

IMPROVEMENTS IN OR RELATING TO ZOOM LENSES

This invention relates to zoom lenses.

A lens having an equivalent focal length less than the diagonal of its image plane may be classified as a wide angle lens. Zoom lenses which have a range from wide angle to a long focus or so-called telephoto equivalent focal length (EFL) present different design criteria when considered from the extremes of the EFL's.

A wide angle lens of about 70° field is not difficult to design. Such design generally includes a negative front group and a positive rear group where the back focal length of the lens is greater than the EFL. Such lens is often termed a retrofocus or reverse telephoto lens. An example of an excellent optic of this category is shown in U.S. Patent No. 4,099,849 and is marketed as a Vivitar (Registered Trade Mark) Series I, 28mm f/1.9 lens. On the other hand, lenses having an EFL several times the diagonal of the image frame present other design considerations. Examples of a well corrected telephoto lens are given in U.S. Patent No. 3,942,876, and have been marketed as Vivitar Series I lenses at 135mm f/2.3, and 200mm f/3.0. A comparison of such lens shows completely different design configurations and considerations.

Where the EFL range of a zoom lens is to cross the so-called wide angle definition, a more sophisticated lens design is demanded requiring more lens elements and movements of various lens groups. An example is shown in U.S. Patent No. 3,975,089, and has been marketed as a Vivitar

This is the replacement sheet

Date:

25/6/87

Series I 35-85mm f/2.8 lens.

Few zoom lenses have been designed and marketed having a lower EFL in the wide angle range and having a zoom range of greater than 3:1, and then the actual EFL extremities are subject to a five percent marking tolerance. In such zoom lenses, the spherical aberrations become excessive as the longer EFL is attempted to be increased and/or attempt is made to increase the relative aperture.

Without size and cost constraints, these problems can be overcome by any experienced optical designer. However, there are presently few, if any, commercially acceptable zoom lenses, from the standpoint of compact size, relative aperture, zoom range, and good quality available from a wide angle range with a rated zoom range of three to one or over for the 24 x 36mm image frame format.

However, Ellis I Betensky in U.S. Patent Application Serial No. 070.749 has disclosed a new configuration for a zoom lens which permits a zoom range of almost five to one from a field angle of over seventy degrees. Such lenses comprise a front positive group, a strong negative second group, a third positive group and in some cases, a fourth positive group. Three of these groups may be movable to vary the EFL of the lens.

According to the present invention there is provided a lens of variable equivalent focal length extending from a dimension below the diagonal of the image frame of the lens to a dimension substantially above, the lens having

- a first positive group,
- a second negative group,

This is the replacement sheet

Date: 25/6/87

an aperture defining means,
a third positive group, and
a fourth positive group,
said first positive group being on the object side of said negative group,

said second negative group being on the object side of said aperture defining means,

said third positive group being positioned intermediate said second negative group and said fourth positive group and being close to and in fixed relation to said aperture defining means,

said fourth positive group being on the image side of said aperture defining means,

there being no optical power between said second negative group and said third positive group and between said third and fourth positive groups,

said first and fourth positive groups being movable axially simultaneously in one direction to vary the equivalent focal length of the lens while said second negative group moves axially in an opposite direction, and said aperture defining means and said third positive group remaining stationary during variations of the equivalent focal length of the lens.

The third positive group and the aperture defining means remain stationary as the EFL is varied. The positive optical power at the aperture permits a larger relative aperture by alleviating the limiting factor of spherical aberration at the longer EFL's. The positive component reduces the marginal ray height of the ray bundle at and past

This is the replacement sheet

Date:

25/6/87

the aperture defining means. The optical power of this positive group is related to other parameters of the lens as hereinafter described.

Embodiments of the present invention may provide improvements over and to the foregoing Betensky lens in that they can have a larger aperture for a given physical size of the lens, or alternatively a reduction in physical size for a given relative aperture.

A first embodiment of the invention comprises a first positive group, a second negative group, the aperture defining means followed by a third positive group in fixed relation to the aperture defining means, and a fourth positive group. During variation of focal length, the first and fourth groups move simultaneously in one direction and the second group moves in the opposite direction; for focusing all groups move in fixed relation.

The invention will now be described, by way of example, with reference to the accompanying drawings, in which:-

FIGS. 1 and 1a are schematic side elevations of one lens form embodying the invention; and

FIG. 2 is a schematic side elevation of another embodiment of the invention.

A lens embodying the invention as shown in Figs. 1 and 1a comprises from the object end thirteen elements L1-L13 in four groups G1-G4.

Group G1 comprises negative meniscus L1, a biconvex element L2, a positive meniscus L3, and is of overall positive power.

Group G2 comprises a negative meniscus L4, a biconcave element L5, and a relatively thick positive doublet shown as a biconvex element L6, and a negative element L7. The doublet L6, L7 is convex to the object

This is the replacement sheet

Date:

25/6/87

and has a large radius image side surface which may be convex or concave to the image as shown by the prescriptions, infra.

Group G3, as shown in Fig. 1, comprises a single element L8 very closely spaced to the aperture defining means or iris D. Component L8 is convex to the object and has an image side surface defined on a very large radius R_1 relative to the object side radius R_0 .

Group G4 comprises a biconvex element L9, a relatively thick biconcave element L10, a positive meniscus L11 convex to the image, a biconvex element L12, and a negative meniscus convex to the image.

As will hereinafter be made apparent, the third group bears a certain relationship to other parameters of the lens:

$$.3 > \frac{K_3}{K_G Z_R} > .15$$

where K_3 is the optical power of the group G3

Z_R is the zoom ratio of the lens, and

K_G is the geometric mean power of the lens, and

$$K_G = \sqrt{K_L K_S}$$

where K_L is the power of the lens at the longest equivalent focal length, and

K_S is the power of the lens at the shortest equivalent focal length.

Three examples of the lenses substantially as shown in Figs. 1 and 1a are set forth in Table I-III. In these examples and as shown in Figs. 1 and 1a, groups G1 and G4 move together toward the object as the EFL increases, group G2 moves toward the image and group G3 and the

This is the replacement sheet

Date:

25/6/87

aperture defining means remains stationary with respect to the focal plane FP.

In the following three examples, the prescriptions are for lenses having a 24 x 36mm image frame; an equivalent focal length (EFL) range of 28.6mm to 87.0mm; and relative apertures which vary from $f/2.9$ to $f/3.9$ from the lower EFL to the higher EFL.

In Tables I-III, the lens elements are identified from the object to the image end by L1-L13, the lens element surfaces are S1-S25, the index of refraction is N_D , and the lens element dispersion as measured by the Abbe Number is V_D . The movements of the various groups are shown by the data under the heading Zoom Data for various EFL's. Z1, Z2 and Z3 are the axial spaces between groups as shown on the drawings. FVD is the front vertex distance of the lens, and BFL is the back focal length of the lens. The relative aperture at the various EFL's is given under the heading f/No .

This is the replacement sheet

Date: 25/6/87

Lens	Surface	Surface Radius (mm)	Axial Distance Between Surfaces (mm)	N_d	V_d
L1	S1	878.67			
	S2	53.00	3.00	1.805	25.5
L2			1.80		
	S3	54.94			
	S4	-295.19	8.70	1.786	43.9
L3			0.15		
	S5	49.87			
	S6	100.18	4.30	1.835	43.0
L4			Z1		
	S7	83.91			
	S8	17.34	2.00	1.850	32.2
L5			1.80		
	S9	-116.10			
	S10	33.18	2.00	1.835	43.0
L6			0.20		
	S11	25.25			
	S12	-17.23	11.54	1.728	28.3
L7					
	S13	-826.07	1.50	1.835	43.0
			Z2		
L8	aperture				
			1.00		
	S14	55.92			
L9			2.23	1.667	48.3
	S15	1165.66			
			Z3		
L10	S16	28.44			
	S17	-41.59	4.79	1.613	58.6
			0.79		
L11	S18	-28.11			
	S19	38.61	12.00	1.593	35.5
			2.68		
L12	S20	-145.85			
	S21	-31.12	3.00	1.835	43.0
			0.20		
L13	S22	51.53			
	S23	-23.68	5.97	1.573	42.6
			0.99		
L13	S24	21.43			
			1.60	1.805	25.5
	S25	-993.13			

This is the replacement sheet

Date: 25/6/87

ZOOM DATA

f/No.	EFL	FVD	Z1	Z2	Z3	BFL
2.9	28.6mm	156.4mm	.80mm	15.3mm	14.7mm	43.6
3.2	40.0	161.3	10.4	10.4	10.3	48.5
3.5	55.0	165.0	18.6	6.5	6.0	53.1
3.9	87.0	171.7	29.2	1.0	0.8	58.9

This is the replacement sheet

Date: 25/6/87

Lens	Surface	Surface Radius (mm)	Axial Distance Between Surfaces (mm)	N _d	V _d
L1	S1	649.67			
	S2	57.37	3.00	1.805	25.5
L2	S3	58.75	1.80		
	S4	-237.36	8.70	1.700	47.8
	S5	52.91	0.15		
L3	S6	120.92	4.30	1.834	37.3
	S7	70.22	Z1		
L4	S8	17.07	2.00	1.805	25.5
	S9	-64.49	5.10		
L5	S10	25.54	2.00	1.589	61.3
	S11	22.97	0.50		
L6	S12	-18.35	7.17	1.699	30.1
L7	S13	158.15	1.50	1.804	46.5
	aperture		Z2		
L8	S14	61.35	1.30		
	S15	-697.26	2.23	1.723	38.0
	S16	31.91	Z3		
L9	S17	-40.93	4.79	1.658	57.3
	S18	-28.41	0.60		
L10	S19	40.69	13.30	1.593	35.5
	S20	-65.65	2.84		
L11	S21	-27.15	3.00	1.583	46.5
	S22	50.97	0.20		
L12	S23	-23.28	7.25	1.517	52.2
	S24	-20.86	1.79		
L13	S25	-56.24	1.60	1.847	23.8

This is the replacement sheet

Date: 25/8/87

ZOOM DATA

f/No.	EFL	FVD	Z1	Z2	Z3	BFL
2.9	28.6mm	156.5mm	0.8mm	15.1mm	16.4mm	42.5mm
3.2	40.0	161.8	10.6	10.4	11.3	47.8
3.5	55.0	166.7	19.0	6.7	6.6	52.8
4.0	87.0	173.3	29.8	1.8	0.8	59.3

This is the replacement sheet

Date: 20/6/87

Lens	Surface	Surface Radius (mm)	Axial Distance Between Surfaces (mm)	N_d	V_d
L1	S1	367.16			
	S2	53.15	3.00	1.805	25.5
L2	S3	54.36	1.80		
	S4	-220.65	8.90	1.700	47.8
	S5	46.30	0.15		
L3	S6	83.28	4.00	1.834	37.3
	S7	59.28	Z1		
L4	S8	16.09	2.00	1.805	25.5
	S9	-59.80	5.04		
L5	S10	28.34	2.00	1.609	59.2
	S11	23.44	0.50		
L6	S12	-17.37	8.00	1.699	30.1
L7	S13	110.83	1.50	1.804	46.5
	Aperture		Z2		
L8	S14	63.48	1.30		
	S15	-659.47	2.00	1.834	37.3
L9	S16	32.68	Z3		
	S17	-42.95	4.79	1.661	57.0
	S18	-29.12	0.60		
L10	S19	43.26	12.32	1.593	35.5
	S20	-229.66	3.27		
L11	S21	-29.26	3.90	1.543	46.9
	S22	57.54	0.20		
L12	S23	-24.09	7.65	1.517	52.2
	S24	-21.66	1.54		
L13	S25	-68.41	1.80	1.847	23.8

This is the replacement sheet

Date: 25/6/87

ZOOM DATA

f/No.	EFL	FVD	Z1	Z2	Z3	BFL
2.9	28.6mm	156.3mm	0.84mm	13.30mm	17.20mm	42.3mm
3.2	48.0	161.8	10.32	9.14	11.89	47.8
3.5	55.0	167.0	18.36	5.95	7.03	53.0
4.0	87.0	174.3	28.70	1.78	.86	60.3

This is the replacement sheet

Date: 25/6/87

In the foregoing prescriptions, the front vertex distance (FVD) is calculated from a plane 6.5mm in front of surfaces S1 when the lenses are focused to a magnification of 1:50.

The lenses set forth in Tables I-III are so designed that the first and fourth groups move in the same direction for zooming. For simplicity of mechanical design of the zooming mechanism and to reduce the required size of the front group, the various lens groups move in fixed relation for focusing. Also the groups G1 and G4 move in fixed relation when zooming.

In the foregoing lens examples, the third group is in simplest form, a single element. In the given examples, the object side surface is convex, and on a much larger radius than the image side surface.

$$\left| \frac{R_1}{R_o} \right| > 8$$

where R_1 is the radius of the image side surface and R_o is the radius of the object side surface.

Fig. 2 illustrates another embodiment of the invention where the third group at the aperture defining means is in the form of an air spaced doublet.

The lens embodying the invention shown in Fig. 2 comprises thirteen elements L1-L13 in four groups G1-G4. Group G1 comprises elements L1-L3 in the same positive configurations. Group G2 comprises elements L4-L7 in the same general negative configuration as Fig. 1. Group G3 is a positive doublet L8 and L9 in fixed relation to an aperture defining iris I. Group G4 comprises a positive element L10, a biconvex doublet

This is the replacement sheet

Date:

25/8/87

L11, L12 and a negative meniscus concave to the object. Group G4 is of positive power.

Two examples of the lens shown in Fig. 2 are set forth in Tables IV and V. Both lenses are scaled to an EFL range of 24.5 to 124mm for a 24 x 36mm image frame. In both lenses, the relative aperture varies from f/3.6 at the shorter EFL to f/4.7 at the larger EFL. In both Tables IV and V, group G3 and the iris I remain stationary. Group G1 moves toward the object end as the EFL is increased, group G2 moves toward the image end, and group G4 moves toward the object end. Group G1 moves for focusing.

This is the replacement sheet

Date: 25/8/87

TABLE IV					
Lens	Surface	Surface Radius (mm)	Axial Distance Between Surfaces (mm)	N_d	V_d
L1	S1	169.45			
	S2	56.72	3.00	1.805	25.5
L2			0.41		
	S3	56.53	12.60	1.487	70.4
	S4	-605.21	0.10		
L3	S5	54.35	6.9	1.834	37.3
	S6	151.66	Z1		
L4	S7	95.83	1.50	1.834	37.3
	S8	14.79	7.53		
L5	S9	-65.44	2.00	1.835	63.0
	S10	42.84	0.20		
L6	S11	27.06	15.72	1.741	27.8
	S12	-26.96	1.53	1.773	49.6
L7	S13	-508.18	Z2		
	aperture		2.05		
L8	S14	33.47	1.50	1.847	23.8
	S15	25.18	2.66		
L9	S16	32.36	4.55	1.487	70.4
	S17	-58.18	Z3		
L10	S18	38.94	6.00	1.564	60.8
	S19	1862.11	10.93		
L11	S20	94.60	2.00	1.850	32.2
	S21	22.04	11.50	1.471	67.3
L12	S22	-25.15	1.94		
	S23	-21.83	2.00	1.620	60.3
L13	S24	-47.40			

This is the replacement sheet

Date: 25/6/87

ZOOM DATA

f/No.	EFL	FVD	Z1	Z2	Z3	BFL
3.6	25.5mm	198.8mm	1.000mm	28.636mm	27.353mm	40.0mm
4.0	40.0	198.3	12.482	16.261	13.378	44.6
4.6	85.0	214.1	37.390	5.983	2.061	67.1
4.7	124.0	220.1	47.590	.874	.700	69.3

This is the replacement sheet

Date: 25/6/87

TABLE V

Lens	Surface	Surface Radius (mm)	Axial Distance Between Surfaces (mm)	N_d	V_d
L1	S1	188.72			
	S2	56.11	3.00	1.806	25.5
L2			0.38		
	S3	56.11	12.20	1.487	70.4
	S4	-608.85	0.10		
L3	S5	55.24	6.94	1.834	37.3
	S6	172.29			
L4			Z1		
	S7	99.95	1.50	1.834	37.3
	S8	14.45	6.83		
L5	S9	-63.20	2.00	1.835	43.0
	S10	42.33	0.20		
	S11	26.50	14.48	1.761	26.8
L6	S12	-28.98			
			1.53	1.743	49.2
L7	S13	-699.54			
			Z2		
L8	aperture		2.05		
	S14	33.36	1.50	1.847	23.8
	S15	24.83	2.50		
L9	S16	31.37	4.55	1.762	26.9
	S17	-56.74			
L10			Z3		
	S18	38.07	6.00	1.570	60.1
	S19	1365.55	11.47		
L11	S20	88.72	2.00	1.850	32.2
	S21	21.05	11.50	1.471	67.3
L12	S22	-25.14	1.47		
	S23	-21.79	2.00	1.591	63.0
	S24	-47.99			

This is the replacement sheet

Date:

2576/87

ZOOM DATA

f/No.	EFL	FVD	Z1	Z2	Z3	BFL
3.6	25.5mm	194.6mm	0.800mm	26.957mm	27.515mm	40.1mm
4.0	40.0	194.8	12.491	15.244	13.209	54.7
4.6	85.0	212.2	38.085	5.614	1.817	67.4
4.7	124.0	219.0	48.820	0.874	0.700	69.4

This is the replacement sheet

Date:

25/6/87

In the prescriptions of Tables IV-V, the front vertex distance (FVD) is calculated from a plane 5.00mm in front of surfaces S1. In Table V the lens is focused for a magnification of 1:40 and in Table IV the lens is focused at infinity.

The powers of the groups G1-G4 of the various lenses are set forth in Table VI as K_1 - K_4 respectively together with the geometric mean of the powers K_G of the lens at the EFL extremities, and the zoom ratio Z_R .

TABLE VI

Table

I	.0121	-.0498	.0114	.0224	.020	3.04
II	.0118	-.0512	.0129	.0220	.020	3.04
III	.0121	-.0556	.0145	.0223	.020	3.04
IV	.0103	-.0521	.0156	.0110	.0178	4.86
V	.0137	-.0748	.0177	.0186	.0178	4.86

$$K_G = \sqrt{K_L K_S}$$

where K_L is the power of the lens at its longest EFL and K_S is the power of the lens at its shortest EFL.

It will be noted from the foregoing examples that the power K_3 of group G3 is substantially equal to or greater than the power K_1 of the front group G1. Also K_3 is substantially equal to or less than the geometric mean power K_G of the lens at the extremes of its EFL range.

The power K_3 of group G3 as shown above bears certain relationships to other parameters of the lens:

This is the replacement sheet

Date:

2076/87

$$1.2 > \frac{K_3}{K_G} > .4$$

$$.006 > \frac{K_3}{Z_R} > .003$$

$$.25 > \frac{K_3}{K_G Z_R} > .15$$

The third group G3 may be placed on either side of the iris; however, in most cases to permit movement of the other groups to provide the smallest FVD, it will be very closely spaced to the image side of the iris.

This is the replacement sheet

Date: 25/8/87

CLAIMS

1. A lens of variable equivalent focal length extending from a dimension below the diagonal of the image frame of the lens to a dimension substantially above, the lens having

a first positive group,

a second negative group,

an aperture defining means,

a third positive group, and

a fourth positive group,

said first positive group being on the object side of said negative group,

said second negative group being on the object side of said aperture defining means,

said third positive group being positioned intermediate said second negative group and said fourth positive group and being close to and in fixed relation to said aperture defining means,

said fourth positive group being on the image side of said aperture defining means,

there being no optical power between said second negative group and said third positive group and between said third and fourth positive groups,

said first and fourth positive groups being movable axially simultaneously in one direction to vary the equivalent focal length of the lens while said second negative group moves axially in an opposite direction, and said aperture defining means and said third positive

This is the replacement sheet

Date:

25/1/87



group remaining stationary during variations of the equivalent focal length of the lens.

2. A lens as claimed in claim 1, wherein said first and fourth groups move in fixed relation to vary the equivalent focal length of the lens.

3. A lens as claimed in claim 1, where all of said groups move axially in fixed relation to focus said lens.

4. A lens as claimed in claim 1, wherein said third group comprises a single element and

$$\left| \frac{R_1}{R_0} \right| > 8$$

where the image side surface of said element has a radius R_1 and the object side surface of said element has a radius R_0 .

5. A lens as claimed in claim 1, wherein said third group comprises two elements.

6. A lens as claimed in claim 5, wherein said third group comprises a negative meniscus and a biconvex element.

7. A lens as claimed in claim 1, wherein:

$$0.3 > K_3/K_G Z_R > 0.15$$

where

K_3 is the power of the third group

K_G is the geometric mean of the powers of the lens at the extremes of its focal range, and

Z_R is the zoom ratio of the lens.

8. A lens as claimed in claim 1, wherein:

$$1.3 > K_3/K_G > 0.4$$

where

K_3 is the power of the third group, and

This is the replacement sheet

Date: 25/6/87



K_G is the geometric mean of the powers of the lens at the extremes of its focal length range.

9. A lens as claimed in claim 1, wherein the power of said third group is substantially equal to or greater than the power of said first group.

10. A lens as claimed in claim 1, wherein the power of said third group is substantially equal to or less than the geometric mean power of said lens at the extremes of the range of equivalent focal lengths.

11. A lens as claimed in claim 1, wherein the power of said third group is substantially equal to or greater than the power of said first group and substantially equal to or less than the geometric mean of the powers of the lens at the extremes of its equivalent focal lengths.

12. A lens as claimed in claim 1, wherein:

$$0.006 > K_3/Z_R > 0.003$$

where

K_3 is the power of said third group, and

Z_R is the zoom ratio of the lens.

13. A lens as claimed in claim 1, wherein

$$0.5 < K_1/K_G < 1.0$$

$$2.0 < K_2/K_G < 5.0$$

$$0.4 < K_3/K_G < 1.2$$

$$0.5 < K_4/K_G < 1.3$$

where K_1 , K_2 , K_3 and K_4 are the powers of said first, second, third and fourth groups respectively, and K_G is the geometric mean of the powers of said lens at the extremes of its equivalent focal lengths.

This is the replacement sheet

Date:

25/6/87



14. A lens as claimed in claim 1, for a camera having a 24 x 36 mm image frame wherein:

$$0.015 > K_1 > 0.010$$

$$0.080 > |K_2| > 0.040$$

$$0.019 > K_3 > 0.010$$

$$0.023 > K_4 > 0.010$$

where K_1 , K_2 , K_3 and K_4 are the optical powers of said first, second, third and fourth groups expressed as the reciprocal of the equivalent focal lengths in millimeters of said groups.

This is the replacement sheet

Date:

25/6/87



15. A lens according to claim 1 having an equivalent focal length of 28.5 to 87.0 mm, a 24 x 36 mm image frame, and defined substantially as

follows:

Lens	Surface	Surface Radius (mm)	Axial Distance Between Surfaces (mm)	N _d	V _d
L1	S1	878.67	3.00	1.805	25.5
	S2	53.00			
L2	S3	54.94	1.80	1.786	43.9
	S4	-295.19	8.70		
	S5	49.87	0.15		
L3	S6	100.18	4.30	1.835	43.0
	S7	83.91	Z1		
L4	S8	17.31	2.00	1.850	32.2
	S9	-116.10	4.80		
L5	S10	33.18	2.00	1.835	43.0
	S11	25.25	0.20		
L6	S12	-17.23	11.51	1.728	28.3
	S13	-826.07	1.50		
L8	aperture		Z2	1.667	48.3
	S14	55.92	1.00		
	S15	1165.66	2.23		
L9	S16	28.14	Z3	1.613	58.6
	S17	-41.59	1.79		
	S18	-28.11	0.79		
L10	S19	38.61	12.00	1.593	35.5
	S20	-145.85	2.68		
L11	S21	-31.12	3.00	1.835	43.0
	S22	51.53	0.20		
L12	S23	-23.68	5.97	1.573	42.6
	S24	21.43	0.99		
L13	S25	-993.13	1.60	1.805	25.5

This is the replacement sheet

Date:

25/8/87



* C L H S *

ZOOM DATA

EFL	FVD	Z1	Z2	Z3	BFL
28.6mm	156.4mm	.80mm	15.3mm	14.7mm	43.6
40.0	161.3	10.4	10.4	10.3	48.5
55.0	165.0	18.6	6.5	6.0	53.1
87.0	171.7	29.2	1.0	0.8	58.9

where L1-L13 are lens elements from the object end; S1-S25 are the lens surfaces from the object end with positive radii struck from the image side and negative radii struck from the object side; N_d is the index of refraction of the lens element; V_d is the Abbe number of the lens elements; Z1, Z2 and Z3 are variable during change in equivalent focal lengths EFL is the equivalent focal length; FVD is the front vertex distance; and BFL is the back focal length.

This is the replacement sheet

Date:

25/6/87



* C L M S *

16. A lens according to claim 1 having an equivalent focal length of 28.5 to 87.0 mm, a 24 x 36 mm image frame, and defined substantially as follows:

Lens	Surface	Surface Radius (mm)	Axial Distance Between Surfaces (mm)	N _d	V _d
L1	S1	649.67			
	S2	57.37	3.00	1.805	25.5
L2	S3	58.75	1.80		
	S4	-237.36	8.70	1.700	47.8
	S5	52.91	0.15		
L3	S6	120.92	4.30	1.834	37.3
	S7	70.22	Z1		
L4	S8	17.07	2.00	1.805	25.5
	S9	-64.49	5.10		
L5	S10	25.54	2.00	1.589	61.3
	S11	22.97	0.50		
L6	S12	-18.35	7.17	1.699	30.1
	S13	158.15	1.50	1.804	46.5
L8	aperture		Z2		
	S14	61.35	1.30		
	S15	-697.26	2.23	1.723	38.0
L9	S16	31.91	Z3		
	S17	-40.93	4.79	1.658	57.3
	S18	-28.41	0.60		
L10	S19	40.69	13.30	1.593	35.5
	S20	-65.65	2.84		
L11	S21	-27.15	3.00	1.583	46.5
	S22	50.97	0.20		
L12	S23	-23.28	7.25	1.517	52.2
	S24	-20.86	1.79		
L13	S25	-56.24	1.60	1.847	23.8

This is the replacement sheet

Date: 25/6/87



ZOOM DATA

EFL	FVD	Z1	Z2	Z3	BFL
28.6mm	156.5mm	0.8mm	15.1mm	16.4mm	42.5mm
40.0	161.8	10.6	10.4	11.3	47.8
55.0	166.7	19.0	6.7	6.6	52.8
87.0	173.3	29.8	1.8	0.8	59.3

where L1-L13 are lens elements from the object end; S1-S25 are the lens surfaces from the object end with positive radii struck from the image side and negative radii struck from the object side; N_d is the index of refraction of the lens elements; V_d is the Abbe number of the lens elements; Z1, Z2 and Z3 are variable during change in equivalent focal length; EFL is the equivalent focal length; FVD is the front vertex distance; and BFL is the back focal length.

This is the replacement sheet

Date:

25/6/87



17. A lens according to claim 1, having an equivalent focal length of 28.5 to 87.0 mm, a 24 x 36 mm image frame, and defined substantially as follows:

Lens	Surface	Surface Radius (mm)	Axial Distance Between Surfaces (mm)	N _d	V _d
L1	S1	367.16			
	S2	53.15	3.00	1.805	25.5
L2	S3	54.36	1.80		
	S4	-220.65	8.90	1.700	47.8
	S5	46.30	0.15		
L3	S6	83.28	4.00	1.834	37.3
	S7	59.28	Z1		
L4	S8	16.09	2.00	1.805	25.5
	S9	-59.80	5.04		
L5	S10	28.34	2.00	1.609	59.2
	S11	23.44	0.50		
L6	S12	-17.37	8.00	1.699	30.1
L7	S13	110.83	1.50	1.804	46.5
	Aperture		Z2		
L8	S14	63.48	1.30		
	S15	-659.47	2.00	1.834	37.3
	S16	32.68	Z3		
L9	S17	-42.95	4.79	1.661	57.0
	S18	-29.12	0.60		
L10	S19	43.26	12.32	1.593	35.5
	S20	-229.66	3.27		
L11	S21	-29.26	3.80	1.543	46.9
	S22	57.54	0.20		
L12	S23	-24.09	7.65	1.517	52.2
	S24	-21.66	1.54		
L13	S25	-68.41	1.80	1.847	23.8

This is the replacement sheet

Date:

25/6/87



* C L M S *

ZOOM DATA

EFL	FVD	Z1	Z2	Z3	BFL
28.6mm	156.3mm	0.84mm	13.30mm	17.20mm	42.3mm
48.0	161.8	10.32	9.14	11.89	47.8
55.0	167.0	18.36	5.95	7.03	53.0
87.0	174.3	28.70	1.78	.86	60.3

where L1-L13 are lens elements from the object end; S1-S25 are the lens surfaces from the object end with positive radii struck from the image side and negative radii struck from the image side; N_d is the index of refraction of the lens elements; Z1, Z2 and Z3 are variable during change in equivalent focal length; EFL is the equivalent focal length; FVD is the front vertex distance; and BFL is the back focal length.

This is the replacement sheet

Date: 25/8/87



18. A lens according to claim 1, having an equivalent focal length of 25.5 to 124.0 mm, a 24 x 36 mm image frame, and defined substantially as follows:

Lens	Surface	Surface Radius (mm)	Axial Distance Between Surfaces (mm)	N _d	V _d
L1	S1	169.45			
	S2	56.72	3.00	1.805	25.5
L2	S3	56.53	0.41		
	S4	-605.21	12.60	1.487	70.4
	S5	54.35	0.10		
L3	S6	151.66	6.9	1.834	37.3
	S7	95.83	Z1		
L4	S8	14.79	1.50	1.834	37.3
	S9	-65.44	7.53		
L5	S10	42.84	2.00	1.835	63.0
	S11	27.06	0.20		
L6	S12	-26.96	15.72	1.741	27.8
	S13	-508.18	1.53	1.773	49.6
L8	aperture		Z2		
	S14	33.47	2.05		
	S15	25.18	1.50	1.847	23.8
L9	S16	32.36	2.66		
	S17	-58.18	4.55	1.487	70.4
	S18	38.94	Z3		
L10	S19	1862.11	6.00	1.564	60.8
	S20	94.60	10.93		
L11	S21	22.04	2.00	1.850	32.2
L12	S22	-25.15	11.50	1.471	67.3
	S23	-21.83	1.94		
L13	S24	-47.40	2.00	1.620	60.3

This is the replacement sheet

Date:

25/8/87



ZOOM DATA

EFL	FVD	Z1	Z2	Z3	BFL
25.5mm	198.8mm	1.000mm	28.636mm	27.353mm	40.0mm
40.0	198.3	12.482	16.261	13.378	44.6
85.0	214.1	37.390	5.983	2.061	67.1
124.0	220.1	47.590	.874	.700	69.3

where L1-L13 are lens elements from the object end; S1-S24 are the lens surfaces from the object end with positive radii struck from the image side and negative radii struck from the object side; N_d is the index of refraction of the lens elements; V_d is the Abbe number of the lens elements; Z1, Z2 and Z3 are variable during change in equivalent focal length; EFL is the equivalent focal length; FVD is the front vertex distance; and BFL is the back focal length.

This is the replacement sheet

Date:

25/6/87



19. A lens according to claim 1, having an equivalent focal length of 25.5 to 124.0 mm, a 24 x 36 mm image frame, and defined substantially as follows:

Lens	Surface	Surface Radius (mm)	Axial Distance Between Surfaces (mm)	N _d	V _d
L1	S1	188.72			
	S2	56.11	3.00	1.806	25.5
L2			0.38		
	S3	56.11			
	S4	-608.85	12.20	1.487	70.4
L3			0.10		
	S5	55.24			
	S6	172.29	6.94	1.834	37.3
L4			Z1		
	S7	99.95	1.50	1.834	37.3
	S8	14.45	6.83		
L5					
	S9	-63.20	2.00	1.835	43.0
	S10	42.33	0.20		
L6	S11	26.50			
	S12	-28.98	14.48	1.761	26.8
L7			1.53	1.743	49.2
	S13	-699.54			
	aperture		Z2		
			2.05		
L8	S14	33.36			
	S15	24.83	1.50	1.847	23.8
L9			2.50		
	S16	31.37			
	S17	-56.74	4.55	1.762	26.9
L10			Z3		
	S18	38.07			
	S19	1365.55	6.00	1.570	60.1
L11			11.47		
	S20	88.72	2.00	1.850	32.2
L12	S21	21.05			
	S22	-25.14	11.50	1.471	67.3
L13			1.47		
	S23	-21.79			
	S24	-47.99	2.00	1.591	63.0

This is the replacement sheet

Date:

25/8/87



ZOOM DATA

EFL	FVD	Z1	Z2	Z3	BFL
25.5mm	194.6mm	0.800mm	26.957mm	27.515mm	40.1mm
40.0	194.8	12.491	15.244	13.209	54.7
85.0	212.2	38.085	5.614	1.817	67.4
124.0	219.0	48.820	0.874	0.700	69.4

where L1-L13 are lens elements from the object end; S1-S24 are the lens surfaces from the object end with positive radii struck from the image side and negative radii struck from the object side; N_d is the index of refraction of the lens elements; V_d is the Abbe number of the lens elements; Z1, Z2 and Z3 are variable during change in equivalent focal length; EFL is the equivalent focal length; FVD is the front vertex distance; and BFL is the back focal length.

20. A lens of variable equivalent focal length constructed, arranged and adapted to operate substantially as hereinbefore described with reference to, and as illustrated in, the accompanying drawings.

This is the replacement sheet

Date:

20/1/87



* C L M S *