated on the front of a camera 21 into which the lens 1 is inserted. When the mount 19 is "coupled" to the receiving device 20, a tracer 22 which projects into the receiving device on the camera side is moved to the right against the action of a spring 25 — reference Fig. 5. A locking device 23 disposed in the region of the disc cam 13 is thus moved into an operative position in which it projects into the path of the rotatable disc cam 13. The said disc cam has a ratchet 24 with which the locking device 23 can engage. The position of the ratchet 24 on the disc cam 13 corresponds to a focus setting of the lens to the plane 7 (see Fig. 1).

The arrangement can be such that the supplementary unit 8 or its mount 19 can be inserted into the receiving device 20 only if the tracer 22 releases the receiving device as a result of the locking means 23 dropping into the ratchet 24. An embodiment of this kind will be described subsequently by reference to Fig. 8. The locking device 23 can however also bear upon the edge of the disc cam by means of a spring, not shown, which must however be weaker than the spring 25 so that by dropping into the ratchet 24 further rotation and therefore adjustment of the focus setting to the plane 7 is prevented. If the supplementary unit 8, 19 is again removed from the camera 21, the

tracing device 22 will assume its position illustrated in Fig. 5 in which said position the locking means 23 will be inoperative. The lens can again be set to any desired plane in the macro range or the normal distance range (cam range α) can be traversed for adjusting the focal length.

Figs. 6A and 6B show a particularly simple and effortless adjustment of the locking means for the focus adjusting device. A camera 30 is provided with a focal length adjusting lever 31 by means of which the adjusting motion of the optical elements 3 and 4 is controlled over the normal distance range. The adjusting range for the focal length control is designated with α in Fig. 6B. If a ratchet, not shown, is released it is possible to move the lever into the region β in which the focusing motion of the elements 3 and 4 for the macro range is controlled by means of known cams. A construction corresponding to this mechanical control device is described in detail, for example, in the German Auslegeschrift 2,029,254.

If a wide-angle exposure is made, a supplementary unit 32 adapted to hold the negative element 8 is placed on a mount 33 which supports the lens 1, namely in a specific position which is defined by a key 34 on the supplementary unit 32 and a keyway 35 on the mount 33. A stop abutment 36 which is provided on the supplementary unit 32 therefore projects at an angle β_1 (see Fig. 6B) into the path of the adjustable lever 31. If the said lever 31 is placed upon the stop abutment 36, the lens 1 (Fig. 1) will be sharply focused on the plane 7 and the wide-angle effect comes into action through the lens 8 which provides its intermediate image plane in the said plane 7.

Fig. 7 shows another embodiment in which the wide-angle supplementary lens unit is associated with a tracing device. The focal length control tube 41 in a camera 40 is provided with a cam 42 in which a cam tracer 43 is guided that is connected to the optical element 4 in Fig. 1. The control tube 41 is rotated about the optical axis 0 by an actuating device not shown when the focal length is adjusted and during focusing in the macro range. The motion of the element 4 along the optical axis 0 is controlled by the cam range α for normal focal width adjustment, but for the focusing motion at the macro distance it is controlled by the cam range β of the cam 4.

A locking tube 44 supported over the control tube 41 is connected through a linkage 45 to a mode selector switch. The said mode selector switch has three positions:

In the "NORMAL" position the locking tube 44 is moved into a position in which a nose 47 prevents the cam follower 43 moving from the range α to the range β .

In the "MACRO" position, the locking tube is moved into a right-hand limiting position — refer to Fig. 7 — in which the cam tracer 43 can traverse over the entire cam 42 and therefore also over its region for macro focussing. The locking tube will be appropriately latched in the "MACRO" position so as to render ineffective the action of a spring 48 which biases the locking tube 44 through an extension 49 into the "NORMAL" direction.

A third "WW" (wide angle) position of the locking tube 44 can be controlled either by the mode selector switch 46 and this position is advantageously automatically set when the wide-angle supplementary unit 50 is mounted on the lens mount 51 for the lens 1. The setting is performed by a tracer rod 52 which extends into the region of the supplementary unit 50 that is to be coupled and is fixedly connected to the extension 49. When the supplementary unit 50 is fitted, the rod 52 and therefore the locking tube, is moved into a middle position in which a second nose 53 on the locking tube 44 projects into the path of the cam follower 43 in the traversing range β . When the cam follower 43 bears upon the nose 53, the lens 1 will be focused on the plane 7.

Fig. 8 finally shows a locking device 60 which prevents the wide-angle supplementary unit 50' not being mounted on the lens mount 51 if the lens 1 is not focused on the plane 7. As in the apparatus illustrated in Fig. 7, the locking device 60 is fixedly connected to the locking tube 44' which in turn can be slid along the optical axis 0 by means of the mode selector switch 46'. The control tube 41' or the cam 42' of this embodiment contains not only the normal focal length adjusting range α but also the range β' in which the lens is automatically focused on the plane 7.

If a wide-angle exposure is desired, it is merely necessary to move the mode selector switch 46' into the position "WW" and to traverse the range β' while the cam follower 43' bears upon the stop abutment in the cam 42'. The locking device 60 prevents the wide-angle supplementary unit 8 or the lens element in the mount 50' being coupled to the lens 1 in the "NORMAL" position.

Fig. 9 shows a method for focusing directly on the macro plane 7 by fitting the supplementary unit on the lens 1. The supplementary unit 70 for the lens element 8 has a flange 71 with a recess 72 of width b . The camera 73 with the lens 1 is provided with an adjusting handle 74 which is rotated about the optical axis when the focal length is adjusted but is moved along the optical axis 0 when the lens is focused on the

(19)

10

1,531,525

10

macro range. A spring, not shown, can bias the handle in the position shown in solid lines in Fig. 9 but the lens is focused to the extreme macro distance when the adjusting device 74 is in the position shown by dash-dot lines. The lens 1 is focused on the plane 7 according to Fig. 1 when set to an intermediate position (broken line position of the adjusting device 74).

This focus setting is performed automatically by mounting the supplementary unit 70 on the lens 1, the endface of the flange 71 displacing the setting handle 74 by the amount $b-1$ (see Fig. 9). In this position, the supplementary unit 70 itself forms the defined stop abutment for the macro focusing device of the lens 1. To prevent the above-mentioned spring for the setting handle acting on the supplementary unit 70 and thus influencing the focus setting of the system, the said spring can be made either weaker than the amount of friction between the supplementary unit and the lens or a ratchet is provided for the supplementary unit in the coupled position.

If the lens is to be set to "macro" by an element which can be inserted into the optical path instead of by a lens element which can be slid along the optical axis, it is possible for the handle of the said lens element to be actuated by the operation of mounting the supplementary unit.

The supplementary unit 8 shown in detail in Fig. 10 is constructed as a negative meniscus and has an aspherical surface nearest to the plane 7 and a spherical surface which is nearest to the lens 1.

The curvature of the spherical surface is defined by the radius r , but the aspherical surface has a vertex curvature radius R_0 in the region of the optical axis 0. A group of aspherical surfaces are available for a defined vertex curvature radius R_0 in accordance with the known approximation for an aspherical surface

$$x = \frac{cs^2}{1 + \sqrt{1 + c^2 s^2}} + a_2 s^2 + a_4 s^4 + a_6 s^6 + \dots + a_n s^n$$

in which x is the aspherical curvature at the appropriate distance s from the optical axis referred to a reference plane and c is the reciprocal value of a radius R .

Example 1.

The embodiment of the invention illustrated in Figure 2 proceeds from a radius R for the aspherical surface of 63.5 and from a radius of curvature r , for the spherical surface of 18.9, given a lens thickness of 3.0. The lens is to be formed from the plastic material PLEXI 7N, which has a refractive index $n_d = 1.492$ and an Abbe number of v_d of 54.67. The lens is also to have a focal length of -55.9 .

The resultant family of aspherical surfaces is listed in the Table below, the individual aspherical surfaces being characterized only by the coefficients a_2 and a_4 for the second or the third term of the above-mentioned approximation in the interests of simplicity.

TABLE 1

a_2	1.10^{-4}	1.10^{-4}	1.10^{-4}	1.10^{-4}	1.10^{-4}	1.10^{-4}	1.10^{-4}	1.10^{-4}	1.10^{-4}
a_4	4.10^{-6}	5.10^{-6}	6.10^{-6}	7.10^{-6}	8.10^{-6}	9.10^{-6}	1.10^{-5}	$1.5.10^{-5}$	
M	R_s	R_s	R_s	R_s	R_s	R_s	R_s	R_s	H_s
F/1.0	35.839	34.455	33.776	33.602	33.812	34.326	35.089	41.630	27
F/1.1	34.835	32.845	31.541	30.727	30.282	30.119	30.184	32.844	25
F/1.4	36.072	33.160	30.883	29.074	27.618	26.438	25.475	22.784	20
F/1.9	41.899	38.823	36.223	33.998	32.076	30.401	28.930	23.678	15
F/2.8	51.014	48.749	46.683	44.791	43.053	41.450	39.968	33.964	10
F/5.6	59.837	59.158	58.494	57.846	57.211	56.590	55.983	53.133	5
Achse	63.5	63.5	63.5	63.5	63.5	63.5	63.5	63.5	0
Y	Distortion %	Distortion %	Distortion %	Distortion %	Distortion %	Distortion %	Distortion %	Distortion %	
2.01	-4.1	-3.0	-2.0	-0.9	0.2	1.3	2.4	7.9	
2.51	-6.5	-4.8	-3.1	-1.4	0.2	1.9	3.5	11.5	
3.55	-14.2	-11.4	-8.7	-6.2	-3.9	-1.6	0.5	10.0	

In this Table, R_s is the appropriate curvature radius of the aspherical surface at the appropriate distance H_s from the optical axis 0 (see Figure 10) and M refers to the numerical aperture. The distortion listed in the above Table as a percentage referred to half the image field diagonally indicates that the aspherical surface 80 having the coefficients $a_2 = 1.10^{-4}$ and $a_4 = 7.10^{-6}$ provides the optimum correct image for an intended slight negative distortion. However, the aspherical surface 81 having the coefficients $a_2 = 1.10^{-4}$, $a_4 = 4.10^{-6}$ and the aspherical surface 82 having the coefficients $a_2 = 1.10^{-4}$ and $a_4 = 1.5.10^{-5}$ also provided images whose quality is perfectly comparable with other commercially available lenses.

The distribution of refractive power of these three embodiments of the invention is shown in Figure 11 by means of a graph. It is possible to define a range over which the

refractive power distribution and therefore indirectly the radius of curvature R_s defined by the coefficients a_2 and a_4 can vary if the supplementary unit is to have a good state of correction.

- 5 The quantity A , representing the ratio of refractive power F_0 (see Figure 10) of the supplementary unit along the optical axis to the refractive power F_s of the supplementary unit at the appropriate distances from the optical axis is plotted on the abscissa, the said refractive power F_s being directly proportional to the radius of curvature R_s .

$$A = \frac{F_0}{F_s}$$

- 10 The range of possible embodiments of the aspherical surface is defined by the equation

$$A = 1 - \frac{1.7}{(1+M)^2}$$

10

Further embodiments of the wide-angle supplementary unit, also constructed as a negative meniscus with the aspherical surface nearest to the object, are described below.

Example 2

	d	n_d	v_d
$r_1 =$ aspherical			
$r_2 = 25.01$	2.4	1.492	54.67
$R = 1141$	$f = -52$		

TABLE 2A

a_2	$1.5 \cdot 10^{-3}$	$1.5 \cdot 10^{-3}$	$1.5 \cdot 10^{-3}$	$1.5 \cdot 10^{-3}$
a_4	$2.5 \cdot 10^{-6}$	$3 \cdot 10^{-6}$	$4 \cdot 10^{-6}$	$5 \cdot 10^{-6}$
Y	Distortion %	Distortion %	Distortion %	Distortion %
2.01	-2.78	-2.1	-0.9	0.3
2.51	-5.85	-11.7	-2.5	-0.3
3.55	-11.7	-8.9	-3.5	1.5

TABLE 2B

a_2	$1.0 \cdot 10^{-3}$	$6.5 \cdot 10^{-4}$	$1.5 \cdot 10^{-4}$	$1.5 \cdot 10^{-6}$
a_4	$5 \cdot 10^{-6}$	$5 \cdot 10^{-6}$	$5 \cdot 10^{-6}$	$5 \cdot 10^{-6}$
Y	Distortion %	Distortion %	Distortion %	Distortion %
2.01	-0.35	-1.6	-3.5	-4.0
2.51	-2.2	-3.5	-4.5	-6.0
3.55	-0.3	-1.6	-3.5	-4.8

Tables 2A, B indicate that the distortion diminishes with an increasing coefficient a_4 . Proceeding from the aspherical embodiment having the coefficients $a_2 = 1.5 \cdot 10^{-3}$ and $a_4 = 5 \cdot 10^{-6}$, the coefficient a_2 was reduced (Table 2B) which again led to a greater distortion. The astigmatism remained constant.

Example 3

	d	n_d	v_d
$r_1 =$ aspherical			
$r_2 = 21.48$	2.4	1.492	54.67
$R = 138.6$	$f = -52$		

TABLE 3A

a_2	$1 \cdot 10^{-3}$	$1 \cdot 10^{-3}$	$1 \cdot 10^{-3}$	$1 \cdot 10^{-3}$
a_4	$3,5 \cdot 10^{-6}$	$4,5 \cdot 10^{-6}$	$5 \cdot 10^{-6}$	$6 \cdot 10^{-6}$
Y	Distortion %	Distortion %	Distortion %	Distortion %
2.01	-2.7	-1.6	-1.0	-0.16
2.51	-5.0	-3.0	-2.0	-0.17
3.55	-10.0	-6.0	-4.0	-0.3

TABLE 3B

a_2	$8 \cdot 10^{-4}$	$5 \cdot 10^{-4}$	$1 \cdot 10^{-4}$	0
a_4	$6 \cdot 10^{-6}$	$6 \cdot 10^{-6}$	$6 \cdot 10^{-6}$	$6 \cdot 10^{-6}$
Y	Distortion %	Distortion %	Distortion %	Distortion %
2.01	-0.4	-1.4	-2.7	-3.0
2.51	-0.8	-1.8	-3.1	-3.4
3.55	-0.8	-1.6	-2.6	-3.0

This example shows substantially the same characteristic changes of the distortion as those obtained in Example 2.

Example 4

	d	n_d	v_d
$r_1 =$ aspherical			
$r_2 = 18.6$	2.4	1.492	54.67
$R = 71.0$	$f = -52$		

23

TABLE 4A

a_2	$3 \cdot 10^{-6}$	$3 \cdot 10^{-6}$	$3 \cdot 10^{-6}$	$3 \cdot 10^{-6}$
a_4	$6 \cdot 10^{-6}$	$8 \cdot 10^{-6}$	$9 \cdot 10^{-6}$	$9.5 \cdot 10^{-6}$
Y	Distortion %	Distortion %	Distortion %	Distortion %
2.01	-3.4	-1.4	-0.3	0.2
2.51	-4.94	-1.7	-0.2	0.7
3.55	-10.9	-5.8	-3.5	-2.4

TABLE 4B

a_2	$-3,0 \cdot 10^{-4}$	0	$3,0 \cdot 10^{-4}$	$8,0 \cdot 10^{-4}$
a_4	$9,5 \cdot 10^{-6}$	$9,5 \cdot 10^{-6}$	$9,5 \cdot 10^{-6}$	$9,5 \cdot 10^{-6}$
Y	Distortion %	Distortion %	Distortion %	Distortion %
2.01	-0.6	0.2	1.0	2.4
2.51	0	0.7	1.5	2.8
3.55	-2.8	-2.4	-2.0	-1.2

This example shows that the distortion remains substantially constant, proceeding from the best correction result from Table 4A. As in Examples 2 and 3, the astigmatism in the embodiments of Table 4B remains constant.

Other embodiments for an aspherical surface in the first place in a supplementary unit constructed from a single negative lens element are shown in the following examples:

Example 5

	d	n_d	v_d
$r_1 =$ aspherical			
$r_2 = 22.5$	3.0	1.492	54.67
$R = 280$	$a_2 = 1,4 \cdot 10^{-3}$	$a_4 = 6 \cdot 10^{-6}$	

Example 6

	d	n_d	v_d
$r_1 =$ aspherical			
$r_2 = 18.4$	3.0	1.492	54.67
$R = 80$	$a_2 = 3 \cdot 10^{-4}$	$a_4 = 9 \cdot 10^{-6}$	

Example 7

	d	n_d	v_d
r_1 = aspherical			
r_2 = 20.5	3.0	1.492	54.67
R = 138.6	$a_2 = 1.10^{-3}$	$a_4 = 6.7.10^{-6}$	

Example 8

	d	n_d	v_d
r_1 = aspherical			
r_2 = 18.1	3.0	1.492	54.67
R = 65	$a_2 = 8.10^{-5}$	$a_4 = 9.4.10^{-6}$	

The supplementary lens disclosed in the following Example 9 is particularly suitable for a lens disclosed in the Swiss Patent Specification 333 580 and is intended to achieve an extreme wide-angle effect for taking lens for the 16 mm film format.

Example 9

	d	n_d	v_d
r_1 aspherical	3.0	1.4875	70.41
r_2 14.61			
R 230.0	$a_2 = 2.5.10^{-3}$	$a_4 = 1,275.10^{-5}$	

The following examples describe wide-angle supplementary lens units constructed of several lens elements. The Example 10 illustrated in Figure 12 refers to a supplementary unit comprising a negative meniscus with an aspherical surface nearest to the object and a negative meniscus with two spherical surfaces but Examples 11 and 12 describe wide-angle supplementary units comprising two similar meniscus elements. Example 12 is diagrammatically illustrated in Figure 13.

Example 10

		n_d	v_d
r_1 = aspherical			
r_1 = 46.9	$d_1 = 2.4$	1.492	54.67
r_2 = 32.5	$L = 0.5$		
r_2' = 17.82	$d_2 = 2.4$	1.492	54.67
	R	a_2	a_4
r_1	100	5.10^{-5}	$6.3.10^{-6}$

55

Example 11

		n_d	v_d
r_1 = aspherical			
$r_1' = 24$	$d_1 = 2.4$	1.492	54.67
r_2 = aspherical	$l = 10$		
$r_2' = 24$	$d_2 = 2.4$	1.492	54.67
	R	a_2	a_4
r_1	43	$5 \cdot 10^{-5}$	$4 \cdot 10^{-6}$
r_2	43	$5 \cdot 10^{-5}$	$4 \cdot 10^{-6}$

Example 12

		n_d	v_d
r_1 = aspherical			
$r_1' = 26$	$d_1 = 2.4$	1.492	54.67
r_2 = aspherical	$l = 10$		
$r_2' = 26$	$d_2 = 2.4$	1.492	54.67
	R	a_2	a_4
r_1	280	$1.4 \cdot 10^{-4}$	$6 \cdot 10^{-6}$
r_2	280	$1.4 \cdot 10^{-4}$	$6 \cdot 10^{-6}$

As already mentioned, the aspherical surface can be arranged not only on the surface nearest to the object but also on the surface nearest to the image or on both curvature surfaces.

5 According to Example 13, the supplementary unit has an aspherical surface on the side nearest to the lens and aspherical surface on the side nearest to the plane 7 of Figure 1.

While the curvature of the spherical surface is defined by the radius r_2 , the aspherical surface can again be defined by the following known approximation:

10
$$x = \frac{cs^2}{1 + \sqrt{1 + c^2 s^2}} + a_2 s^2 + a_4 s^4 + a_6 s^6 + \dots + a_n s^n$$

For this aspherical surface, the ratio A between the focal length of the supplementary element along the optical axis and a focal length of the supplementary element at a distance M from the optical axis, M being the numerical aperture, is expressed by the following condition:

15
$$A \leq 1 + \frac{1.7}{M-1}$$

Example 13

	d	n_d	v_d
$r_1 = 138.6$			
$r_2 = \text{aspherical}$	2.4	1.492	54.67
$R = 21.5$	$a_2 = -8.10^{-4}$	$a_4 = -2.10^{-7}$	$a_6 = -7.10^{-8}$

One modification of the embodiment in which both curved surfaces are aspherically constructed as stated in the following Example 14:

Example 14

	d	n_d	v_d
$r_1 = \text{aspherical}$			
$r_2 = \text{aspherical}$	2.4	1.492	54.67
R	a_2	a_4	a_6
$r_1 = 138.6$	3.10^{-5}	1.10^{-6}	
$r_2 = 21.5$	-8.10^{-4}	-2.10^{-7}	-6.10^{-8}

The negative lens element 100 illustrated in Figure 14 has a focal point F' in which the axially parallel incident rays from the object converge. The aperture of the lens is defined by the magnitude h_F of the free aperture associated with the curved surface which is distal with respect to the object. The curvature r_{02} of this surface is essential for the correction of this optical element and if the following condition is observed it also defines the curvature radius r_{01} of the curved surface nearest to the object.

$$\begin{aligned} r_{02} &< 1.5 \cdot h_F \\ r_{02} &< f_F \cdot (n_d - 1) \end{aligned}$$

Figure 14 shows the negative supplementary lens in conjunction with a zoom lens 102 when set to an extremely close object. This macro setting of the lens 102 is obtained by sliding a negative lens L_s from position L_s' into the position shown in solid lines in Figure 14. The position L_s' corresponds to the positions of the lens at the minimum focal length setting of the lens 102.

A zoom lens which is particularly suitable in conjunction with the negative supplementary lens element 100 is that claimed in Claim 6 of the Austrian Patent Specification 325 325 and also described therein.

The said lens 102 has its entry pupil situated at a distance of 1.29 referred to a mean focal length of 1.006. The minimum focal length of the said lens also referred to the above-mentioned focal length amounts to 0.301 without the lens element 100. By moving the lens element L_s from the position L_s' into the position shown in solid lines in Figure 14 and by attaching the lens element 100 according to the invention, it is possible to reduce the focal length of the entire system to 0.167, i.e. by nearly 50% of the minimum focal length of the lens 102. The image angle thus obtained is shown in solid lines in Figure 14, the edge ray of the lens 102 being shown in broken lines.

Figure 15 shows in diagrammatic form part of the curved surface of a lens 111 having the radius r_{01} and being nearest to the object, the said curved surface being aspherically constructed. In the region of the optical axis 0 the said aspherical surface has a curvature radius R_0 . The spherical surface associated with the aforementioned vertex curvature radius R_0 is shown in dash-dot lines in Figure 15. This discloses that the distance Δg_A between the aspherical surface and the spherical surface is increased with an increasing height h from the optical axis 0. The value Δg_A is calculated as the difference between g_A and g_s , these two quantities being calculated by the following formula:

51

$$q_s = \frac{c \cdot h^2}{1 + \sqrt{1 - c^2 h^2}}$$

$$q_A = \frac{c \cdot h^2}{1 + \sqrt{1 - c^2 h^2 (k+1)}} + \sum_{i=2}^n a_{2i} h^{2i}$$

5 In these formulae, c refers to the surface curvature in the optical axis, the curvature c representing the reciprocal of the vertex curvature radius R_0 for the aspherical surface. A deformation factor is represented by K , $a_{22}, a_{24}, \dots$ are coefficients which can be selected at random and can be inserted up to any desired power. The value of g should be in the region of $\pm 20\%$ of

$$\frac{h^5}{R_0 \cdot (2 h_F)^3}$$

10 if optimum correction by the aspherical surface is to be obtained. Embodiments of negative lens elements according to the invention with aspherical curvature surfaces nearest to the object are disclosed in the following Table:—

TABLE 5

Example	15	16	17	18	19	20	21
r_{01}							
r_{02}		0.901			0.967	1.058	1.057
d		0.125					
n_d		1.492					
v_d		54.67					
$2h_F$		1.513					
R_0		3.038		3.346	4.389	7.942	10.783
K	5.3	4.5	0	0	0	54	0
a_4	$0.15 \cdot 10^{-5}$	0	$0.24 \cdot 10^{-5}$	$0.28 \cdot 10^{-5}$	$0.52 \cdot 10^{-5}$	$0.34 \cdot 10^{-5}$	$0.329 \cdot 10^{-5}$
a_5	$-0.3 \cdot 10^{-5}$	0	$0.1 \cdot 10^{-5}$	$0.1 \cdot 10^{-5}$	$0.16 \cdot 10^{-5}$	$0.4 \cdot 10^{-5}$	

The distance 1 (see Figure 14) between a supplementary lens and the zoom lens 102 is 0.5 in the Examples 15—19, it is 0.37 in Example 20 and it is 0.418 in the lens element according to Example 21.

The curvature surface 121 which is distal with respect to the object in the negative lens element 120 according to Figure 16 is aspherical. The axial curvature radius R_0 of the aspherical surface is shown in dash-dot lines in Figure 16, a difference

$$-g_s + g_\Delta = \Delta g_s$$

being obtained for the values of g_Δ and g_s calculated from the above-mentioned expressions. The said quantity $|\Delta g_s|$ should not deviate by more than 20% from

$$\frac{h^2}{R_0 \cdot (2h_F)^2}$$

if optimum correction of the negative lens element is to be obtained.

28

29

Exemplified embodiments of negative lens elements with the aspherical surface disposed on the inside are shown in Table 6.

TABLE 6

Example	22	23	24	25	26	27	28	29
r_{01}	2.04		2.471	4.466	5.686	2.726	2.926	3.511
r_{02}								
d				aspherical				
n_d				0.125				
v_d				1.492				
				54.67				
$2h_F$				1.513				
aspherical surface	R_0	0.749	0.7958	0.932	0.974	0.839	0.839	0.8778
	K	-0.25	-1.2	-4.5	-4.0	-0.25	0	-4.0
	a_4	$-0.5 \cdot 10^{-5}$	$-0.1 \cdot 10^{-4}$	$0.35 \cdot 10^{-4}$	$0.3 \cdot 10^{-4}$			$0.37 \cdot 10^{-4}$
	a_6	$-0.3 \cdot 10^{-7}$	$0.25 \cdot 10^{-7}$	$-0.3 \cdot 10^{-7}$	$-0.3 \cdot 10^{-7}$		$-0.17 \cdot 10^{-7}$	$-0.25 \cdot 10^{-7}$
	a_8						$-0.1 \cdot 10^{-9}$	
	a_{10}					$-0.8 \cdot 10^{-13}$		

These negative lens elements are particularly suitable in conjunction with the lens illustrated in Figure 14. The relevant distance 1 will be 0.5 in the embodiments according to Examples 22 to 24 and it will be 0.418 in the embodiments according to Examples 25 to 29.

Figure 17 finally shows a preferred embodiment with two aspherical curvature surfaces 131, 132 of a lens element 130. The above-mentioned condition according to the invention for the value of Δg is calculated from the sum of the values Δg_1 and Δg_2 at the relevant height h . One modified embodiment of such a lens element can be obtained from the following Table:—

59

21

1,531,525

21

	d	n_d	v_d	$2h_F$
r_{01} aspherical	0.125	1.492	54.67	1.513
r_{02} aspherical				
	R_0	k	a_4	a_5
r_{01}	3.039	1.2	$0.35 \cdot 10^{-5}$	
r_{02}	0.901	-0.25		$0.3 \cdot 10^{-10}$

5

The negative supplementary unit is not restricted for use with a zoom lens. However, special advantages are undoubtedly obtained by the use of a zoom lens because of the numerous application facilities. For example, the lens element is also feasible in conjunction with a zoom lens having a supplementary unit of the reverse Vario-Glaucar kind comprising a fixed front element and two movable element groups of different sign.

5

10

For reasons of manufacturing technology and cost-saving, plastics is a preferred material for negative lens elements with an aspherical surface. An embodiment of glass would be advantageous for a lens element without aspherical surfaces because of the available material, further correction facilities being possible by the appropriate choice of the glass, as is already known.

10

15

All the above-described embodiments of the invention are combined with a vari-focal objective or lens that can be focused to a macro distance. For example, by combining the said supplementary units with the lens described in the Austrian patent specification 325,325 it is possible to obtain an overall focal length of approximately 4 mm.

15

20

The kind of material of the individual lens elements is not restricted to a specific material. Plastics, for example PLEXI 7N, is however used for preference because the aspherical surface can be produced more readily with this material than with glass. Kinds of glass with a similar refractive index and Abbe number are however also feasible if only the aberrations are to be corrected.

20

25

The zoom lens illustrated in Fig. 18 comprises a first negative element 201, a positive element 202, a negative element 203 and finally a positive base lens 204. The positive lens element 202 performs a linear motion towards the element 201 in the course of adjusting the focal length but the negative element 201 moves in accordance with an irregular law of kinetics in order to maintain the image position constant while the focal length is adjusted. Specifications for such a lens are listed in the following Table:

25

	r	d	n_d	v_d
201	-55.09	2.0	1.586	34.7
	43.8			
		53.2867		
202	450	3.6	1.492	54.67
	- 32.64	3.6		
	27.5	1.0	1.492	54.67
	-340.2	1.3769		
203	- 66.06	1.0	1.487	70.41
	26.77			

(B)

22		1,531,525	22
	r	d	n _d
		3.0	
(P)	∞	5.0	1.586
	∞	8.67	56.13
	11.1	3.4	1.744
	-37.44	0.75	44.77
	-17.62	6.75	1.808
204	9.25	0.95	25.43
	20.80	3.2	1.744
	-12.48		44.77

Proceeding from the minimum focal length setting, displacement of the lens element 201 towards the object results in the lens being focussed to the object situated in the macro plane 205 (see Figure 18A). If a toric lens element 207, for example with a horizontal refractive power and vertical cylinder surface, is mounted in front of the lens in this focus setting, the focal point of the horizontally refracting surface being situated in the macro plane 205, the following effect will occur:

An object at infinity produces an image with sharply defined horizontal curves through the lens 207 in the plane 205, the said image being transferred into the film plane 208 by the lens which is set to the macro plane 205. Since the lens has no refractive power for vertical contours it is necessary to provide an equalizing lens element which projects the vertical contours of an object at infinity sharply into the film plane 208, despite the lens being set to the macro plane 205. The said lens element, designated with the numeral 209 in Figure 18, is disposed between the lens elements 203 and 204 and because of the cylindrical surface has no refractive power in the horizontal direction. The optical ray path of the lens is shown diagrammatically in an inclined view in Figure 18D.

Lens elements with the following specifications are particularly suitable for the abovementioned lens:

20	Vertical plane	Radii	d	n _d	v _d	20
	207	Horizontal plane				
	∞	aspherical	3.0	1.492	54.67	
	∞	23.0				
25	209	Distance from front element 1:	7.386			25
	∞	∞	1.0	1.517	64.17	
	218.21	∞				
		Distance from element 203:	2.0			

The refractive surface of the lens element 207 which acts in the horizontal direction and has the radius r₁ is aspherical and is defined by the following expression:

$$x = \frac{cs^2}{1 + \sqrt{1 - c^2s^2}} + a_2s^2 + a_4s^4 + a_6s^6$$

In this expression, x is the curvature of the aspherical surface referred to a reference plane at the relevant distance s from the optical axis and c corresponds to the reciprocal value of the radius R. The said aspherical surface of the lens 207 is expressed by the following data:

R	a ₂	a ₄	a ₆
90.0	0	6.10 ⁻⁶	0

The image of the object at infinity is distorted by the horizontal refractive power of the lens 207 and is therefore distorted in the horizontal direction of the image plane 208. The toric equalizing lens 208, which defines a plane of sharp focus at infinity in one direction and in the other direction has a refractive power, where appropriate zero refractive power which displays the intermediate image of the lens 207 in the film plane

32

208 in the other direction, ensures that the image is sharply projected in the above-mentioned film plane 208 but as already mentioned with distortion.

Another modification is shown in Fig. 19. As in Fig. 18, Fig. 19A shows the lens element contours which are effective for horizontal rays and Fig. 19B shows the lens contours which are effective for the vertical rays. The zoom lens 210 shown in solid lines in Fig. 19C is described in the Austrian patent specification 325,325 and comprises a supplementary unit 211 and a base lens 212. A prism P, which deflects the incident rays, for example into a finder system of a single-lens reflex camera, can be disposed between the two lens groups. In the lens according to Fig. 19, focusing to a macro plane 205' is achieved by placing a lens 213 between the supplementary unit 211 and the base lens 212. The said lens element 213 has a refractive power in the horizontal direction and therefore defines the sharply focused plane 205' for the lens 210 but in the vertical direction the lens element 213 has no refractive power and therefore defines a plane of sharp focus of the lens 210 at infinity. If the lens is preceded by a supplementary lens element 214, which has a light refracting action in the horizontal direction in the same way as the lens 213 but has no refractive power in the vertical direction, a horizontal distorted image of an object at infinity will be produced in the film plane 208'. This is conditional on the said supplementary element mounted on the lens 210 also having a "horizontal" sharply focused plane in the "horizontal" sharply focused plane 205' and a "vertical" sharply focused plane at infinity. Data for lens 213 and 214 are disclosed below and these are calculated more particularly for a lens as described in Claim 6 of the Austrian Patent Specification 325 325.

	Radii		d	n _d	v _d	
	Vertical plane	Horizontal plane				
25	213	∞	∞	1.5	1.517	64.17
		∞	-260.2			
		∞	aspherical			
30	214	∞	∞	2.4	1.492	54.67
			18.6			

The aspherical refractive surface of the lens 214 is defined by the above-mentioned formula and the said surface is expressed by the following data:

	R	a ₂	a ₄	a ₆	
35	71.0	0	9.6.10 ⁻⁴	0	35

If the overall focal length of the lens for the vertical direction is related to the overall focal length of the lens for the horizontal direction, the value thus found will be the anamorphic ratio. In the lens shown in Figure 18 this ratio will be 1.5, but in the modification according to Figure 19 it will be 1.8. It is of course also possible to obtain advantages with the modification illustrated in Figure 19 in conjunction with a lens in accordance with Figure 18 and *vice versa*.

The lens 201—204 illustrated in Figure 18 could then be combined with a supplementary unit and an element which focuses the lens to a macro plane 205 and having the following data:

	Radii		d	n _d	v _d	
	Vertical plane	Horizontal plane				
45	Supplementary element	∞	aspherical	3.0	1.492	54.67
	∞	23.0				
50	toric lens	∞	∞	1.5	1.586	56.1
			-175.13			
	Aspherical surface	∞				
55			R	a ₂	a ₄	a ₆
			90.0	0	6.10 ⁻⁴	0

Data for a supplementary element and a toric lens element in accordance with the modification of the invention illustrated in Figure 18 for a lens according to Figure 19 may be obtained from the following Table:

	Radii		d	n_d	v_d	
	Vertical plane	Horizontal plane				
	Supplementary element aspherical					
			2.4	1.492	54.67	
5	∞	18.6				
	toric lens	∞				
			1.5	1.517	64.17	
	440.1	∞				
	aspherical surface					
10		R	a_2	a_4	a_6	10
		71.0	0	$9.5 \cdot 10^{-6}$	0	

An anamorphic ratio of 1.486 is obtained for the first-mentioned example and a ratio of 1.8 for the last-mentioned modification.

Figure 20 shows a camera to which the invention can be advantageously applied. The camera 220 has a varifocal objective lens 221 whose focal length can be adjusted by means of the handle 222. A wide-angle supplementary unit 223, having a lens, for example a lens 214 of Figure 19, mounted therein is also mounted in front of the lens 221. The lens element 213 (Figure 21) must be moved into the optical path of the lens 21 so that the camera can obtain a sharply focused image of an object at infinity, said image being distorted in the horizontal direction. To this end, the camera is provided with a disc 224 shown in Figure 21 supported in the manner of a turret and provided with lens mounts, for example three lens mounts 225—227, and a free aperture 228. The lens mounts as well as the free aperture can each be indexed into a position in which they are in alignment with the optical axis of the lens 221. This is achieved by means of a knurled device 229 which projects from the casing wall of the camera. The appropriate indexed position is defined by a ratchet 230 which is fixed to the camera.

In the position illustrated in Fig. 21, the lens element 213 inserted into the mount 225 is in alignment with the optical axis and the effect described by reference to Fig. 19 is obtained in conjunction with the supplementary element 223. A lens element corresponding to the lens element 209 of Fig. 18 could be supported in the mount 226 to produce a different anamorphic ratio in conjunction with the lens element 207 as the supplementary unit. A purely spherical lens element could be supported in the mount 228 to permit exposures to be obtained with the lens without any axial distortion. Objects in the macro range could thus be sharply focused without the supplementary lens element or a special wide-angle effect could be achieved by fitting a spherical or aspherical supplementary unit. Zooming over the normal focal length range without a supplementary element is possible with the camera if the aperture 228 is positioned opposite the optical path of the lens.

Rotation of the above-described lenses through 90° can achieve distortion of the object *in situ* in the horizontal and vertical direction. The use of an aspherical surface in the supplementary element is not absolutely necessary but the aspherical surface provides corrective advantages. It would also be possible to construct the second surface of the torus lens element in the supplementary lens element as well as in the main lens with a specific refractive power instead of cylindrically, so that the second plane of sharp focus can also be positioned in the macro range or at a "finite" distance.

It is also feasible to control the indexing of several lens elements on a disc in accordance with Figs. 20, 21 by means of the wide-angle supplementary unit. A modification of this kind could be constructed so that the wide-angle supplementary unit cannot be fitted unless its associated main lens is indexed into the optical path or *vice versa*.

Figs. 22—36 show advantageous embodiments of lens mounts which, in conjunction with the wide-angle system according to the invention, permit variation of the focal length of the main lens without the supplementary unit as well as variation of the focal length of a lens with a negative supplementary element.

Fig. 22 shows a zoom lens designed particularly for the Super 8 film format. The Table below describes an embodiment of the lens where r refers to the radii, d to the vertex distances, n_d to the refractive indices and v_d to the Abbe numbers.

34

25

1,531,525

25

		n_d	v_d
$r_1 + 6.308$	$d_1 = 0.07$	1.805	/ 25.4
$r_2 + 1.976$	$d_2 = 0.06$		
$r_3 + 2.082$	$d_3 = 0.26$	1.620	/ 60.3
r_4 plan	$d_4 = 0.01$		
$r_5 + 2.341$	$d_5 = 0.15$	1.623	/ 58.1
$r_6 + 4.961$	$d_6 = 0.01$		
$r_7 + 1.805$	$d_7 = 0.22$	1.623	/ 58.1
$r_8 + 12.664$	$d_8 = 0.04 \dots f_{\min}$ $0.69 \dots f_M$ $1.03 \dots f_{\max}$		
$r_9 + 5.981$	$d_9 = 0.05$	1.658	/ 50.9
$r_{10} + 0.567$	$d_{10} = 0.16$		
$r_{11} - 1.086$	$d_{11} = 0.05$	1.669	/ 57.4
$r_{12} + 0.652$	$d_{12} = 0.15$	1.805	/ 25.4
$r_{13} + 7.039$	$d_{13} = 1.09 \dots f_{\min}$ $0.32 \dots f_M$ $0.14 \dots f_{\max}$		
$r_{14} - 0.639$	$d_{14} = 0.05$	1.624	/ 47.0
$r_{15} - 1.288$	$d_{15} = 0.10 \dots f_{\min}$ $0.22 \dots f_M$ $0.06 \dots f_{\max}$		
$r_{16} + 1.097$	$d_{16} = 0.10$	1.691	/ 54.7
$r_{17} - 3.661$	$d_{17} = 0.46$		
$r_{18} + 2.052$	$d_{18} = 0.10$	1.620	/ 60.3
$r_{19} - 2.052$	$d_{19} = 0.01$		
$r_{20} + 0.686$	$d_{20} = 0.13$	1.717	/ 48.0
$r_{21} + 26.527$	$d_{21} = 0.04$		
$r_{22} - 0.848$	$d_{22} = 0.16$	1.785	/ 26.1
$r_{23} + 0.535$	$d_{23} = 0.18$		
$r_{24} + 1.614$	$d_{24} = 0.19$	1.720	/ 50.4
$r_{25} - 0.639$			

The varifocal lens comprises a stationary positive element 301 nearest to the object, a negative element 302 situated adjacent to the element 301 and being slidable along the optical axis for the purpose of altering the overall focal length, furthermore a negative element 303 which is slidable along the optical axis to maintain a constant image position and a stationary positive element 304 which converges the pencil of rays diverging behind the element 303 so that they proceed axially parallel in the diaphragm space

35

between the above-mentioned element 304 and a positive base lens 305 which is also stationary.

Fig. 23A shows the wide-angle position of the lens, Figs. 23D and 23E showing middle focal length settings, Fig. 23F showing the maximum focal length setting, the individual elements being shown as lenses which are infinitely thin. Focusing of an object situated in the extreme macro range is made possible in the setting for minimum overall focal length, but also in every other focal length setting, by sliding the element 303 into the position 303' while the other elements remain in the same position. The construction of the varifocal lens therefore complies with the prior art and is disclosed, for example in the Austrian patent specification 317,576. As already mentioned, the focal length is to be additionally adjustable in the said macro range while the image position is to remain constant. This is made possible by initially setting the element 303 towards the element 302, for example in position 303a. In this position the entire lens is focused to an object plane 306 which is situated in the macro range and the lens will have a focal length of $f=0.28$. To increase the aspect ratio for the object situated in the plane 306, the elements 302 and 303 are moved into the positions marked with the index b, c in Figs. 23B and 23C, the element 302 traversing through part of the distance which it would traverse in normal adjustment of the focal length. The focal length adjustment range for macro exposures was terminated in position c because the movement of the element 303, which increases steeply towards the front, would cause the said element to move into the path of the element 302. Overlapping of the movements of elements 302 and 303 would occur even earlier if the objects were set at the extreme macro distance (position 303' of the element 303). The pitch of the cam for the element 303 however depends merely on the individual focal lengths of the lens elements and can yield an optimum focal length range if suitably selected.

The focal length of the lens in position c is 0.43 and thus adjoins directly on the minimum total focal length of the lens with a normal distance setting. However, as will be described subsequently by reference to Fig. 25, it is possible to increase the zoom ratio for macro exposures despite the rapid rise in the adjustment travel for the element 303.

Fig. 23A shows a negative element 307 in broken lines. With said element an extreme wide-angle effect could be achieved. In the example illustrated in Fig. 23A, the focal length of the element 307 is -3.48 referred to a mean total focal length of the lens 301-305 of 1.0.

Fig. 24 also shows a zoom varifocal lens but of a different kind to that of Fig. 22. This lens incorporates a positive front element 310 (see also Fig. 25), a slidable negative element 311 in second place, a third slidable positive element 312 and a fourth negative element 313. The element 313 is followed by a positive base lens 314. Data for such a lens may be obtained from the Table below in which r refers to the radii, d to the vertex distances and n_d to the refractive indices and v_d to the Abbe numbers.

		n_d	v_d
$r_1 - 67.2$	$d_1 = 1.9$	/ 1.805	25.4
$r_2 + 105$	$d_2 = 1.9$		
$r_3 + 116$	$d_3 = 8.3$	/ 1.574	56.4
$r_4 - 60.8$	$d_4 = 4.9$		
$r_5 + 187$	$d_5 = 4.4$	/ 1.643	48.0
$r_6 - 187$	$d_6 = 0.1$		
$r_7 + 45.4$	$d_7 = 5.7$	/ 1.658	50.9
$r_8 + 166$	$d_8 = 0.8 - 29.3$		
$r_9 + 93.2$	$d_9 = 3.8$	/ 1.805	25.4
$r_{10} - 52.2$	$d_{10} = 1.0$	/ 1.620	60.3
$r_{11} + 16.6$	$d_{11} = 4.9$		

	n_d	v_d
$r_{12} = 37.9$		
$r_{13} = +41.2$	$d_{12} = 1.0$ / 1.744	44.8
$r_{14} = +77.7$	$d_{13} = 41.8 - 2.0$	
$r_{15} = +30.0$	$d_{14} = 0.8$ / 1.741	27.6
$r_{16} = 30.0$	$d_{15} = 3.8$ / 1.652	44.9
$r_{17} = +19.9$	$d_{16} = 0.1$	
$r_{18} = +78.2$	$d_{17} = 2.7$ / 1.720	50.4
$r_{19} = -41.1$	$d_{18} = 2.8$ - 14.1	
$r_{20} = +17.4$	$d_{19} = 0.9$ / 1.620	60.3
$r_{21} = \infty$	$d_{20} = 1.9$	
$r_{22} = \infty$	$d_{21} = 8.2$ / 1.569	56.1
$r_{23} = +17.8$	$d_{22} = 5.05$	
$r_{24} = -49.7$	$d_{23} = 4.2$ / 1.570	49.5
$r_{25} = -16.5$	$d_{24} = 3.5$	
$r_{26} = +16.5$	$d_{25} = 2.4$ / 1.847	23.8
$r_{27} = -585$	$d_{26} = 1.35$	
$r_{28} = -12.4$	$d_{27} = 3.8$ / 1.569	63.1
$r_{29} = +18.9$	$d_{28} = 0.2$	
$r_{30} = -23.3$	$d_{29} = 3.1$ / 1.620	60.3

This lens, which is disclosed in the Austrian patent specification 291,619, is diagrammatically illustrated in Fig. 25 by lenses which are infinitely thin, Fig. 25A representing the wide-angle position, Fig. 25G the teleposition of the lens and Figs. 25D and 25F showing medium focal settings for the normal distance range.

By moving the element 312 into the position 312a the lens is focused to the plane 315 in the macro range. If the focal length is to be adjusted with a constant image position, proceeding from the setting which is focused to the plane 315, the element 311 will take up the positions 311b, 311c with progressive adjustment and the element 312 will take up positions 312b and 312c. In Fig. 25C, the image ratio is 1:1 due to the element 312. The direction of motion of the element 311 is reversed and the element 312 is moved to the front more steeply (see Fig. 25F) to obtain a further increase of the zoom ratio without encountering mechanical difficulties in socketing and guiding the moving lens elements 311 and 312. In this position the focal length is 12.07 and therefore already extends far into the normal focal length adjusting range from 7.28 to 55.46. The focal length of 12.07 can be increased still further by a distributed construction of the control cams for the elements 311 and 312, for example on two different supports, the elements 311 and 312 then moving towards the front element 310.

Zooming with this lens is possible not only in the macro range, but the wide-angle range can be increased to an extreme degree by the addition of a negative element 315 — similar to the procedure described by reference to Fig. 23. The element 315 has an assumed focal length of -28.38 . In the present exemplified embodiment the zooming ratio which can be achieved by the invention extends down to 3.48 to produce an image angle of approximately 90° by attaching the element 315 in front of the front element 310 by means which can be easily constructed.

Fig. 26 shows a lens mount for the elements 302 and 303 of the varifocal lens, the

drive for the adjusting motion being applied to the cam support which is constructed as a tube 333 and incorporates a control cam 325' from Fig. 28A to be described subsequently, for example for the element 302, and a cam slot 323 from Fig. 27 for the element 303. An operating handle 334 is rotated for adjusting the focal length. Cam followers 322, 324 are supported in the tubular handle and are entrained in the course of rotation, the elements 302, 303 sliding along the optical axis 0 of the lens in accordance with the shape of the control cam.

When the follower 324 is set to the second cam in the slot 323 for controlling the focal length adjustment in the macro range the element 303 also performs the focusing motion for the object plane in the macro range associated with the second focal length adjusting cam while the element 302 remains stationary. In mechanical terms this is achieved by the operating tube 334 being constructed in two parts, the part 334' which supports the follower 322 for the element 302 remaining stationary by virtue of the pin-slot guide 335. The pin of this guide 335 entrains the parts 334' only when the handle 334 is rotated. The follower 324 can be driven into its two positions by means of a changeover spring which applies a load to one of the two flanks of the cam slot 323.

Embodiments showing the arrangement of the control cams on a cam support are diagrammatically illustrated in Figs. 27, 28A and 28B. The embodiment illustrated in Fig. 27 shows a cam support 320 with control cams, for example for the lens illustrated in Figs. 22 and 23. The said cam support 320 can be constructed as tube and is shown in developed form in Fig. 27. One cam slot 321 is associated with a cam follower 322, connected to the element 302, and one cam slot 323 is associated with a cam follower 324 of the element 303.

When the focal length is adjusted in the normal distance range the cam follower 322 bears non-positively upon the cam slot boundary 325 and the follower 324 bears non-positively upon the cam 326. The facilities for controlling the cam follower when this engages with the cams will be described subsequently. The construction or shape of the cams 325 and 326 is known and it is therefore not necessary to describe in detail the relative positions of cams and cam followers.

On the side of the lens corresponding to the wide-angle position the slots 321 and 323 have extensions 327, 328 of a length x for focusing the lens in the macro range. The cam follower 322 does not alter its relative position in the extension 327 along the optical axis of the lens but the element 303 is displaced by the amount " y " parallel to the optical axis by means of the followers 328. The amount " y " corresponds to the distance through which the element 303 slides into the position 303' (see also Fig. 23A). If zooming is to be performed in the macro range, the cam followers 322, 324 are applied to the left-hand flank of the control slot 321 or 323, with reference to Fig. 27. These flanks are constructed as the focal length adjusting cams 329, 330 for an object situated at a macro distance defined by the traversing distance " z " of the follower 324. In the course of adjusting the focal length the element 303 which is driven by the cam follower 324 moves progressively towards the element 302 while the cam 329 for the element 302 has a point of reversal at a magnification $\beta=1$ through the lens 303 in the direction of motion in order to increase the zooming ratio (in a manner similar to that described by reference to Fig. 25).

The position of the cam followers 322 and 324 illustrated in Fig. 27 is not equivalent to the position of the mounts for the lens elements which are to be controlled because the transmission means between the cam followers and the lens mounts are not shown in the interests of clarity.

Fig. 28A shows a cam support 331 in which the operation of tracing by means of the cam followers 322 and 324 is performed in positive manner. The cams 325', 326' extend over a first range of the support. The ends of the cams are provided with a cam member 332 which changes over the cam followers 322, 324 from the focal length adjusting cams 325', 326' associated with the normal distance range to the focal length adjusting cams 329', 330', for a specific object plane in the macro range.

Fig. 28B shows another method of constructing a cam support 331A. In this case the cams 325'', 329'' or the cams 326'', 330'' are separate, each of the lens elements 302 and 303 being associated with two cam followers 322a, 322b or 324a and 324b respectively. In this embodiment the cam followers 322a, 324a or 322b, 324b must be capable of being alternately switched to the lenses 302, 303.

Fig. 29A shows a cam support 344 constructed in flat form. The elements 302, 303 are supported in mounts 345 or 346 which can slide along a column 343. Each of the mounts or their cam followers 349, 350 are biased to the appropriate focal length adjusting cams by a torsion spring 347 or 348 whose direction of force is reversible. The focal length adjusting cams are constructed as the boundary surfaces of control slots 351, 352. The support 344 with the cam slots can slide transversely to the optical

28

axis 0 along pin-slot guides 353, the shape of the control cams in the slots converting the said sliding motion into a motion along the optical axis towards the mounts 345, 346. The focal length adjustment for the normal range is limited by a ratchet 354 on the support 344.

If focusing is desired in the macro range of this system, adjustment of the carrier merely requires overcoming the spring force of the ball ratchet 355 to enable the cam follower to bear upon the cam sections 356 or 357 while the direction of the spring force 347, 348 remains the same.

The cam followers must bear upon the cam sections 358, 359 if the focal length is to be adjusted at a specific macro distance. This is achieved by changing the control levers 360 into the illustrated arrow direction. The changeover can be effected after the ratchet 354, 355 has engaged.

Locking means illustrated in Fig. 29B for the operation of the changeover lever 360 are provided to prevent any changeover of the cam followers to the macro focusing cam in the macro zooming range. Only one of the levers is shown in the interests of simplicity. The said lever 360a has two ratchet grooves 361, 362 which co-operate with a pawl 364 that can pivot about an axis 363. Pivoting about the axis 363 drives an axial cam 365 on the carrier 344.

The method of operation of the locking device is as follows. In the position illustrated in Fig. 28B, the spring 348a biases the mount 346 or its cam follower 350 upon the cam 359 of the cam slot 352. The axial cam 365, which is raised with respect to the carrier 344, incorporates a ramp where the ball 355 drops into the ratchet 354. This occurs when the cam follower 349, 350 merges into the expanded cam slot region. The pawl 364 which is driven by the cam 365 pivots about the axis 363 and drops into the ratchet 362. The lever 360a is therefore locked against any changeover of the spring 348a for the entire tracing range of the cam 359.

Changeover of the direction of spring force is not possible in the region of the control slot 352 since the pawl 364, driven by a cam which corresponds to the cam 365, can drop into a ratchet 361 in which position of the lever the follower 350 bears upon the cam 357 (macro focusing).

One embodiment in which the focal length setting can be controlled in several macro distances is shown in Figs. 30A and 30B. The lens 303 is accommodated in a mount 366. The mount is provided in known manner with a cam follower 367. In the course of the tracing motion of the cam follower 367 with respect to various control cams in a control slot 368 of a support 369, the lens 303 is moved along the optical axis 0 in accordance with kinetic laws which are specific to the control cams. The control slot 368 has at least one cam section 370 which drives the lens 303 for zooming over the normal distance range. Another cam section 371 is allocated to focusing in the macro region. A spring 372', whose direction of force is reversible, switches the cam follower 367 to the cams 370 or 372 respectively in a manner similar to that of the device illustrated in Fig. 29. In the position illustrated in Fig. 30A the cam follower 367 is biased towards a control cam 372 which is disposed on another carrier 373. The carrier 373 by itself can be adjusted parallel to the optical axis 0 for preselecting the focal length control cams, namely by a changeover device not shown in detail, and can be adjusted in the direction of the arrow 374 together with the carrier 369 by a focal length adjusting device which is not shown. The control cam 372 directly adjoins one end of the macro focusing cam 371 and is thus allocated to focal length adjustments at the macro distance which corresponds to focusing at this end of the macro cam 371. If the support 373 is moved to the left — with reference to Fig. 30A — the spring 372' will urge the cam follower 376 to another focal length adjusting cam 375 in the control slot 368 for another specific macro distance. Focal length adjustment for the normal distance range, focusing in the macro range and focal length adjustment for objects situated in two different planes in the macro range is thus possible with relatively simple means of construction.

One embodiment in which any desired number of focal length adjustment cams associated with specific planes in the macro range can be used for control purposes and is shown in Fig. 31A to C.

Two mount parts 378, 379 for the lenses 302, 303 are guided parallel to the optical axis 0 on stationary guide columns 376, 377. To control the adjusting motion along the optical axis the mount 378 supports a cam follower 380 and the mount 379 supports a cam follower 381. Both cam followers 380, 381 are guided in control cams of a plate cam 382. The cam 383 associated with the cam follower 380 as well as the cam 384 associated with the cam follower 381 have a section α which is associated with focal length adjustment in the normal distance range. In the course of adjusting the focal length in the macro range, the cam followers 380, 381 traverse through the section β of

both cams. A focal length adjusting device 385, comprising an operating handle 386 and an operating handle 387 (Fig. 31B) is provided for transmitting the shape of the control cams to the cam followers. The handle 386 supports the plate cam 382, a further plate cam 388 being mounted on the operating handle 387. Both plate cams with their handles can be independently rotated about a stationary axis 389. As can be seen by reference to Fig. 31C, the plate cam 388 is provided with several spline grooves so that one of three pairs of cams for the macro adjustment of the lenses 302 and 303 can engage in a specific angular position with the cam followers 380, 381 which are mounted on the spindle 389.

The plate cam 388 assumes the position shown in broken lines in Fig. 31B for adjusting the focal length in the normal distance range, neither of the two cam followers being able to engage with the cams of the plate cam 388. The lenses 302 and 303 are therefore driven merely by the cams 383, 384 through the range α . The transition angle to the section β is so acute that rotation of the handle 386 or of the plate cam 382 beyond the α region results in self-locking action.

If the operating handle 387 together with the plate cam 388 is then moved into the position shown in solid lines in Fig. 31B, one of the cam pairs 390, 391 or 392 will engage with the associated cam follower 380 or 381. All cams of the plate cam 388 have cut-outs to permit free motion of the cam followers 380, 381 for focal length adjustments over the normal distance range α . This can be effected solely by clockwise rotation of the handle 387 or of the plate cam 388 associated therewith — with reference to Figs 31A and C — the cam followers bearing on the appropriate underside of the cam and being deflected laterally in dependence on the shape of the cams 383, 384 which are situated beneath. To effect the adjustment, it is necessary that the cam followers are situated in the transition of the regions α and β — with reference to cams 383 and 384 — at the beginning of the adjusting motion.

If the plate cam 388 is rotated in the clockwise direction proceeding from this position, it results in a focal length adjusting motion of the lenses 302 and 303 in terms of forming an image of an object in the macro region with a constant image position. In this case the cam followers 380, 381 will move in accordance with laws defined by the cam regions β of the cams 391 or 392.

The circular middle line 393 illustrated in Fig. 31C discloses that with the exception of the cam 390 the cams associated with the cam follower 380 for the element 302 have an inwardly extending characteristic. This means that the cams 391, 392 control focal length adjustment in the macro region while the circular cam 390 does not result in any axial adjustment of the element 303 and therefore controls macro focusing accompanied by simultaneous adjustment of the element 303. The cams 391 and 392 are focal length adjustment cams for different macro distances. The effect of fading out in the form of dissolving the image sharpness can also be achieved by the above-described facility of changing directly from the focal length adjustment for the macro range or macro focusing cam into the normal focal length adjustment cam. This device also permits zooming in other macro distances, in which case the plate cam 388 must be exchanged for another plate with further cams 391, 392 which correspond to the focal length adjustment cams.

Fig. 32 shows another possible embodiment of a cam support with focal length adjustment cams which are positively traced for several macro distances. All cams of this embodiment are disposed on a single support 394. One cam follower 395 is associated with the element 302 and is guided in a slot 396. One follower 397 is associated with the element 303 and is guided in a slot 398 for adjusting the focal length over the normal distance range. Altering the focal length results in the support 394 being adjusted in the direction of the arrow 399.

The changeover of the focal length range for normal distances to macro distances is obtained by adjustment of the cam follower 397 to the left, with reference to Fig. 32. To this end, the locking device 400 for a focal length adjusting cam 401 or the said locking device 400 and a further locking device 402 for the focal length adjusting cam 403 must first be released. The method of controlling the locking device will be described subsequently.

The cams 401 and 403 for the element 303 are associated with different planes in the macro range, the element 302 moving towards the element 303 due to being driven by the cam follower 395 and the cam section 404. The support 394 also has a cam section 405 for controlling focusing in the macro range.

A support illustrated in Figs. 33A and B has a cam slot 407 in which a cam follower 408 is positively guided. The cam slot is defined by three cam sections which control different settings of the lens which is not shown in the interests of simplicity. The cam section 409 controls the motion of the cam follower 408 for normal focal

40

length adjustment, the cam section 410 provides this control for macro focusing and the cam section 411 provides this control for focal length adjustment in the macro range.

A further cam support 412, which is adjustable with the support 406 in the control direction for the cam follower 408 but can be adjusted in the direction of the arrow 413' when changing over the adjusting facilities of the lens, is also provided since, as already mentioned, the cam follower 408 is to be positively guided. The support 412 incorporates cams 409a to 411a which are parallel to the cams 409 to 411. A specific path for the cam follower is thus released in dependence on the lateral position of the support 412 in relation to the support 406. According to Fig. 33A it is possible to adjust the focal length over the normal distance range and to obtain focusing in the macro range. The focal length adjusting cam for the macro range is released in Fig. 33B. Stop abutments, which limit the lateral adjusting travel of the support 406 so that the cam slot generated thereby corresponds to the diameter of the cam follower 408, are designated with the numerals 413 to 414.

One embodiment in which several cam followers are provided for controlling an adjustable optical element is shown in Figs. 34A and 34B. Controlling the element 302 by means of cam supports 415 has already been described in similar exemplified embodiments but the lens element 303 is associated with a cam support 416 which supports four cams 417 to 420 each of which can be brought into engagement with a cam follower 421 to 424. A mount 425 for the lens element 303 is guided along the optical axis 0 by means of a column 426 and supports a pin 427 which is inserted into the support 416 and is guided in a guide slot 428 (Fig. 34B).

The cam followers 421 to 424 support operating keys 429 to 432 each of which is associated with a known ratchet device 433 so that only one of the cam followers can be engaged with the cam associated therewith.

The cam followers 421 to 424 are stationarily supported while the support 416 can be adjusted relative to the cam followers in the direction of the arrow 434 (Fig. 34B). In the illustrated example, the cam follower 423 is in engagement with the cam 419 associated therewith. The cams 417 to 419 control the adjustment of focal length in the macro range.

In the course of the adjusting motion of the support 416 the support 415 is entrained in the same direction by means of the guide rod 435 but the rails 436 prevent adjustment of the support 415 in the direction of the optical axis 0 while the support 416 can be adjusted along the rods 435 in the direction of the optical axis, namely in dependence on the shape of the cam 437 to 420 which is being traced. In the course of the adjusting motion the pin 427 of the mount 425 slides in the slot 428. Advantageously, the operating handle for adjustment in the direction of the arrow 434 acts on the guided support 415.

Figs. 35 and 36 show a particularly advantageous embodiment of the above-described apparatus for cine cameras. A wide-angle supplementary unit 441 can be fitted in front of the front element 301 of a cine camera 440 similar to the camera of Fig. 7, part of which is shown in Fig. 35. The wide-angle supplementary lens comprises the negative element 306 (see Fig. 23) which is supported in a mount 443 that can be fitted upon a camera lens mount 442.

Fitting the supplementary wide-angle lens 441 displaces a tracer rod 444 which thus releases a locking device 446. The locking device is constructed in tubular form and extends over the actual focal length cam tube 447, which can be constructed for example in the same way as the tube 331 of Fig. 26B. Displacement of the locking tube 446 in relation to the cam tube 447 releases the cam sections 329" and 330" for adjusting the focal length in the macro range, the intermediate image situated in the macro range being sharply focused by means of the negative lens 306. The lens 306 will then provide the extreme wide-angle effect. The locking devices 400, 402 of Fig. 32 can be controlled by the tracer rod 444 in place of the locking tube 447.

Fig. 36 shows a similar embodiment for a cine camera 450. Operation of a macro button 451 causes a similarly constructed locking tube 452 to be moved into the illustrated position so that the cam sections 329" and 330" are released for adjusting the focal length in the macro range. At the same time, a locking nose 453 is adjusted by a rod 454, associated with the tube 452, from the region of the leading front of the lens 442 so that a transparency holder 455 can be placed in front of the front element 301. The transparency 456 which is inserted into the transparency holder is situated accurately at the distance from the lens 301 with which the macro focal length adjusting cams 329", 330" are also associated. If several such zoom cams are provided, it is possible to switch the locking nose 453 in the position which will only permit the supple-

mentary device to be fitted which is associated with the selected focal length adjusting cam.

WHAT WE CLAIM IS:—

1. The combination of a camera having a varifocal objective incorporating movable lens means to shift the position of an object plane in front of the camera over macro and normal ranges, and a supplementary lens of negative refractivity removably mounted in front of the objective and having a focal length less than the distance between the front lens of the varifocal objective and the far limit of the macro range.

2. The combination claimed in Claim 1, in which the objective incorporates a first toric lens providing two mutually perpendicular planes of sharp focus at right angles to the optical axis with a first of such planes lying in the macro range, and the supplementary lens incorporates a second toric lens having two planes of sharp focus which coincide, respectively, with the planes of sharp focus of the first toric lens.

3. The combination claimed in Claim 2, in which the or each toric lens has a cylindrical refractive surface.

4. The combination claimed in Claim 3 and capable of zooming, in which the first toric lens is positioned between an image plane (film plane) of the objective and a lens element which focusses the objective onto the first plane in the macro range, the refractive power of the first toric lens being such that the second plane of sharp focus is focussed in the image plane (film plane).

5. The combination claimed in Claim 2 and capable of zooming, in which the first toric lens is mounted on a device movable to substitute for it a second lens which focusses the objective in the macro range.

6. The combination claimed in Claim 5, in which the device is located between a base lens of the objective and lens elements of it which displace to produce zooming.

7. The combination claimed in Claim 6, in which the device comprises a disc rotatable about an axis parallel to the optical axis and carrying the first toric lens and second lens at arcuately spaced positions, an indexing device positively locating the disc when the lenses it carries are individually located on the optical axis of the objective.

8. The combination claimed in Claim 2, and characterized by the following data, subject to a deviation of the curvature of individual surfaces and of the thicknesses of up to $\pm 10\%$ of the refractive power of the relevant element, up to ± 0.03 of the refractive indices and up to ± 5 of the Abbe numbers:

	Radii		d	n _d	v _d
	Vertical plane	Horizontal plane			
r ₁	∞	aspherical	3.0	1.492	54.67
r ₂	∞	23.0	7.386		
r ₃	-65.09		2.0	1.586	34.7
r ₄	43.8		38.096		
r ₅	450		3.6	1.492	54.67
r ₆	-32.64		0.1		
r ₇	27.5		3.6	1.492	54.67
r ₈	-340.2		1.377		
r ₉	-66.06		1.0	1.487	70.41
r ₁₀	26.77		1.0		
r ₁₁	∞	∞	1.5	1.586	56.13
r ₁₂	∞	-175.13	1.0		



mentary device to be fitted which is associated with the selected focal length adjusting cam.

WHAT WE CLAIM IS:—

- 5 1. The combination of a camera having a varifocal objective incorporating movable lens means to shift the position of an object plane in front of the camera over macro and normal ranges, and a supplementary lens of negative refractivity removably mounted in front of the objective and having a focal length less than the distance between the front lens of the varifocal objective and the far limit of the macro range.
- 10 2. The combination claimed in Claim 1, in which the objective incorporates a first toric lens providing two mutually perpendicular planes of sharp focus at right angles to the optical axis with a first of such planes lying in the macro range, and the supplementary lens incorporates a second toric lens having two planes of sharp focus which coincide, respectively, with the planes of sharp focus of the first toric lens.
- 15 3. The combination claimed in Claim 2, in which the or each toric lens has a cylindrical refractive surface.
- 20 4. The combination claimed in Claim 3 and capable of zooming, in which the first toric lens is positioned between an image plane (film plane) of the objective and a lens element which focusses the objective onto the first plane in the macro range, the refractive power of the first toric lens being such that the second plane of sharp focus is focussed in the image plane (film plane).
- 25 5. The combination claimed in Claim 2 and capable of zooming, in which the first toric lens is mounted on a device movable to substitute for it a second lens which focusses the objective in the macro range.
- 26 6. The combination claimed in Claim 5, in which the device is located between a base lens of the objective and lens elements of it which displace to produce zooming.
- 27 7. The combination claimed in Claim 6, in which the device comprises a disc rotatable about an axis parallel to the optical axis and carrying the first toric lens and second lens at arcuately spaced positions, an indexing device positively locating the disc when the lenses it carries are individually located on the optical axis of the objective.
- 30 8. The combination claimed in Claim 2, and characterized by the following data, subject to a deviation of the curvature of individual surfaces and of the thicknesses of up to $\pm 10\%$ of the refractive power of the relevant element, up to ± 0.03 of the refractive indices and up to ± 5 of the Abbe numbers:

	Radii		d	n _d	v _d
	Vertical plane	Horizontal plane			
r ₁	∞	aspherical	3.0	1.492	54.67
r ₂	∞	23.0	7.386		
r ₃	-65.09		2.0	1.586	34.7
r ₄	43.8		38.096		
r ₅	450		3.6	1.492	54.67
r ₆	-32.64		0.1		
r ₇	27.5		3.6	1.492	54.67
r ₈	-340.2		1.377		
r ₉	-66.06		1.0	1.487	70.41
r ₁₀	26.77		1.0		
r ₁₁	∞	∞	1.5	1.586	56.13
r ₁₂	∞	-175.13	1.0		



42

33

1,531,525

33

	Radii		d	n _d	v _d
	Vertical plane	Horizontal plane			
P					
r ₁₃	∞		5.0	1.567	56.13
r ₁₄	∞		8.67		
r ₁₅	11.1		3.4	1.744	44.77
r ₁₆	- 37.44		0.75		
r ₁₇	- 17.62		6.25	1.805	25.43
r ₁₈	9.25		0.95		
r ₁₉	20.80		3.2	1.744	44.77
r ₂₀	12.48				

the aspherical surface defined by the formula:

$$x = \frac{cs^2}{1 + \sqrt{1 - c^2s^2}} + a_2s^2 + a_4s^4 + a_6s^6$$

5 in which said formula x is the aspherical surface curvature referred to a reference plane at the relevant distance s from the optical axis and c is the reciprocal value of the radius R, the aforementioned aspherical surface has the following data:

5

	R	a ₂	a ₄	a ₆
r ₁	90.0	0	6.10 ⁻⁶	0

10 9. The combination claimed in Claim 4 and characterized by the following data, subject to a deviation of the curvature of individual surfaces and of the thicknesses of up to ±10% of the refractive power of the relevant elements, up to ±0.03 of the refractive indices and up to ±5 of the Abbe numbers:

10

	Radii		d	n _d	v _d
	Vertical plane	Horizontal plane			
r ₁	∞	aspherical	3.0	1.492	54.67
r ₂	∞	23.0	7.386		
r ₃	-55.09		2.0	1.586	34.7
r ₄	43.8		53.286		
r ₅	450		3.6	1.492	54.67
r ₆	- 32.64		0.1		
r ₇	27.5		3.6	1.492	54.67
r ₈	-340.2		1.377		
r ₉	- 66.06		1.0	1.487	70.41
r ₁₀	26.77		2.0		
r ₁₁	∞	∞	1.0	1.517	64.17
r ₁₂	218.21	∞	1.0		

H₂



34

1,531,525

34

	Radii		d	n _d	v _d
	Vertical plane	Horizontal plane			
P	r ₁₃	∞	5.0	1.567	56.13
	r ₁₄	∞	8.67		
	r ₁₅	11.1	3.4	1.744	44.77
	r ₁₆	-37.44	0.75		
	r ₁₇	-17.62	6.25	1.805	25.43
	r ₁₈	9.25	0.95		
	r ₁₉	20.80	3.2	1.744	44.77
	r ₂₀	-12.48			

the aspherical surface defined by the formula:

$$x = \frac{cs^2}{1 + \sqrt{1 - c^2 s^2}} + a_2 s^2 + a_4 s^4 + a_6 s^6$$

in which said formula x is the aspherical surface curvature referred to a reference plane at the relevant distance s from the optical axis and c is the reciprocal value of the radius R, the aforementioned aspherical surface has the following data:

	R	a ₂	a ₄	a ₆
r ₁	90.0	0	6.10 ⁻⁶	0

10. The combination claimed in Claim 2 and characterized by the following data, subject to a deviation of the curvature of individual surfaces and of the thicknesses of up to ±10% of the refractive power of the relevant element, up to ±0.03 of the refractive indices and up to ±5 of the Abbe numbers:

	Radii		d	n _d	v _d
	Vertical plane	Horizontal plane			
Supplementary element	∞	aspherical	2.4	1.492	54.67
	∞	18.6			
toric main lens	∞	∞	1.5	1.517	64.17
	∞	360.2			

the aspherical surface defined by the formula:

$$x = \frac{cs^2}{1 + \sqrt{1 - c^2 s^2}} + a_2 s^2 + a_4 s^4 + a_6 s^6$$

in which said formula x is the aspherical surface curvature referred to a reference plane at the relevant distance s from the optical axis and c is the reciprocal value of the radius R, the aforementioned aspherical surface has the following data:

	R	a ₂	a ₄	a ₆
	71.0	0	9.6.10 ⁻⁶	0

11. The combination claimed in Claim 4, characterized by the following data, subject to a deviation of the curvature of individual surfaces and of the thicknesses of up to ±10% of the refractive power of the relevant element, up to ±0.03 of the refractive indices and up to ±5 of Abbe numbers:



44

	Radii		d	n _d	v _d
	Vertical plane	Horizontal plane			
Supplementary element	∞	aspherical	2.4	1.492	54.67
	∞	18.6			
Toric main lens	∞	∞	1.5	1.517	64.17
	410.1	∞			

the aspherical surface defined by the formula:

$$x = \frac{cs^2}{1 + \sqrt{1 - c^2 s^2}} + a_2 s^2 + a_4 s^4 + a_6 s^6$$

in which said formula x is the aspherical surface curvature referred to a reference plane at the relevant distance s from the optical axis and c is the reciprocal value of the radius R, the aforementioned aspherical surface has the following data:

	R	a ₂	a ₄	a ₆
r ₁	90.0	0	6.10 ⁻⁶	0

12. A camera having a varifocal objective incorporating movable lens means to shift the object plane in front of the camera over macro and normal ranges, a mount for positioning a supplementary lens of negative refractivity in front of the varifocal objective so that the varifocal objective can focus in the macro range on the focal plane of the supplementary lens, and additional marker or mechanical means which are correlated to the mount and which provide the correct setting for the varifocal objective to suit the supplementary lens when it is correctly positioned on the mount.

13. A camera as claimed in Claim 12, in which the additional marker or mechanical means is a special marker on a setting controller for the varifocal objective.

14. A camera as claimed in Claim 13, in which the means is a mechanism which responds to fitting of the supplementary lens to the mount by moving a setting controller for the varifocal objective to the correct setting for use with the supplementary lens.

15. A camera as claimed in Claim 12, in which the means is a marker visible in a range finder of the camera and to which the user can get the varifocal objective.

16. A camera as claimed in any one of Claims 12 to 15, including a stop positionally-controlled by adjustment of the varifocal objective and which acts to prevent a supplementary lens being fitted to the mount unless the varifocal objective is at the correct setting to be used with the supplementary lens.

17. A supplementary lens of negative refractivity for removably fitting in front of a varifocal objective of a camera to provide the combination claimed in Claim 1, such lens containing a lens element having back and front facing surfaces at least one of which is aspherical and is provided with radially inner and outer surface portions co-axially arranged with respect to the optical axis of the lens, the radius of curvature of the inner surface portion being different from the radius of curvature of the outer surface portion.

18. A lens as claimed in Claim 17, in which the lens element front facing surface is aspherical and the radius of curvature of the inner surface portion is larger than the radius of curvature of the outer surface portion.

19. A lens as claimed in Claim 18, in which the lens element has an aspherical back facing surface.

20. A lens as claimed in Claim 18, in which the ratio of the radius (r₁) of a concave back facing surface to the lens element satisfies the following condition:

$$3 < \left| \frac{r_1}{r_2} \right| < 10$$

21. A lens as claimed in Claim 18, constructed in accordance with the data given in any one of the above-mentioned examples numbered 1 to 12 and Example 14 and having a convex front facing surface lens element.

15



22. A lens as claimed in Claim 18 or Claim 19, in which the portion of the lens element adjacent the optical axis satisfies the following condition:

$$f_F \cdot (n_d - 1) > r_{od} < 1.5 h_F$$

where f_F , n_d , r_{od} and h_F have the meanings hereinbefore set forth.

23. A lens as claimed in Claim 22, in which the aspherical front facing surface of the lens element has a deformation Δg of an imaginary spherical surface with a curvature radius corresponding to the vertex curvature radius R_o of the aspherical surface which is defined by the following expression, as measured at the appropriate height h from the optical axis:

$$\Delta g = \frac{h^5}{R_o \cdot (2h_F)^3} \pm 20\%$$

where h_F is the free height of the lens curvature surface which is distal with respect to the object.

24. A lens as claimed in Claim 23, in which the following condition is satisfied:

$$|\Delta g_i| > \Delta g > |\Delta g_a|$$

where g_a refers to the deformation of the aspherical lens curvature surface nearest to the object, g_i refers to the deformation of the aspherical lens curvature surface which is distal with respect to the object and g refers to the sum of the two deformations.

25. A lens as claimed in Claim 24 when dependent on Claim 19, constructed in accordance with the following data subject to a deviation of the curvature of individual surfaces and of the thickness of up to $\pm 10\%$ of the refractive power of the relevant element, up to ± 0.03 of the refractive indices and up to ± 5 of the Abbe numbers:

	d	n_d	v_d	$2h_F$
r_{o1} aspherical	0.125	1.492	54.67	1.513
r_{o2} aspherical				

the aspherical surfaces defined in accordance with the formula:

$$g_A = \frac{c \cdot h^2}{1 + \sqrt{1 - c^2 h^2 (K+1)}} + \sum_{i=2}^n a_{2i} h^{2i}$$

where g_A is the aspherical surface curvature referred to a reference plane at the relevant distance h from the optical axis, c is the reciprocal value of the vertex curvature radius R_o of the aspherical surfaces and K refers to a constant expansion factor, are constructed in accordance with the following data:

	R_o	K	a_4	a_6
r_{o1}	3.039	1.2	$0.35 \cdot 10^{-5}$	
r_{o2}	0.901	-0.25		$0.3 \cdot 10^{-10}$

26. A lens as claimed in Claim 22, in which

$$r_{od} < 0.375 \cdot h_F \cdot f_a \text{ where } 0.5 f_{a-F} < f_d < 0.8 f_{a-F}$$

in which said conditions f_a refers to the focal length of the optical system and f_{a-F} refers to the focal length of the system which is reduced by the negative individual lens element.

27. A lens as claimed in Claim 22, constructed in accordance with the data given in any one of the above-mentioned Examples 15 to 21.

28. A lens as claimed in Claim 17, in which the back facing surface of the lens element is aspherical and the radius of curvature of its inner portion through which the optical axis passes is less than that of the front facing surface in the region where the optical axis passes through it, the ratio A , as defined hereinabove, at a distance M from the optical axis where M is the numerical aperture, satisfying the following equation:



37

1,531,525

37

$$A \leq 1 + \frac{1.7}{M-1}$$

29. A lens as claimed in Claim 28, in which the front facing surface of the lens element is spherical.

5

30. A lens as claimed in Claim 29, having a lens element constructed in accordance with the data set forth in the Example 13 hereinabove.

5

31. A lens as claimed in Claim 29, in which the inner portion of the back surface has a radius of curvature r_{02} satisfying the following equation:

$$f_F \cdot (n_d - 1) > r_{02} < 1.5h_F$$

10

where f_F , n_d and h_F have the meanings hereinabove specified.

32. A lens as claimed in Claim 31, in which the aspherical back facing surface of the lens element has a deformation Δg of an imaginary spherical surface with a curvature radius corresponding to the vertex curvature radius R_0 of the aspherical surface which is defined by the following expression, as measured at the appropriate height h from the optical axis:

10

15

$$\Delta g = \frac{h^4}{R_0 \cdot (2h_F)^3} \pm 20\%$$

15

where h_F is the free height of the lens curvature surface which is distal with respect to the object.

20

33. A lens as claimed in Claim 32, in which the aspherical back facing surface of the lens element satisfies the following equation in which the following condition is satisfied:

20

$$|\Delta g_i| > \Delta g > |\Delta g_a|$$

where Δg_a refers to the deformation of the aspherical lens curvature surface nearest to the object, Δg_i refers to the deformation of the aspherical lens curvature surface which is distal with respect to the object and Δg refers to the sum of the two deformations.

25

34. A lens as claimed in Claim 33, in which the back facing surface of the lens element is defined by the formula:

25

$$g_A = \frac{c \cdot h^2}{1 + \sqrt{1 - c^2 h^2 (K+1)}} + \sum_{i=2}^n a_{2i} h^{2i}$$

30

where g_A is the aspherical surface curvature referred to a reference plane at the relevant distance h from the optical axis, c is the reciprocal value of the vertex curvature radius R_0 of the aspherical surface and K corresponds to a constant deformation factor, the condition for R_0 and h_F , the free height of the curved lens surface distal with respect to the object — measured from the optical axis — is given as:

30

$$R_0 > 0.9 h_F$$

35

35. A lens as claimed in Claim 34, characterized in that the following condition applies if K is the constant deformation factor, R_0 the vertex curvature radius of the aspherical surface and h_F is the free height of the curved surface distal with respect to the object — as measured from the optical axis:

35

$$0 \leq K < -\left(\frac{R_0}{0.9 \cdot h_F}\right)^2$$

40

36. A lens as claimed in Claim 35, wherein the deformation factor K and the coefficients a_4 , a_6 satisfy the following expression:

40

$$\left| \frac{K}{10} + a_4 \cdot 10^4 + a_6 \cdot 10^7 \right| < 0.5$$

45

37. A lens as claimed in Claim 31, constructed in accordance with the data given in any one of the hereinabove numbered Examples 22 to 29.

38. The combination claimed in Claim 1, constructed and arranged to operate substantially as described with reference to any one of the embodiments, or modification thereof, shown in the accompanying drawings.

45

(47)



39. A camera as claimed in Claim 12, arranged and adapted to operate substantially as described with reference to any one of the embodiments, or modifications thereof, shown in the accompanying drawings.

5

40. A supplementary lens as claimed in Claim 17, arranged and adapted to operate substantially as described with reference to any one of the supplementary lens embodiments, or modifications thereof, shown in the accompanying drawings.

MARKS & CLERK,
Agents for the Applicants.

Printed for Her Majesty's Stationery Office by the Courier Press, Leamington Spa, 1978.
Published by the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from
which copies may be obtained.