

[54] LARGE APERTURE EXTENDED RANGE ZOOM LENS
[75] Inventor: Andor A. Fleischman, Northbrook, Ill.
[73] Assignee: Bell & Howell Company, Chicago, Ill.
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[22] Filed: Jan. 23, 1978

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[51] Int. Cl.² G02B 15/18

[52] U.S. Cl. 350/423
[58] Field of Search 350/184-187
[56] References Cited
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Primary Examiner—Conrad J. Clark
Attorney, Agent, or Firm—Harold V. Stotland; Roger M. Fitz-Gerald
[57] ABSTRACT
Disclosed is an optical design for a variable focal length lens of large effective aperture which is focusable over an extended range including the “macro” range and is provided with a high degree of correction.
5 Claims, 33 Drawing Figures

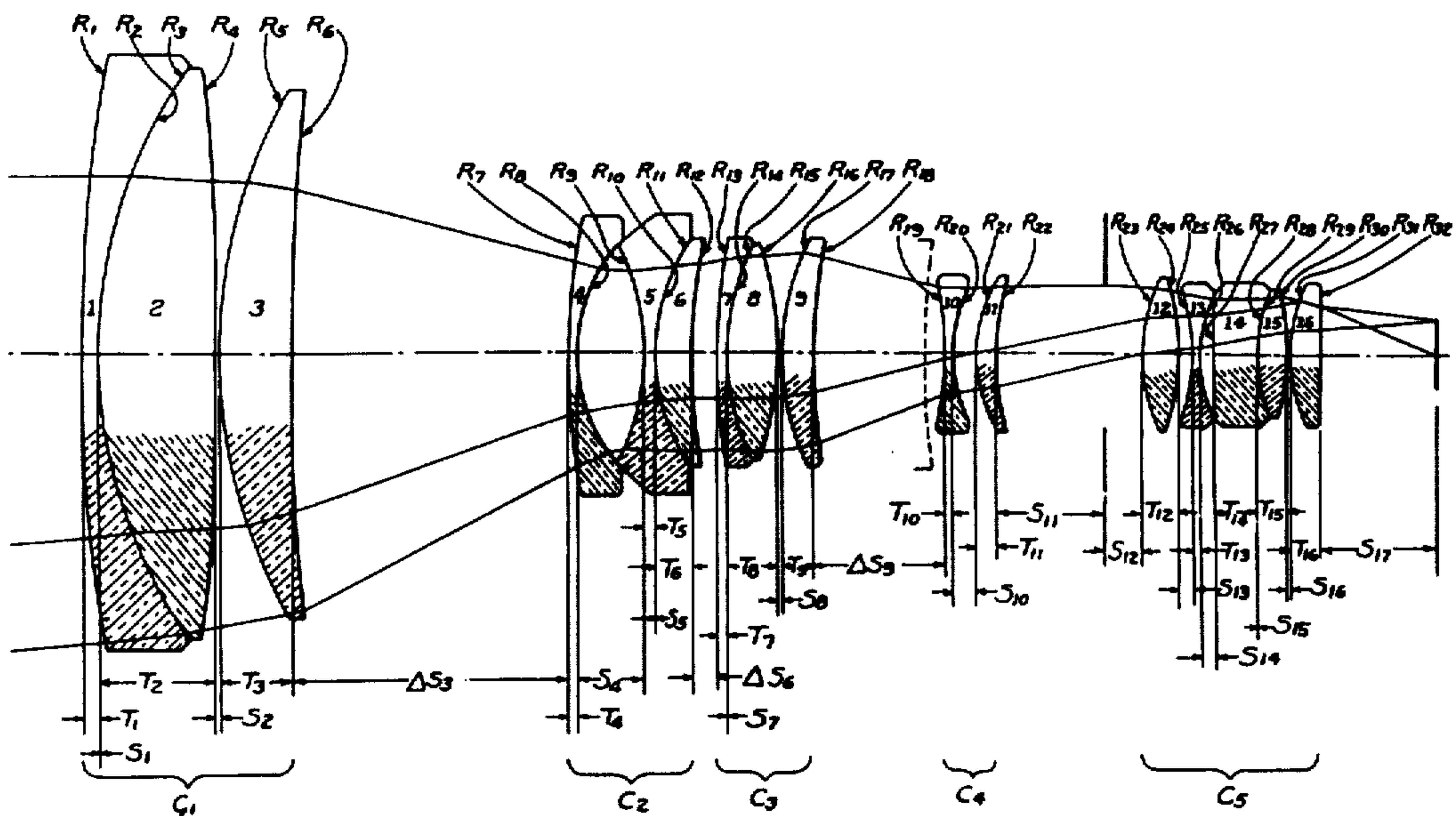
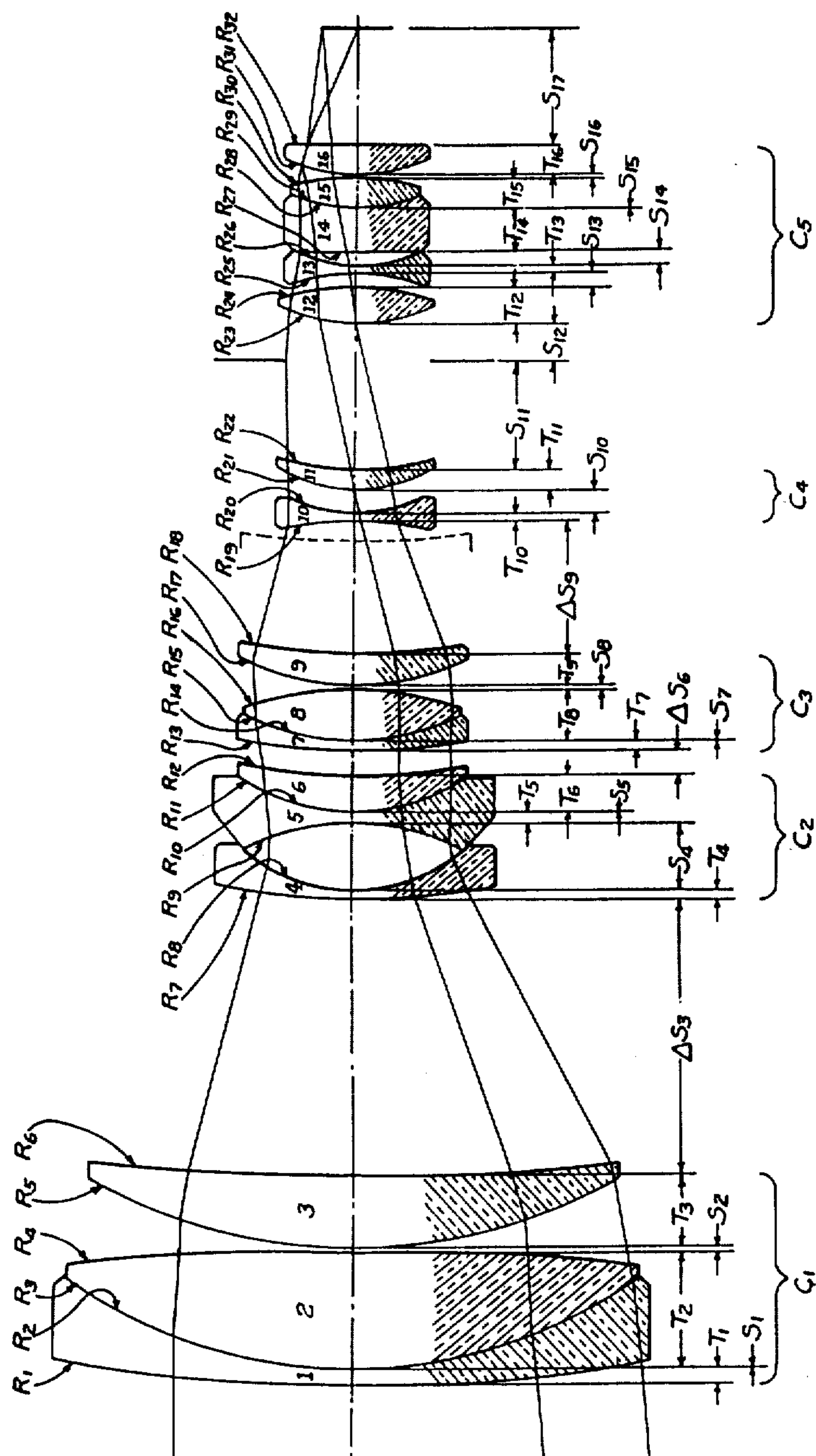


Fig. 1.



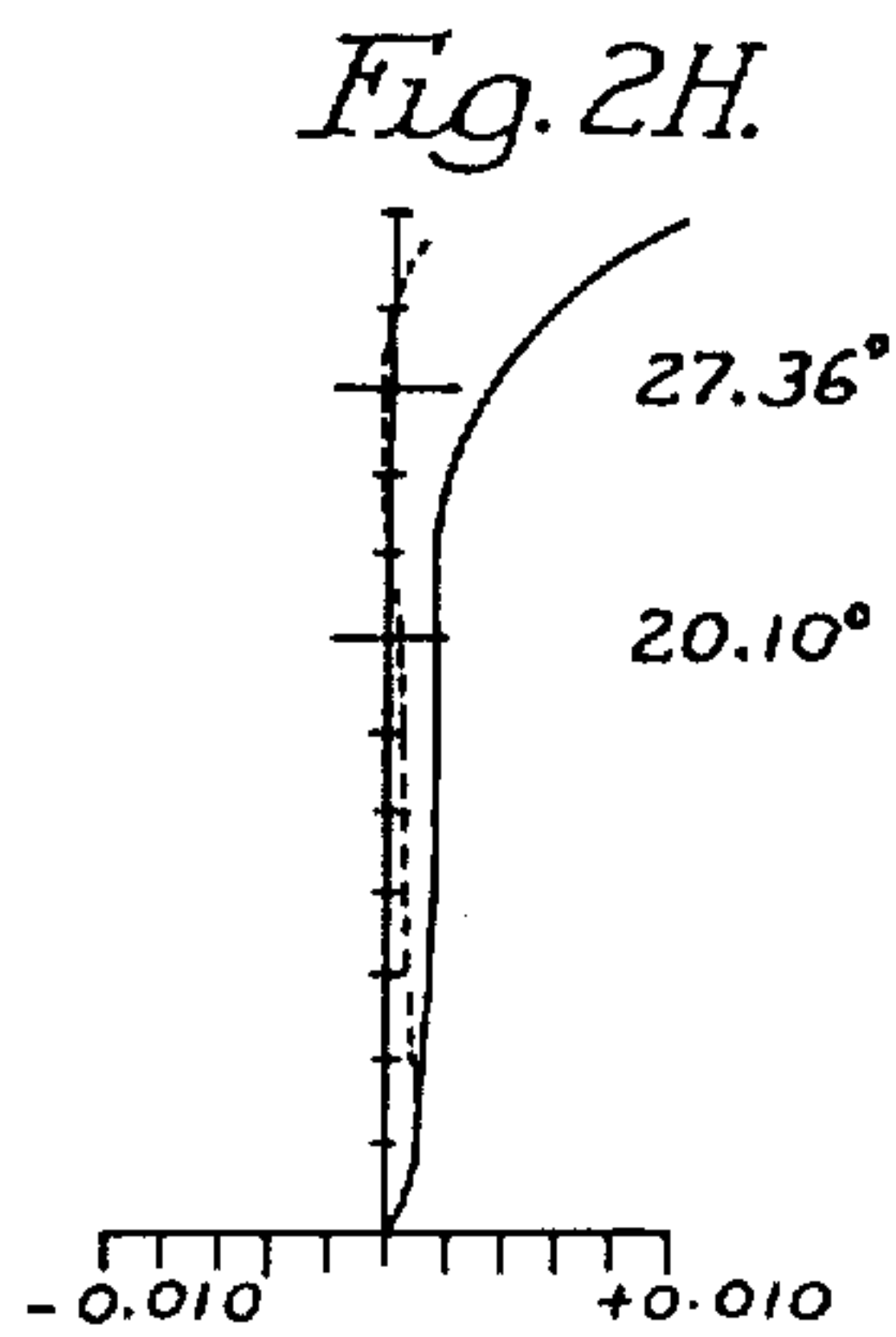
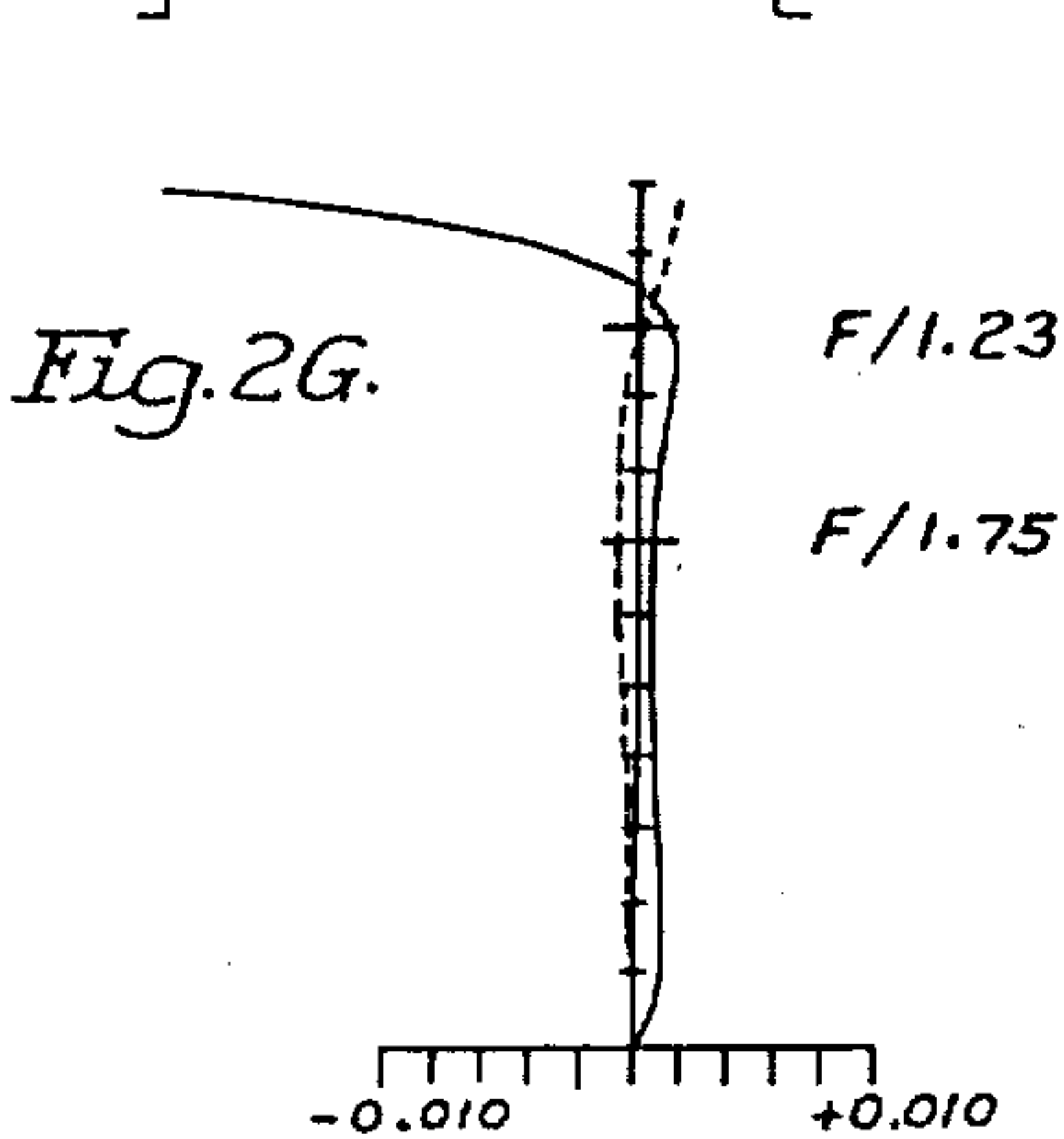
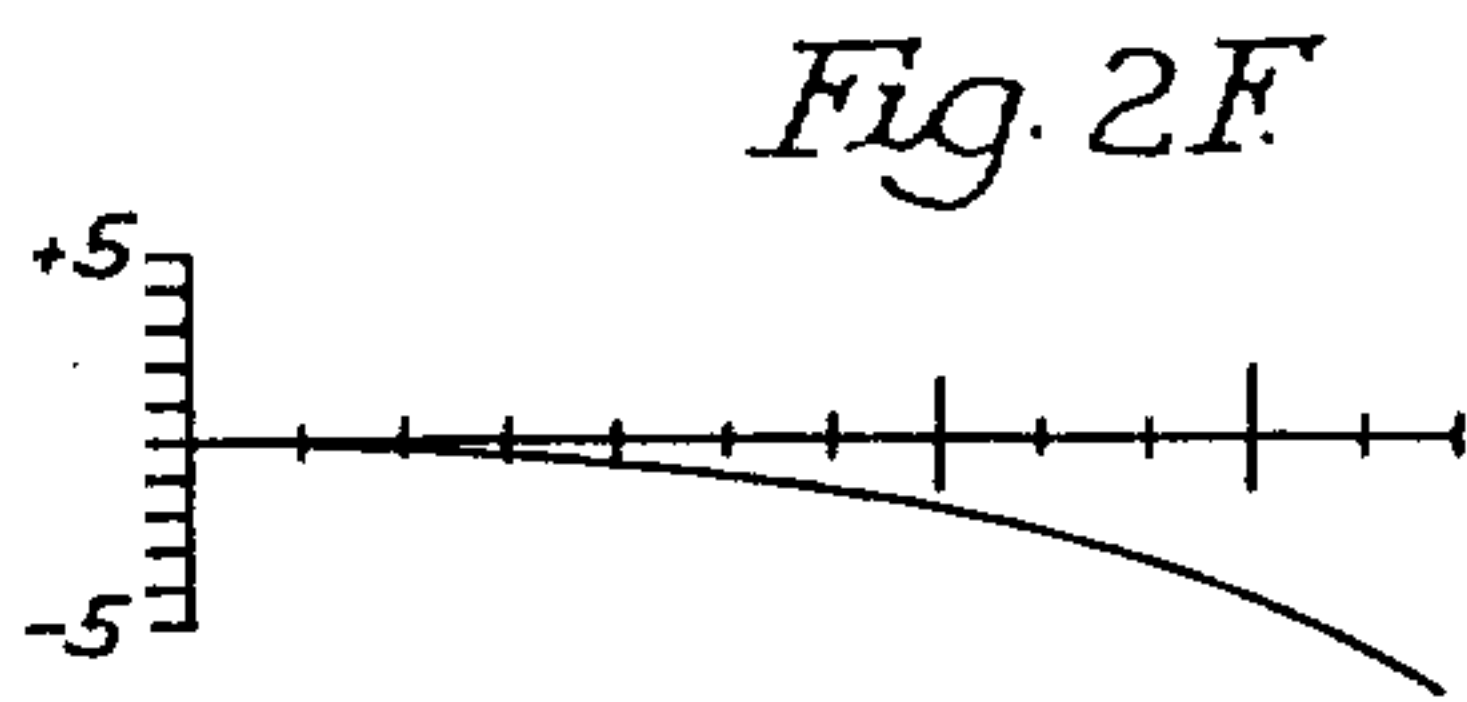
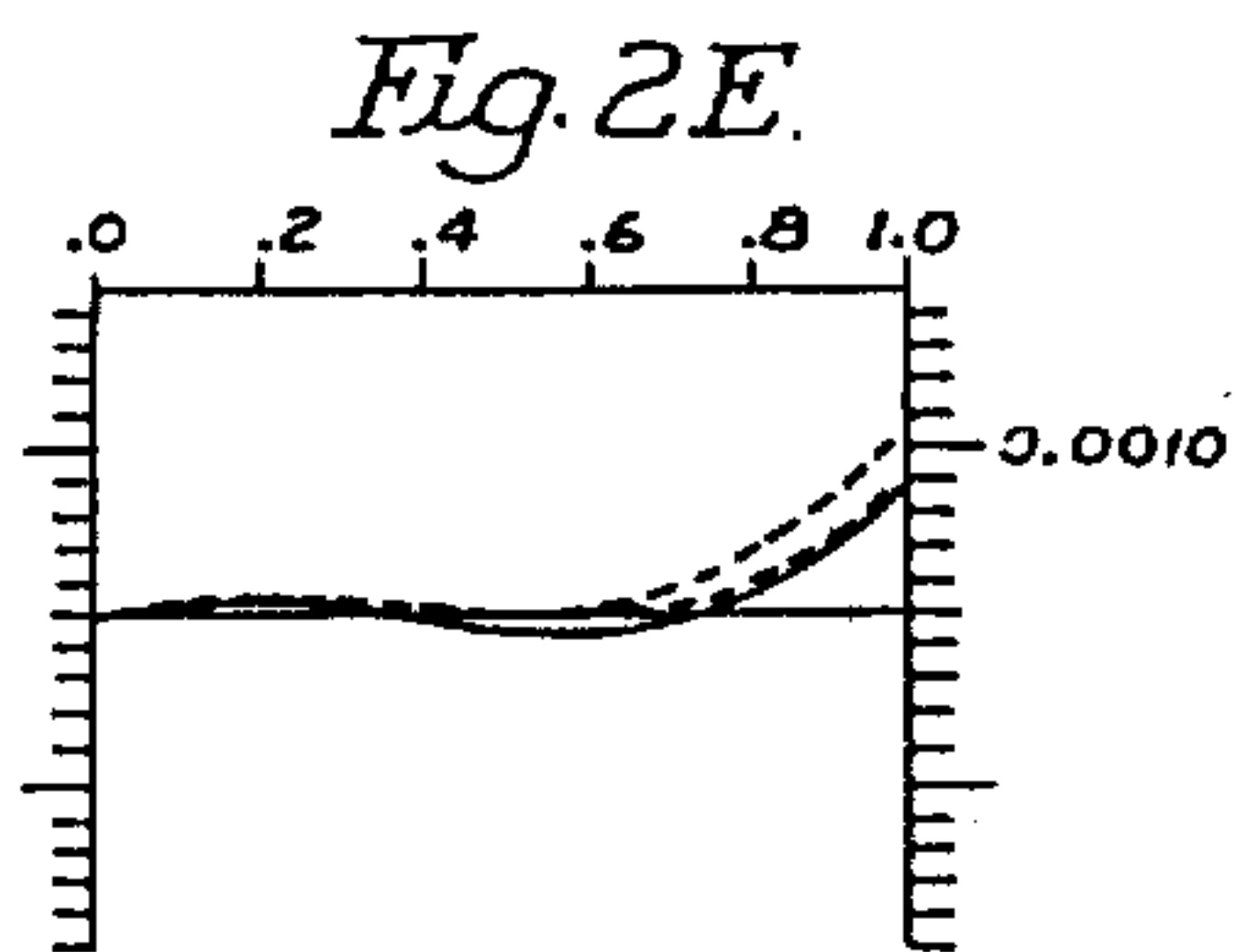
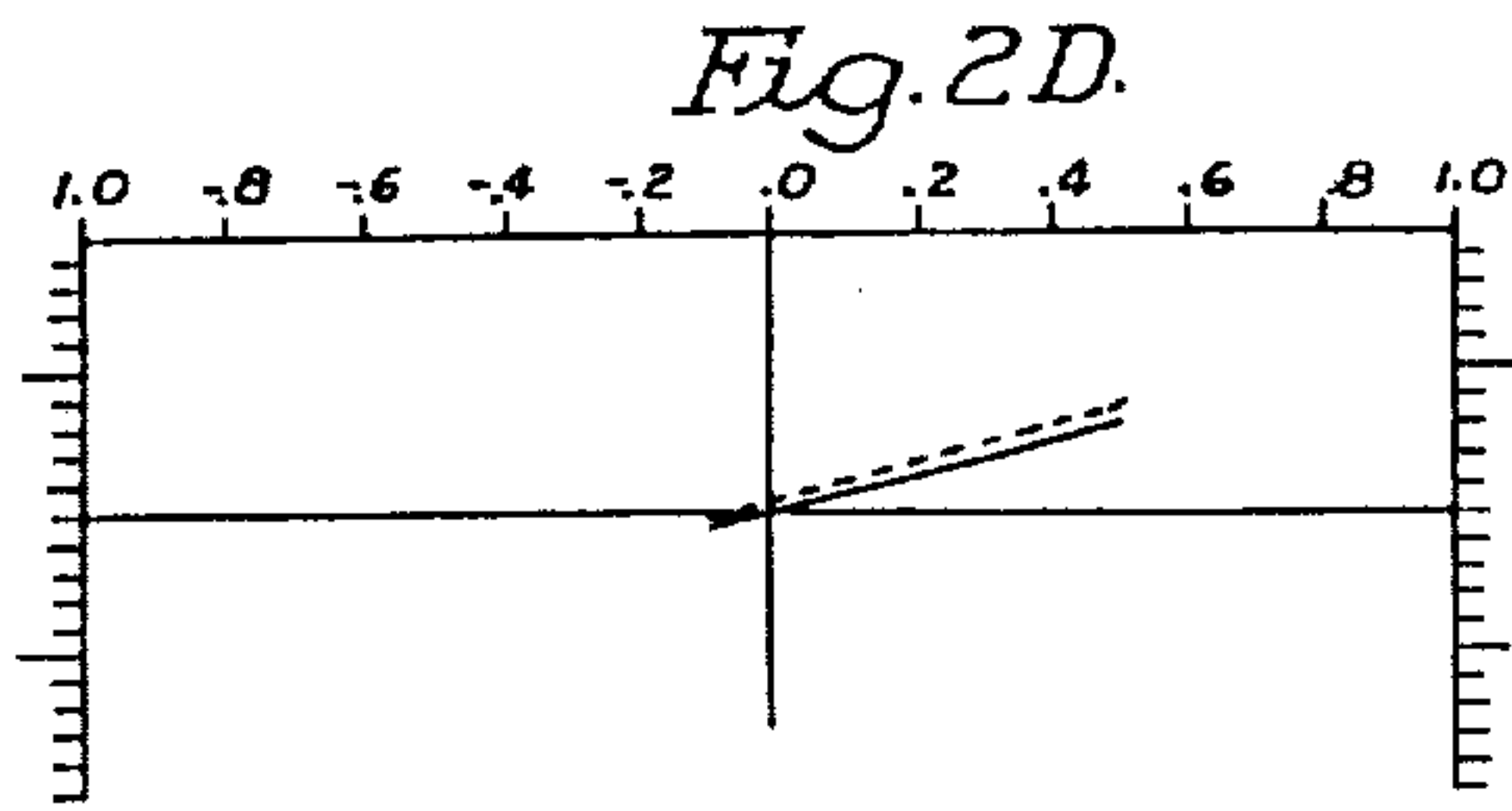
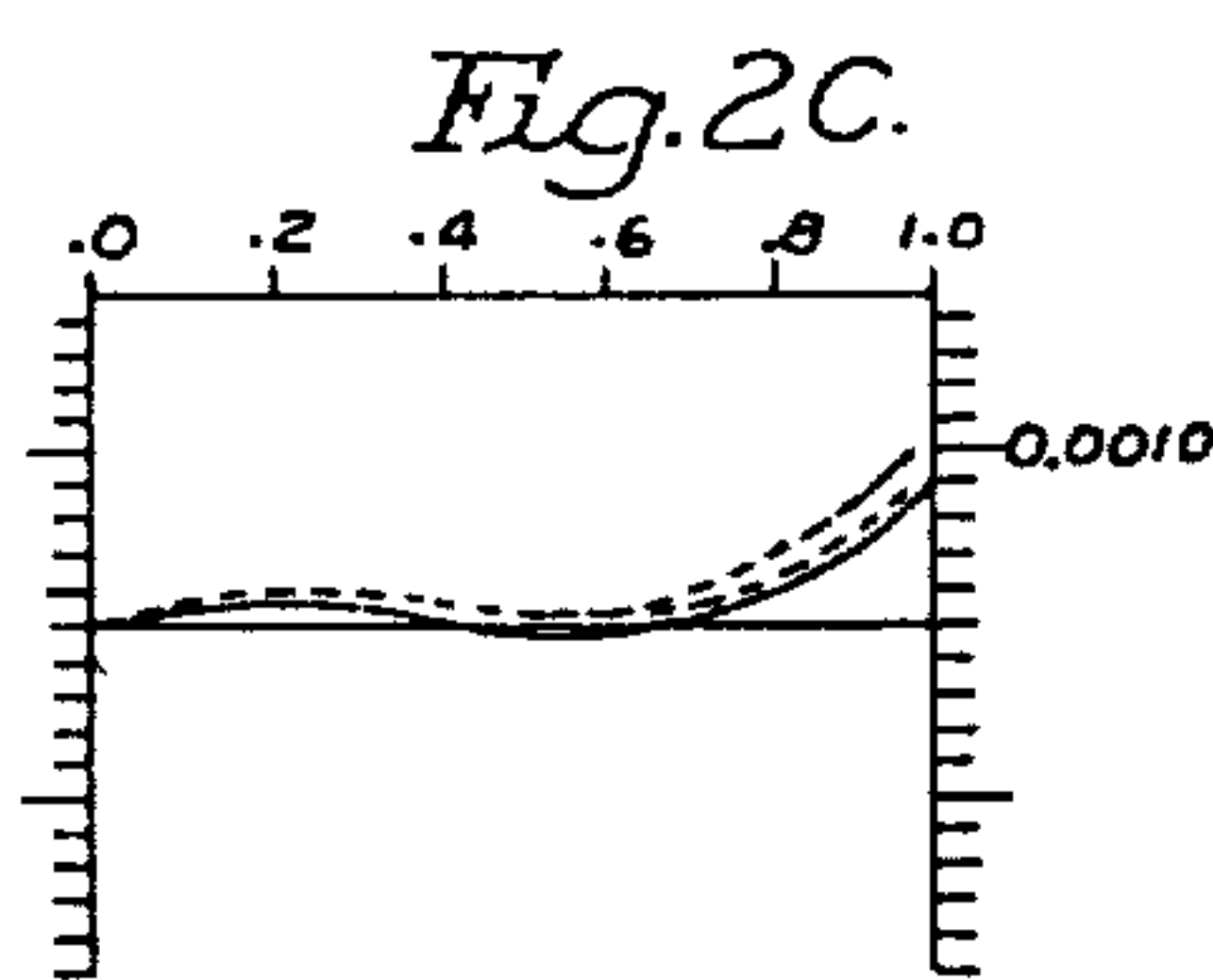
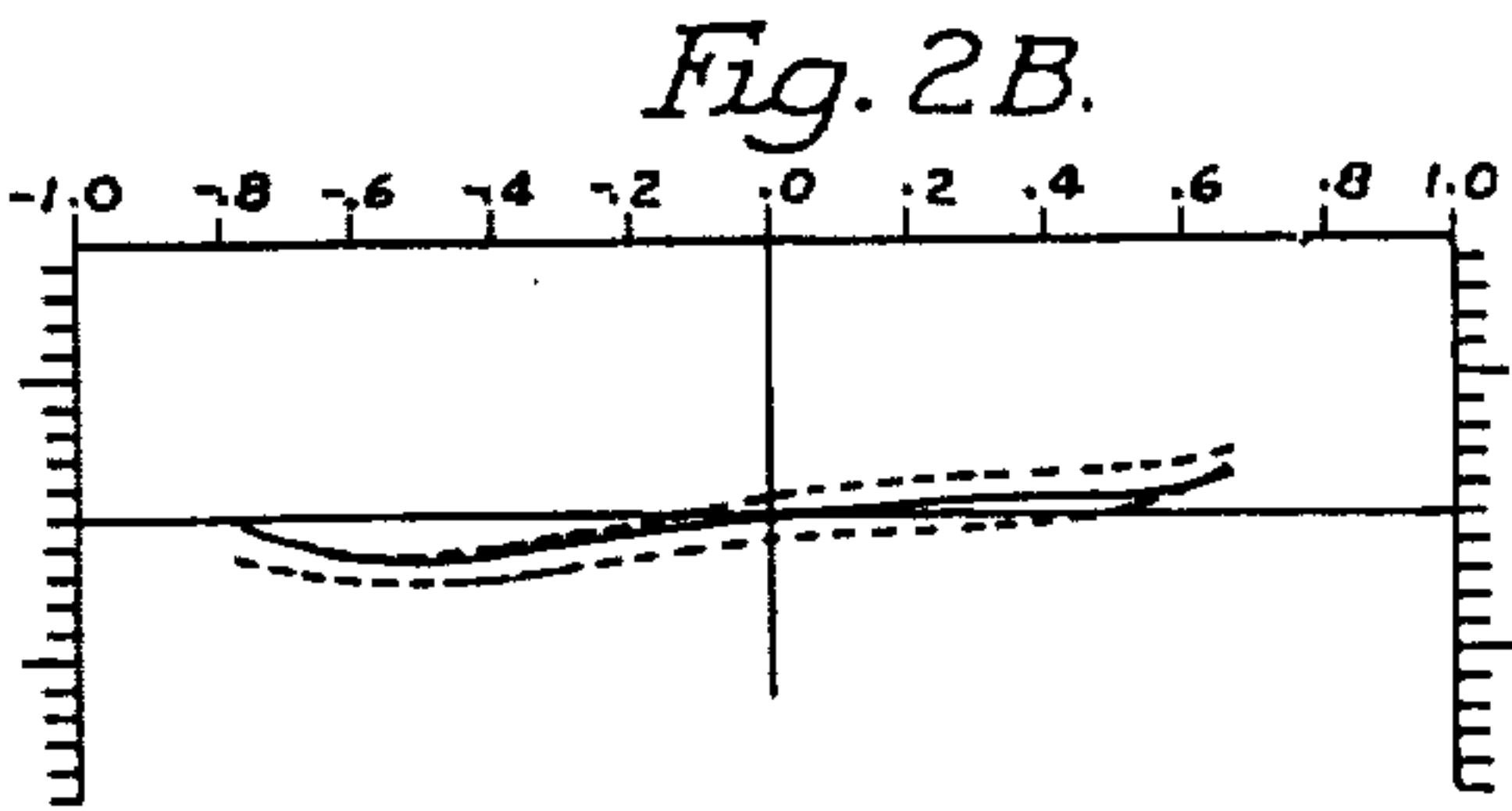
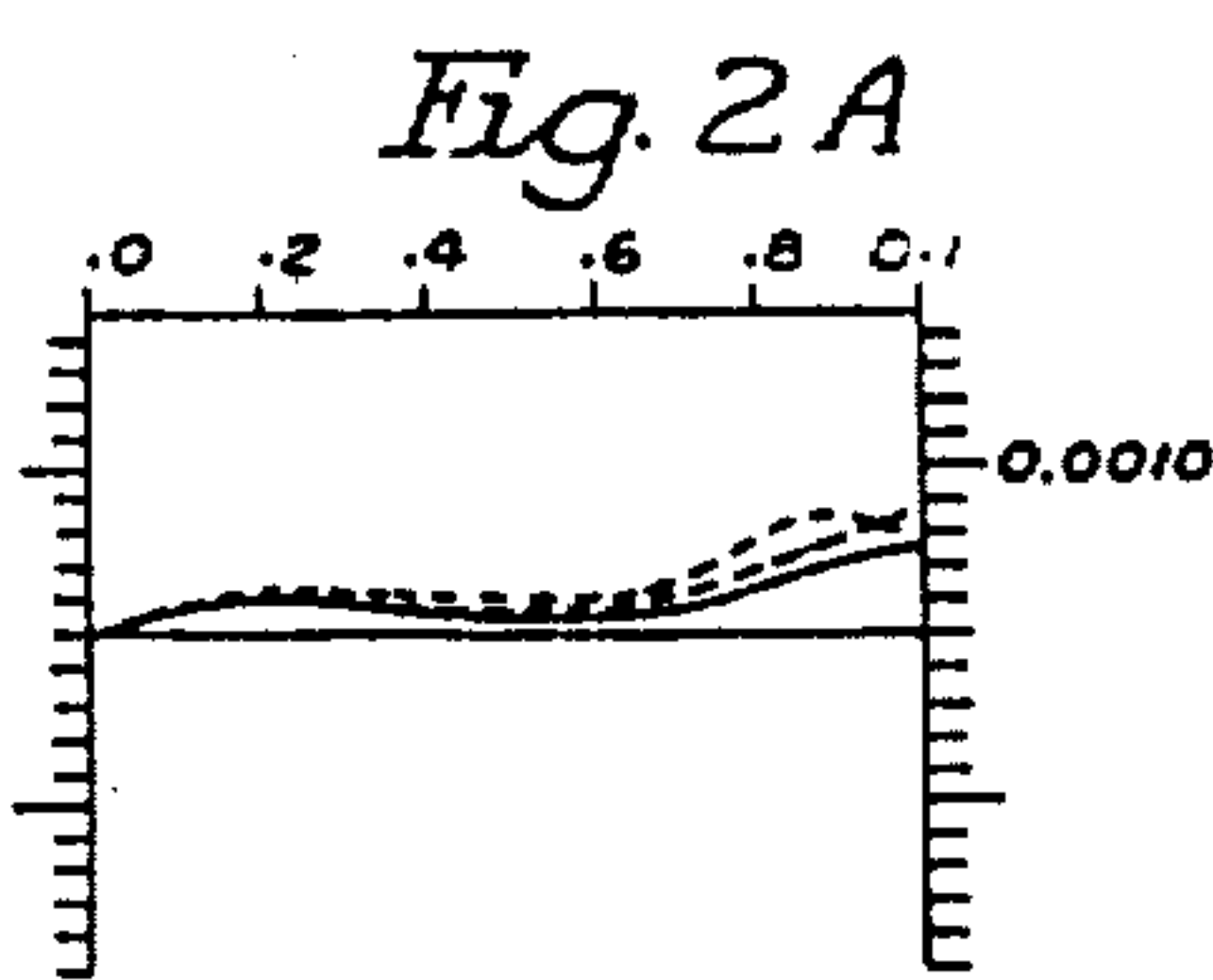


Fig. 3A.

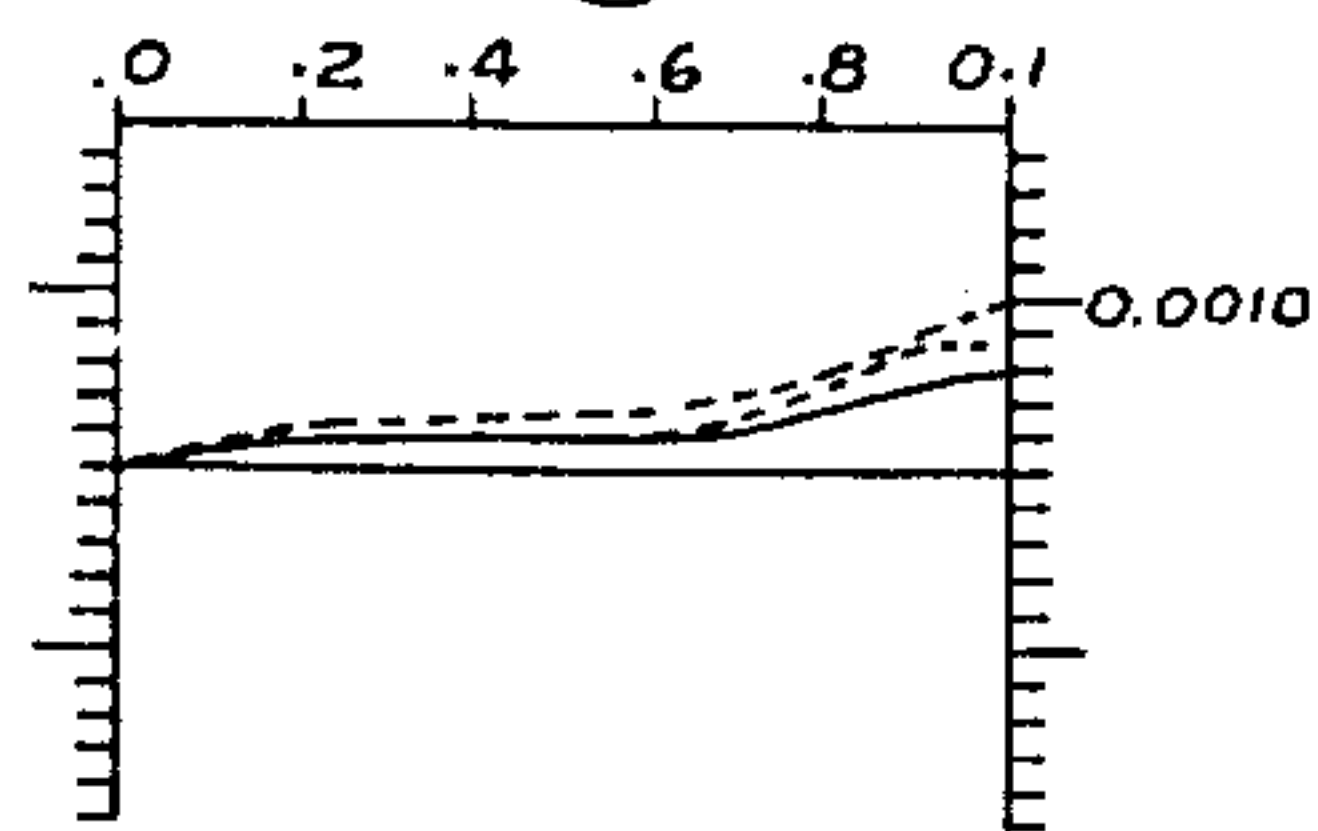


Fig. 3B.

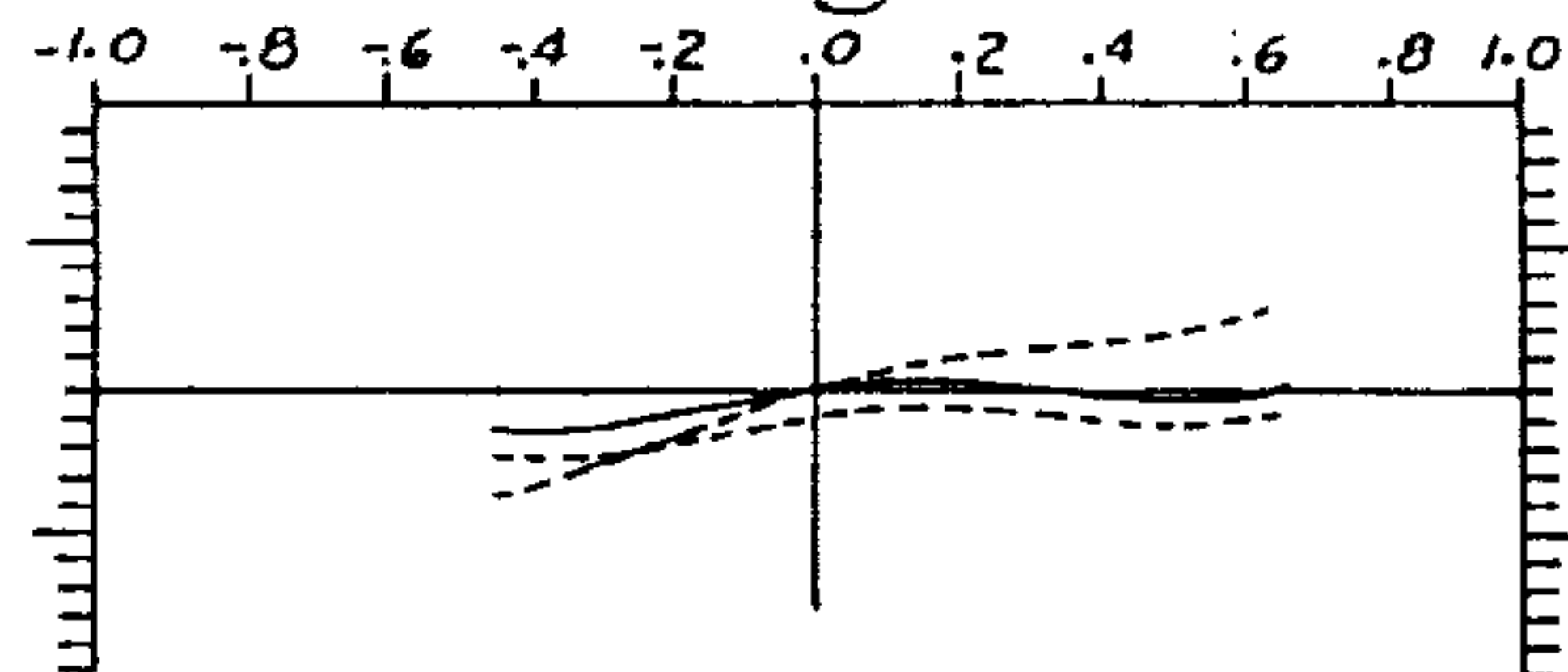


Fig. 3C.

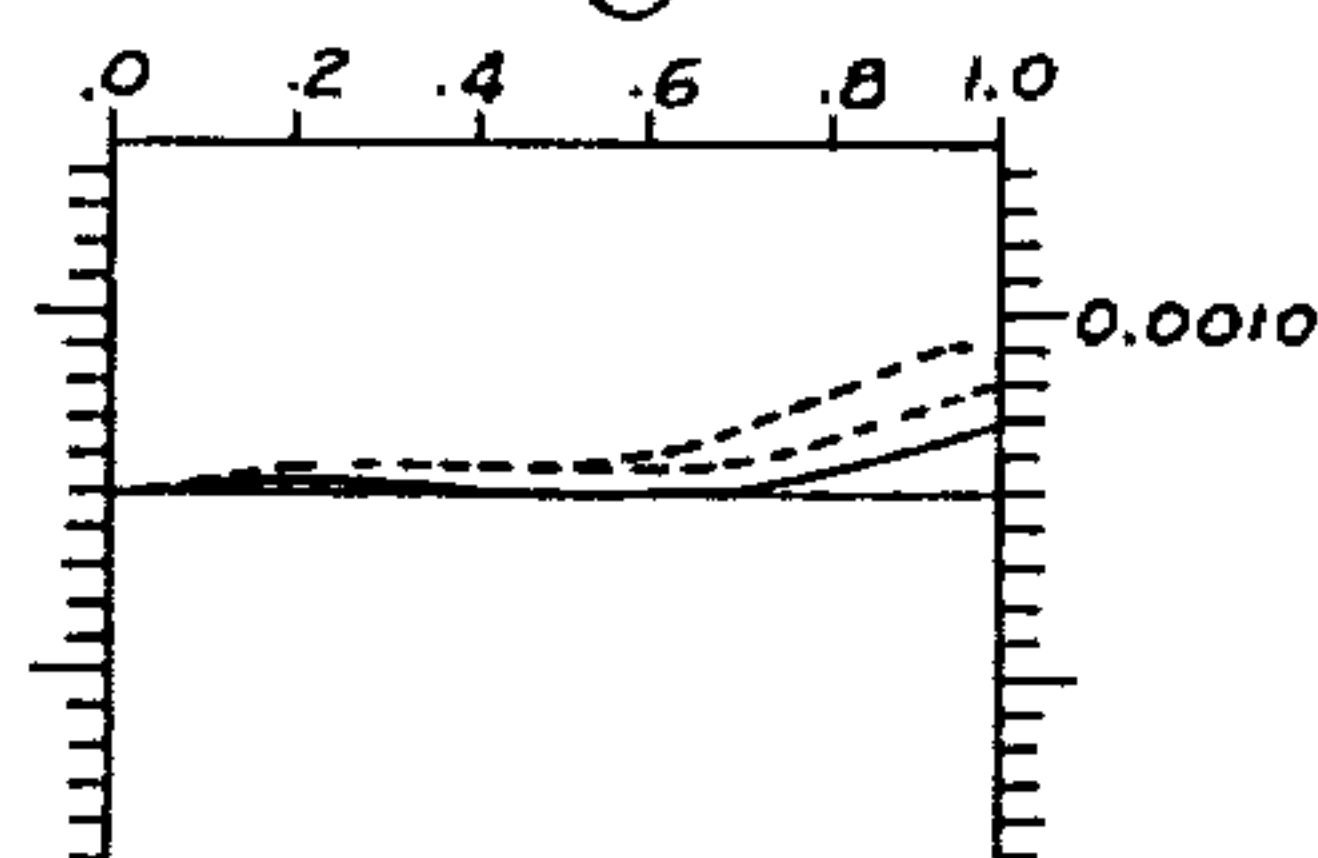


Fig. 3D.

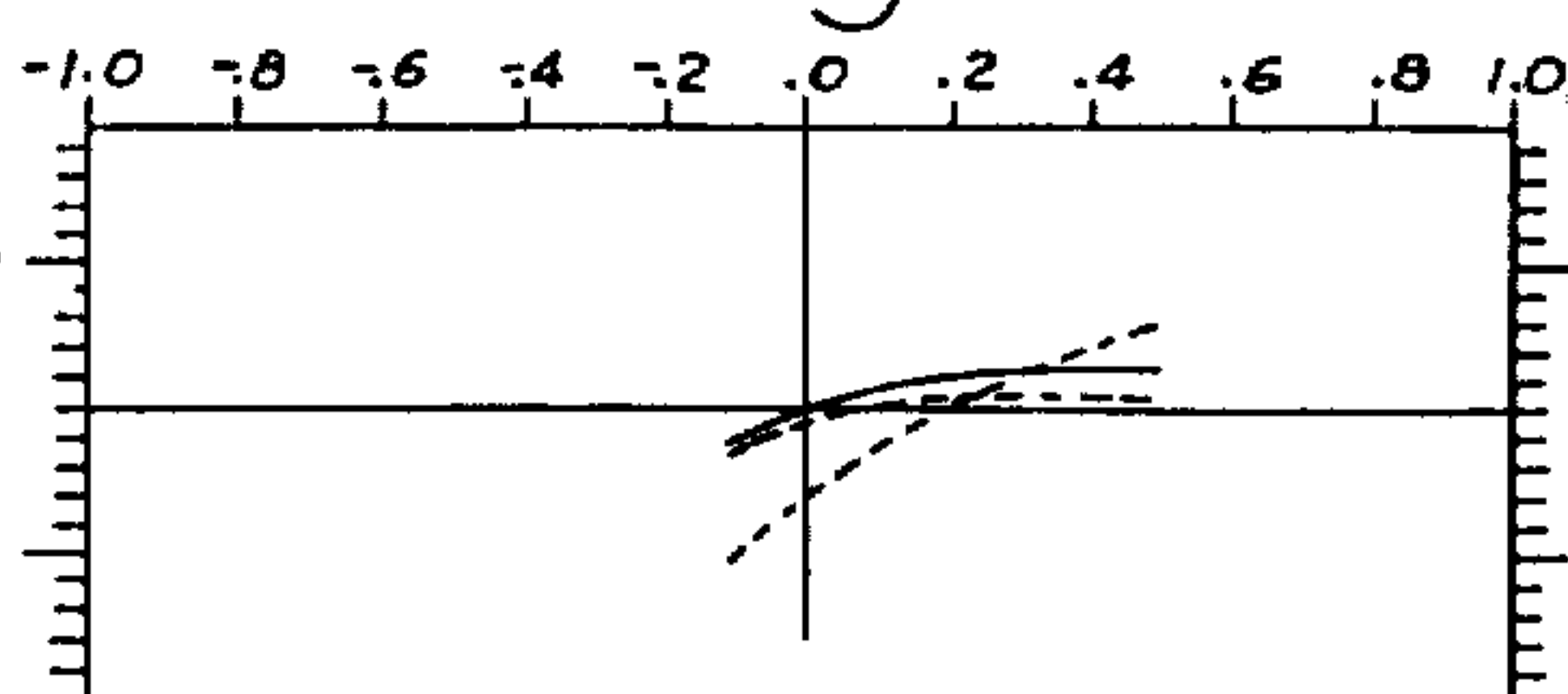


Fig. 3E.

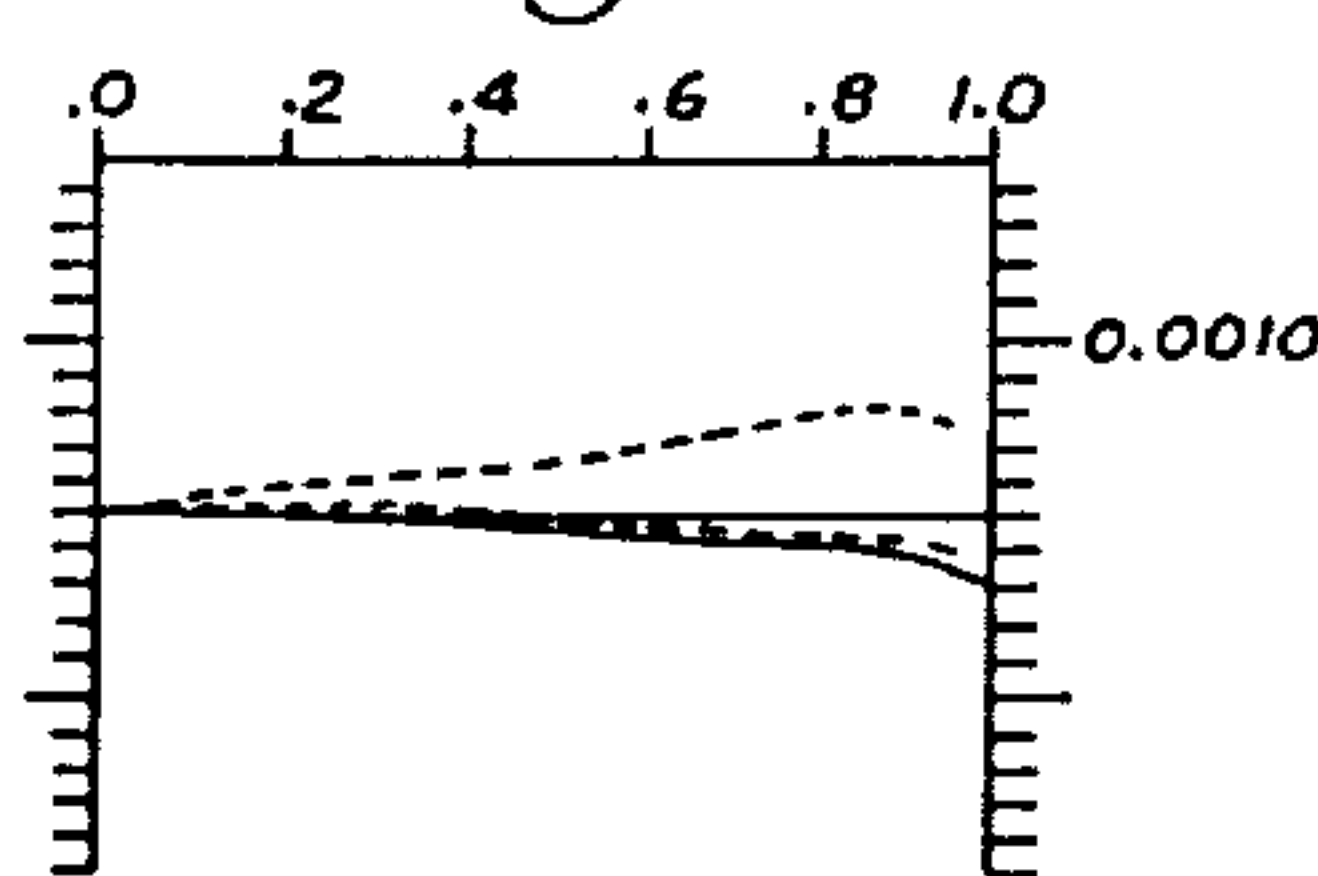


Fig. 3F.

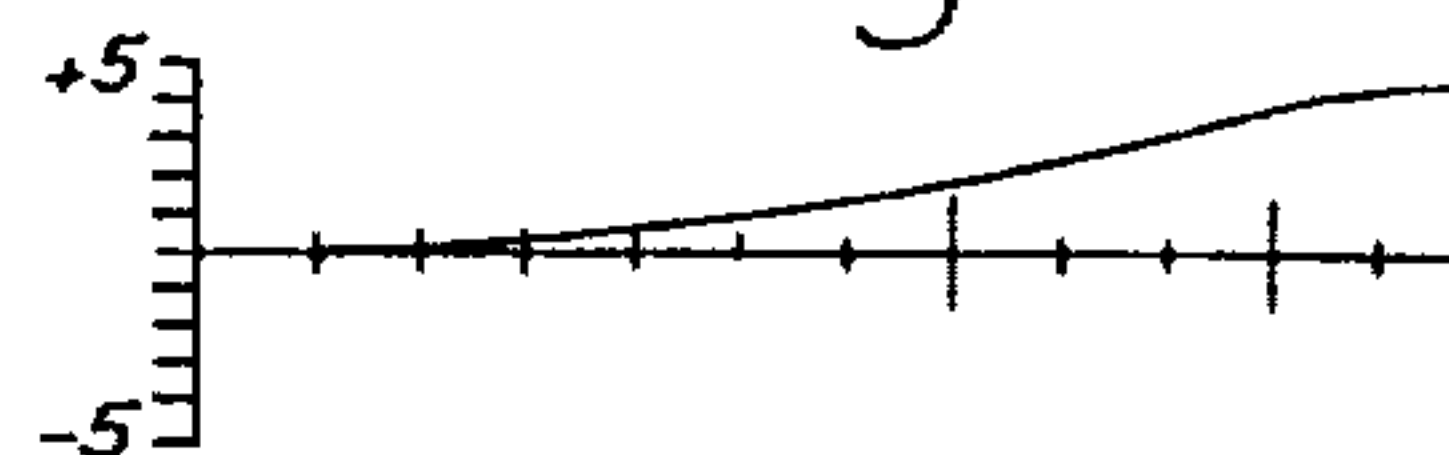


Fig. 3G.

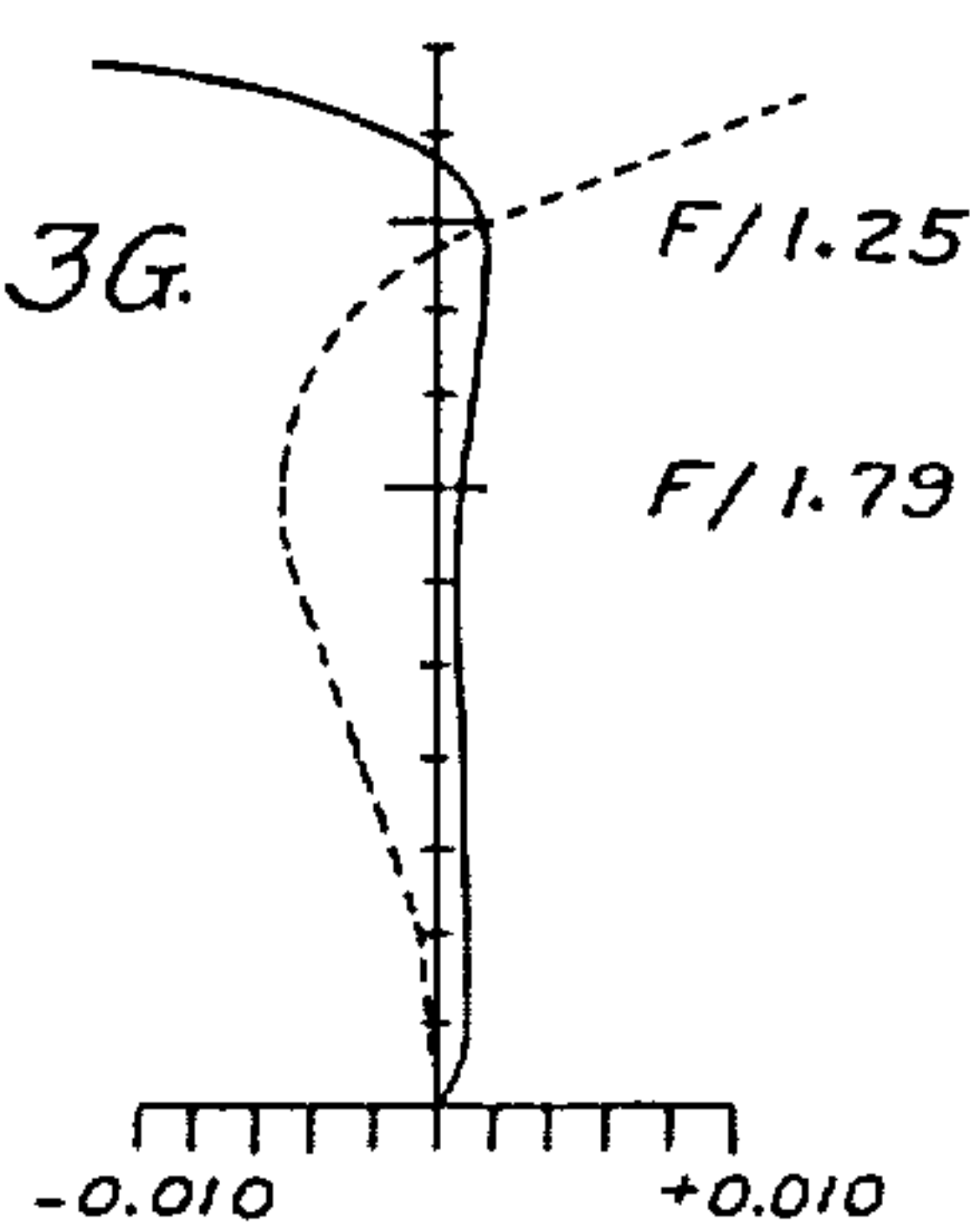
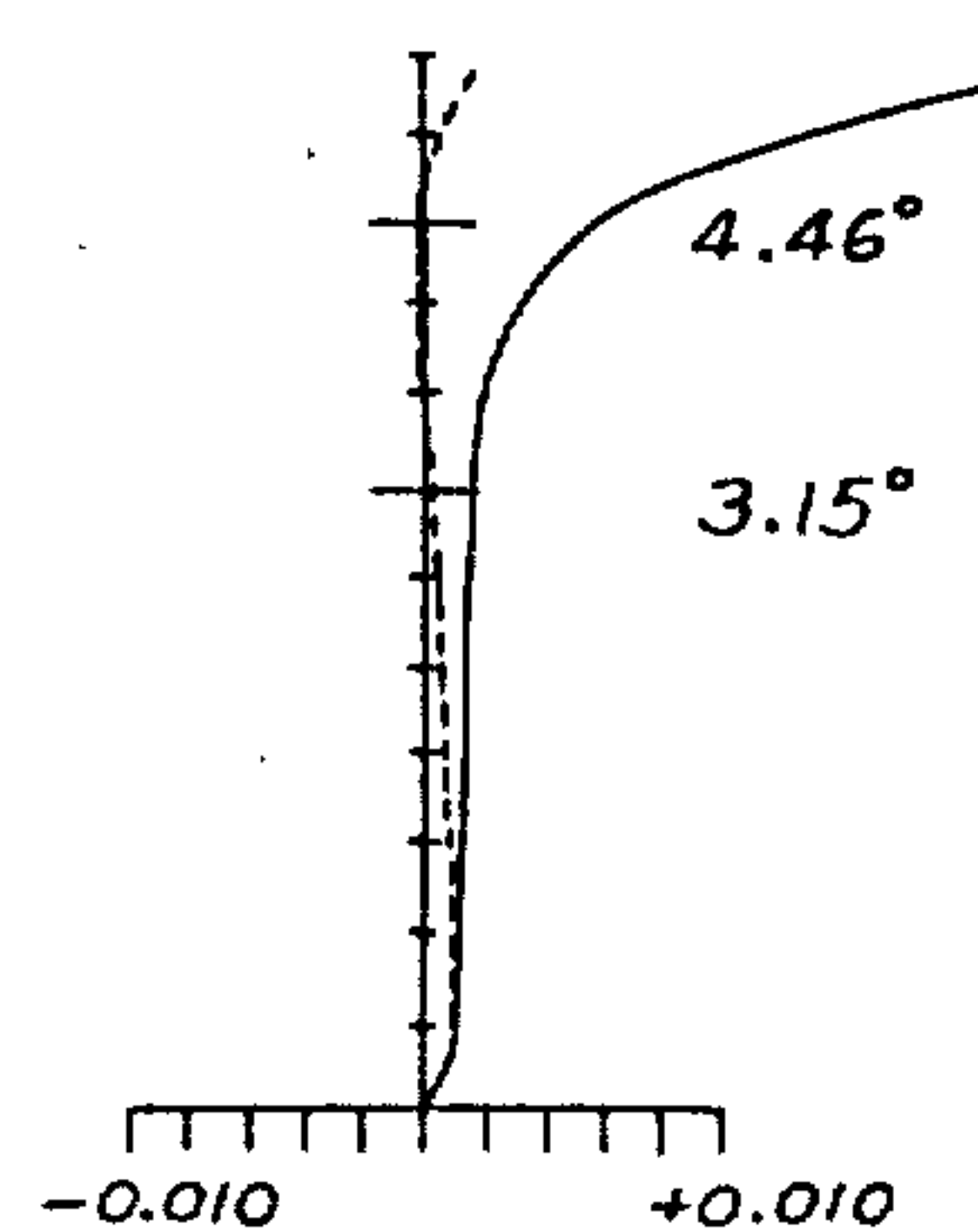


Fig. 3H.



LARGE APERTURE EXTENDED RANGE ZOOM LENS

Matter enclosed in heavy brackets [] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.

This application is a continuation-in-part of Ser. No. 625,965 filed Oct. 28, 1975, and now abandoned.

Another such lens is disclosed in the present applicant's U.S. Pat. application Ser. No. 944,341, filed Sept. 21, 1978.

This invention relates to a variable focal length lens of large effective aperture, and more particularly to a variable focal length lens, focusable over an extended range, and highly corrected over a large range of magnification.

Many zoom lenses or variable equivalent focal length lenses have been designed having moderate effective apertures insofar as they are desired to be competitive with the existing market of photographic equipment, such as motion picture cameras. Recently, another generation of zoom lenses has been designed having unusually large apertures in the f/1.2 class. Generally, these lenses have had magnification ratios not exceeding three-to-one. Thus, the benefit of the high effective aperture has been offset against a low magnification ratio. Other lenses of lesser apertures, although of similar or slightly greater magnification ratios to the high aperture lenses, have been designed for focusing in a range of less than the normal range of approximately 1 meter to infinity. This less than normal focusing range, enabling focusing from several millimeters from the lens to the closest distance of the normal range, is referred to as the "Macro" range. Most lenses with a high aperture [of] or a high magnification ratio are not capable of maintaining the required high degree of correction when focusing in the macro range. Hence, only a few relatively special, and therefore generally expensive lenses have been designed and are available having the combination of features incorporated in the present lens design. Also, because of the expense of these lenses, most have not been competitive so as to receive acceptance in the mass market by the "home" movie makers.

[Another] An object of the invention is to provide a relatively compact and relatively inexpensive zoom lens highly corrected over a magnification range greater than the more conventional three-to-one range from zoom lens of comparable large effective apertures.

It is to be understood that the terms "front" and "rear" as used herein refer to the ends of the objective respectively nearer the long and short conjugates thereof.

Other objects and advantages of the invention will become apparent from the detailed description which follows when taken in conjunction with the accompanying drawings in which:

FIG. 1 is a diagrammatic sectional view of a preferred optical system according to the present invention;

FIGS. 2A to 2H are graphical representations of the various aberrations of the lens system shown in FIG. 1 and having the design data given in Table 1 in the wide angle mode; and

FIGS. 3A to 3H are similar graphical representations of the lens system aberrations in the telephoto mode.

[FIGS. 4A to 4H are graphical representations of the various aberrations of the lens system having the design data given in Table 2 when in the wide angle mode.]

[FIGS. 5A to 5H are similar graphical representations of the Table 2 lens system when in the telephoto mode.]

Referring to the drawings, a zoom lens or variable equivalent focal length objective lens is shown. Particularly, the lens is highly corrected over a relatively large magnification range, and is capable of focus in the macro range as well as the normal range. Further, the lens has a relatively large effective aperture when compared to other lens designs having [the] a zoom range.

The lens includes a positive first component C₁, starting at the ray entrance side of the optical system, which component is adjustable axially through a short distance for focusing of the optical system throughout a range of approximately 1 meter to infinity. Component C₂ is a variator or negative component variable along the axis of the optical system for varying the equivalent focal length of the objective. The equivalent focal length is variable over greater than a six-to-one range of magnification while maintaining a high degree of optical correction for a large aperture of at least f/1.2 throughout the range. Component C₃ is a component adjustable axially upon axial adjustment of the variator, to function as a compensator for correcting aberrations caused by varying the focal length of the optical system, and being [independently] adjustable for focusing of the optical system in the macro range. Component C₄ is a fixed lens member for further collimating rays exiting the compensator component C₃. Rear component C₅ is a prime lens group forming an afocal system with the earlier described components.

The front component C₁, comprises a front biconvex cemented doublet L₁, L₂, and a rear singlet L₃, predominately convex forwardly and spaced close to the doublet L₁, L₂. Air spaced from the rear of the singlet L₃ and adjustable relative thereto is component C₂ which comprises a front negative meniscus singlet L₄ convex forwardly and a rear biconcave, cemented doublet L₅, L₆ predominately concave forwardly. The doublet has collective internal contact surfaces R₁₀, R₁₁.

Component C₃ is variably air spaced relative to component C₂ and the following component C₄. Component C₃ comprises a positive doublet L₇, L₈ predominately convex rearwardly. During a zooming or focal length varying operation, the component C₃ is moved axially at a rate proportional to the rate of movement of component C₂. However, for macro focusing action, the driver (not shown) of the components C₂ and C₃ by which axial adjustment thereof is accomplished is disconnected. [from component C₂ to cause that component to remain stationary while component C₃ is adjusted axially for focusing.]

Component C₄ is fixed ahead of the stop of the optical system and comprises a front negative meniscus singlet L₁₀ and a rear positive meniscus singlet L₁₁ which together form a substantially afocal system cooperating with the rear prime lens system C₅.

Component C₅ comprises a front biconvex singlet L₁₂, spaced somewhat from a negative element L₁₃. A doublet of elements L₁₄ and L₁₅ is arranged between element L₁₃ and rear element L₁₆ which is a singlet predominately convex forwardly.

The [element] elements L₁ to L₁₆ have spherical surfaces or radii of curvature R₁ to R₃₂, axial thicknesses T₁ to T₁₅ and axial separations S₁ to S₁₄. The separations

at S_{11} and S_{12} are sufficient to provide clearance for an aperture adjusting stop.

A preferred embodiment of the macro focusing, large aperture, zoom lens of the invention is constructed according to the table following wherein dimensions are as set forth and the refractive indices for the sodium D line and the Abbe dispersion numbers are respectively designated at N_D and V .

spacings between the respective elements, and the nominal image plane. EFL is the effective focal length of the lens system at wide angle condition W/A, at [telephone] telephoto condition T/P, and at mid range condition MID. "One-half Angle of Field" is one half the angle between the continuation of the lens axis and a line from the nodal point of the lens to the most oblique point recorded on the film when considered at the

TABLE 1

| SYSTEM EFL | | | HALF ANGLE OF FIELD | | |
|-------------------------------|--|------------------|---|-------|------|
| at W/A = 7.22mm (.2835 in.) | | | 27.36° | | |
| at T/P = 43.86mm (1.7268 in.) | | | 4.46° | | |
| at MID = 19.25mm (.7579 in.) | | | 10.02° | | |
| LENS | RADII (mm.) | THICKNESS (mm) | SPACINGS (mm) | N_D | V |
| 1 | $R_1 = 166.0901$ $R_2 = -45.7200$ | $T_1 = 1.702$ | $S_1 = 0$ | 1.755 | 27.6 |
| 2 | $R_3 = 45.7200$ $R_4 = 233.4001$ | $T_2 = 11.430$ | $S_2 = .1016$ | 1.623 | 56.9 |
| 3 | $R_5 = 50.3428$ $R_6 = -301.7523$ | $T_3 = 7.112$ | $S_3 = 1.4910$ at W/A 27.1882 at T/P 17.7851 at MID | 1.651 | 56.2 |
| 4 | $R_7 = 70.3580$ $R_8 = -16.8656$ | $T_4 = 0.800$ | $S_4 = 6.584$ | 1.639 | 55.4 |
| 5 | $R_9 = -24.0030$ $R_{10} = -19.1008$ | $T_5 = 0.800$ | $S_5 = 0$ | 1.620 | 60.3 |
| 6 | $R_{11} = 19.1008$ $R_{12} = -59.9948$ | $T_6 = 3.556$ | $S_6 = 38.3210$ at W/A 2.7508 at T/P 17.1018 at MID | 1.785 | 25.7 |
| 7 | $R_{13} = 53.9750$ $R_{14} = -21.3106$ | $T_7 = 0.800$ | $S_7 = 0$ | 1.805 | 25.4 |
| 8 | $R_{15} = 21.3106$ $R_{16} = 31.6230$ | $T_8 = 5.121$ | $S_8 = .1016$ | 1.640 | 60.2 |
| 9 | $R_{17} = 23.2664$ $R_{18} = -101.5237$ | $T_9 = 3.150$ | $S_9 = 1.7348$ at W/A 11.6103 at T/P 6.6573 at MID | 1.691 | 54.8 |
| 10 | $R_{19} = -45.5168$ $R_{20} = -12.8016$ | $T_{10} = 0.711$ | $S_{10} = 2.2758$ | 1.691 | 54.8 |
| 11 | $R_{21} = 14.6431$ $R_{22} = -27.4320$ | $T_{11} = 2.091$ | $S_{11} = 10.668$ STOP $S_{12} = 3.556$ | 1.805 | 25.4 |
| 12 | $R_{23} = 17.2720$ $R_{24} = 30.4292$ | $T_{12} = 3.226$ | $S_{13} = 1.6764$ | 1.774 | 44.8 |
| 13 | $R_{25} = -19.3040$ $R_{26} = -17.1196$ | $T_{13} = 0.711$ | $S_{14} = .8890$ | 1.805 | 25.4 |
| 14 | $R_{27} = 173.1519$ $R_{28} = -16.5100$ | $T_{14} = 4.496$ | $S_{15} = 0$ | 1.805 | 25.4 |
| 15 | $R_{29} = 16.5100$ $R_{30} = 21.8034$ | $T_{15} = 2.794$ | $S_{16} = .1270$ | 1.744 | 44.8 |
| 16 | $R_{31} = 14.9758$ $R_{32} = -424.1817$ | $T_{16} = 3.023$ | $S_{17} = 11.277$ BFL | 1.734 | 51.5 |

In the Table 1 above, the first column lists the lens elements numerically starting at the ray entrance side of the system. The second column lists the respective radii of the elements in millimeters. The third column lists the axial thickness T of the respective elements in millimeters. The fourth column lists in millimeters the axial

above expressed conditions.
FIGS. 2A to 2H graphically represent various aberrations of the form of the optical system, as shown in FIG. 1 and having the design data recited in Table 1. FIG. 2A represents correction of the rays on axis. FIG. 2B represents off axis aberrations of rays passing from the zone

of the film format and through the lens transversely and tangentially. FIG. 2C represents the aberrations of the rays passing from the corner of the film format through the lens tangentially and transversely. FIG. 2D represents the radial or longitudinal aberrations from the zone of the film format of rays entering the lens at 3 o'clock, while FIG. 2E represents similar aberrations from full field or corner rays. FIG. 2F represents distortion as a percentage of a "perfect" image. FIG. 2G represents the spherical aberrations by a full line and the offense-against-sine condition by the dotted line. FIG. 2H represents the curvature of field with tangential curvature being shown in full line and sagittal curvature being shown in dashed line.

FIGS. 3A to 3H graphically represent various aberrations of the optical system with the lens adjusted to the telephoto condition, as opposed to the wide angle con-

dition as represented in FIGS. 2A to 2H. In FIGS. 2A to 2E and 3A to 3E, the solid line represents the aberrations of a light ray at 5893 Å, the dotted line represents a light ray at 6563 Å, and the dashed line a light ray at 4861 Å.

【The design data of another embodiment of the optical system is shown in Table 2 set forth hereinafter. This optical system has a similar construction to the system shown in FIG. 1. FIGS. 4A to 4H, and FIGS. 5A to 5H graphically represent various aberrations related to the form of the optical system as described in the data of Table 2. The graphs in FIGS. 4A to 4H relate to the wide angle condition of the optical system, while the graphs of FIGS. 5A to 5H relate to the telephoto condition. The aberrations are identified with respect to FIGS 2A to 2H.】

【TABLE 2

| SYSTEM EFL | | | HALF ANGLE OF FIELD | | |
|-------------------------------|--|--------------------------|--|----------------|-------|
| at W/A = 7.61mm (.2997 in.) | | | 25.35° | | |
| at T/P = 56.98mm (2.2433 in.) | | | 3.31° | | |
| at MID = 25.67mm (1.0105 in.) | | | 7.58° | | |
| LENS | RADII (mm.) | THICKNESS (mm.) | SPACINGS (mm) | N _D | V |
| 1 | R ₁ = 240.7589 R ₂ = -51.1988 | T ₁ = 1.6510 | S ₁ = 0 | 1.755 | 27.6 |
| 2 | R ₃ = 51.1988 R ₄ = 152.7810 | T ₂ = 12.7000 | | 1.620 | 60.4 |
| 3 | R ₅ = 43.6880 R ₆ = -139.7000 | T ₃ = 7.7978 | S ₂ = .1016 | 1.651 | 55.9 |
| 4 | R ₇ = 71.7550 R ₈ = -16.5100 | T ₄ = .8128 | S ₃ = 4.2875 at W/A 29.5554 at T/P 22.3952 at MID | 1.639 | 55.4 |
| 5 | R ₉ = -24.0030 R ₁₀ = -19.1008 | T ₅ = .8382 | S ₄ = 6.6294 | 1.620 | 60.4 |
| 6 | R ₁₁ = 19.1008 R ₁₂ = -59.9948 | T ₆ = 3.5052 | S ₅ = 0 | 1.785 | 25.8 |
| 7 | R ₁₃ = 58.9280 R ₁₄ = -21.7424 | T ₇ = .8890 | S ₆ = 38.4048 at W/A 2.5857 at T/P 14.2570 at MID | 1.805 | 25.4 |
| 8 | R ₁₅ = 21.7424 R ₁₆ = 30.2260 | T ₈ = 5.6388 | S ₇ = 0 | 1.641 | 60.1 |
| 9 | R ₁₇ = 22.7203 R ₁₈ = 93.1672 | T ₉ = 3.1496 | S ₈ = .1016 | 1.691 | 54.9 |
| 10 | R ₁₉ = -45.5168 R ₂₀ = -12.8016 | T ₁₀ = .7112 | S ₉ = 1.6002 at W/A 12.1514 at T/P 7.6403 at MID | 1.691 | 54.9 |
| 11 | R ₂₁ = 16.6431 R ₂₂ = -27.0256 | T ₁₁ = 2.0574 | S ₁₀ = 2.2352 | 1.805 | 25.4 |
| 12 | R ₂₃ = 18.0848 R ₂₄ = 32.8168 | T ₁₂ = 3.6576 | S ₁₁ = 11.0490 STOP | 1.744 | 44.8 |
| 13 | R ₂₅ = -21.9202 R ₂₆ = -16.8656 | T ₁₃ = .7112 | S ₁₂ = 3.5560 | 1.805 | 25.4 |
| 14 | R ₂₇ = 61.2140 R ₂₈ = -14.5288 | T ₁₄ = 4.3180 | S ₁₃ = 1.6002 | 1.805 | 25.4 |
| 15 | R ₂₉ = 14.5288 R ₃₀ = 26.9494 | T ₁₅ = 3.2512 | S ₁₄ = .7336 | 1.744 | 44.8】 |
| | | | S ₁₅ = 0 | | |
| | | | S ₁₆ = .1270 | | |

TABLE 2-continued

| SYSTEM EFL | | | HALF ANGLE OF FIELD | | |
|-------------------------------|--|--------------------------|---------------------------|----------------|------|
| at W/A = 7.61mm (.2997 in.) | | | 25.35° | | |
| at T/P = 56.98mm (2.2433 in.) | | | 3.31° | | |
| at MID = 25.67mm (1.0105 in.) | | | 7.58° | | |
| LENS | RADII (mm.) | THICKNESS (mm.) | SPACINGS (mm) | N _D | V |
| 16 | R ₃₁ = 14.7320 R ₃₂ = -463.9259 | T ₁₆ = 2.5654 | S ₁₇ = 11.4529 | 1.734 | 51.7 |

What I claim is:
1. An optical system for a variable focal length lens of large effective aperture, which is focusable over an extended range, having substantially the following 15 specification:

| SYSTEM ELF | | | HALF ANGLE OF FIELD | | |
|-------------------------------|---|------------------------|---|----------------|------|
| at W/A = 7.22mm (.2835 in.) | | | 27.36° | | |
| at T/P = 43.86mm (1.7268 in.) | | | 4.46° | | |
| at MID = 19.25mm (.7579) | | | 10.02° | | |
| Lens | Radii(mm.) | Thickness (mm.) | Spacings(mm) | N _D | V |
| 1 | R ₁ =166.0901 R ₂ = -45.7200 | T ₁ =1.702 | S ₁ =0 | 1.755 | 27.6 |
| 2 | R ₃ =45.7200 R ₄ =233.4001 | T ₂ =11.430 | S ₂ = .1016 | 1.623 | 56.9 |
| 3 | R ₅ =50.3428 R ₆ = -301.7523 | T ₃ =7.112 | S ₃ = 1.4910 at W/A 27.1882 at T/P 17.7851 at MID | 1.651 | 56.2 |
| 4 | R ₇ =70.3580 R ₈ = -16.8656 | T ₄ =0.800 | S ₄ =6.584 | 1.639 | 55.4 |
| 5 | R ₉ = -24.0030 R ₁₀ = -10.1008 | T ₅ =0.800 | S ₅ =0 | 1.620 | 60.3 |
| 6 | R ₁₁ =19.1008 R ₁₂ = -59.9948 | T ₆ =3.556 | S ₆ = 38.3210 at W/A 2.7508 at T/P 17.1018 at MID | 1.785 | 25.7 |
| 7 | R ₁₃ =53.9750 R ₁₄ = -21.3106 | T ₇ =0.800 | S ₇ =0 | 1.805 | 25.4 |
| 8 | R ₁₅ =21.3106 R ₁₆ =31.6230 | T ₈ =5.121 | S ₈ = .1016 | 1.640 | 60.2 |
| 9 | R ₁₇ =23.2664 R ₁₈ = -101.5237 | T ₉ =3.150 | S ₉ = 1.7348 at W/A 11.6103 at T/P 6.6573 at MID | 1.691 | 54.8 |
| 10 | R ₁₉ = -45.5168 | T ₁₀ =0.711 | | 1.691 | 54.8 |

| SYSTEM ELF | | | HALF ANGLE OF FIELD | | |
|-------------------------------|--|------------------------|--|----------------|------|
| at W/A = 7.22mm (.2835 in.) | | | 27.36° | | |
| at T/P = 43.86mm (1.7268 in.) | | | 4.46° | | |
| at MID = 19.25mm (.7579) | | | 10.02° | | |
| Lens | Radii(mm.) | Thickness (mm.) | Spacings(mm) | N _D | V |
| 11 | R ₂₀ = -12.8016 R ₂₁ =14.6431 R ₂₂ = -27.4320 | T ₁₁ =2.091 | S ₁₀ =2.2758 S ₁₁ =10.668 - - - STOP - - - S ₁₂ =2.556 | 1.805 | 25.4 |
| 12 | R ₂₃ =17.2720 R ₂₄ =30.4292 | T ₁₂ =3.226 | S ₁₃ =1.6764 | 1.774 | 44.8 |
| 13 | R ₂₅ = -19.3040 R ₂₆ = -17.1196 | T ₁₃ =0.711 | S ₁₄ = .8890 | 1.805 | 25.4 |
| 14 | R ₂₇ =173.1519 R ₂₈ = -16.5100 | T ₁₄ =4.496 | S ₁₅ =0 | 1.805 | 25.4 |
| 15 | R ₂₉ =16.5100 R ₃₀ =21.8034 | T ₁₅ =2.794 | S ₁₆ = .1270 | 1.744 | 44.8 |
| 16 | R ₃₁ =14.9758 R ₃₂ = -424.1817 | T ₁₆ =3.023 | S ₁₇ =11.277 BFL | 1.734 | 51.5 |

wherein the first column lists the lens elements numerically starting at the ray entrance side of the system; the second column lists the respective base radii R₁ to R₃₂; the third column lists the thicknesses T₁-T₁₆ of the respective elements; the fourth column lists the axial spacings S₁ to S₁₇ between the respective elements, and stop, and the image plane; and the fifth and sixth columns respectively list the index of refraction for the Sodium D line N_D and the dispersive index V of the optical materials of the respective elements.
[2. An optical system for a variable focal length lens of large effective aperture, which is focusable over an extended range, having substantially the following specification:

| SYSTEM EFL | | | HALF ANGLE OF FIELD | | |
|-------------------------------|---|--------------------------|--|----------------|------|
| at W/A = 7.61mm (.2997 in.) | | | 25.35° | | |
| at T/P = 56.98mm (2.2433 in.) | | | 3.31° | | |
| at MID = 25.67mm (1.0105 in.) | | | 7.58° | | |
| LENS | RADII (mm.) | THICKNESS (mm.) | SPACINGS (mm) | N _D | V |
| 1 | R ₁ = 240.7589 R ₂ = -51.1988 | T ₁ = 1.6510 | S ₁ = 0 | 1.755 | 27.6 |
| 2 | R ₃ = 51.1988 R ₄ = 152.7810 | T ₂ = 12.7000 | S ₂ = .1016 | 1.620 | 60.4 |
| 3 | R ₅ = 43.6880 R ₆ = -139.7000 | T ₃ = 7.7978 | S ₃ = 4.2875 at W/A 29.5554 at T/P 22.3952 at MID | 1.651 | 55.9 |
| 4 | R ₇ = 71.7550 R ₈ = -16.5100 | T ₄ = .8128 | S ₄ = 6.6294 | 1.639 | 55.4 |
| 5 | R ₉ = -24.0030 R ₁₀ = -19.1008 | T ₅ = .8382 | S ₅ = 0 | 1.620 | 60.4 |
| 6 | [R ₁₁ 19 1008] | | | | |

-continued

| 【SYSTEM EFL | | | HALF ANGLE OF FIELD | | |
|-------------------------------|--|--------------------------|--|----------------|------|
| at W/A = 7.61mm (.2997 in.) | | | 25.35° | | |
| at T/P = 56.98mm (2.2433 in.) | | | 3.31° | | |
| at MID = 25.67mm (1.0105 in.) | | | 7.58° | | |
| LENS | RADII (mm.) | THICKNESS (mm.) | SPACINGS (mm) | N _D | V |
| | R ₁₂ = -59.9948 | T ₆ = 3.5052 | S ₆ = 38.4048 at W/A 2.5857 at T/P 14.2570 at MID | 1.785 | 25.8 |
| 7 | R ₁₃ = 58.9280 R ₁₄ = -21.7424 | T ₇ = .8890 | S ₇ = 0 | 1.805 | 25.4 |
| 8 | R ₁₅ = 21.7424 R ₁₆ = 30.2260 | T ₈ = 5.6388 | S ₈ = .1016 | 1.641 | 60.1 |
| 9 | R ₁₇ = 22.7203 R ₁₈ = 93.1672 | T ₉ = 3.1496 | S ₉ = 1.6002 at W/A 12.1514 at T/P 7.6403 at MID | 1.691 | 54.9 |
| 10 | R ₁₉ = -45.5168 R ₂₀ = -12.8016 | T ₁₀ = .7112 | S ₁₀ = 2.2352 | 1.691 | 54.9 |
| 11 | R ₂₁ = 16.6431 R ₂₂ = -27.0256 | T ₁₁ = 2.0574 | S ₁₁ = 11.0490 STOP S ₁₂ = 3.5560 | 1.805 | 25.4 |
| 12 | R ₂₃ = 18.0848 R ₂₄ = 32.8168 | T ₁₂ = 3.6576 | S ₁₃ = 1.6002 | 1.744 | 44.8 |
| 13 | R ₂₅ = -21.9202 R ₂₆ = -16.8656 | T ₁₃ = .7112 | S ₁₄ = .7336 | 1.805 | 25.4 |
| 14 | R ₂₇ = 61.2140 R ₂₈ = -14.5288 | T ₁₄ = 4.3180 | S ₁₅ = 0 | 1.805 | 25.4 |
| 15 | R ₂₉ = 14.5288 R ₃₀ = 26.9494 | T ₁₅ = 3.2512 | S ₁₆ = .1270 | 1.744 | 44.8 |
| 16 | R ₃₁ = 14.7320 R ₃₂ = -463.9259 | T ₁₆ = 2.5654 | S ₁₇ = 11.4529】 | 1.734 | 51.7 |

wherein the first column lists the lens elements numerically starting at the ray entrance side of the system; the second column lists the respective base radii R₁ to R₃₂; the third column lists the thicknesses T₁-T₁₆ of the respective elements; the fourth column lists the axial spacings S₁ to S₁₇ between the respective elements, and stop, and the image plane; and the fifth and sixth columns respectively list the index of refraction for the Sodium D line N_D and the dispersive index V of the optical materials of the respective elements.】

3. An optical system for a variable focal length lens which is focusable over an extended range defined by a first range portion for normal object distances and a second range portion for shorter object distances, said optical system comprising:

- a focusing component including
 - first and second elements arranged into a positive doublet, and
 - a positive third element;
- a variator component including
 - a negative fourth element, and
 - fifth and sixth elements arranged into a negative doublet;
- a compensator component including
 - seventh and eighth elements arranged into a positive doublet, and
 - a positive ninth element;
- a collimator component including

- 40 a negative tenth element, and a positive eleventh element; and
- a prime lens component including
 - a positive twelfth element,
 - a negative thirteenth element,
 - fourteenth and fifteenth elements arranged into a positive doublet, and
 - a positive sixteenth element;
- all of said elements being located on a common optical axis and following one another in the order set forth; said focusing component being movable for focusing said optical system over said first range portion; said variator component being movable for variation of the focal length of said optical system; said compensator component being movable relative to said variator component for focusing of said optical system over said second range portion.

4. An optical system for a variable focal length lens which is focusable over an extended range defined by a first range portion for normal object distances and a second range portion for shorter object distances, said optical system comprising:

- 60 a focusing component including
 - first and second elements arranged into a positive doublet,
 - said first element being a negative meniscus and said second element being biconvex, and
 - a positive meniscus third element;
- a variator component including
 - a negative meniscus fourth element, and

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fifth and sixth elements arranged into a negative doublet, said fifth element being biconcave and said sixth element being a positive meniscus;
a compensator component including 5 *seventh and eighth elements arranged into a positive doublet, said seventh element being a negative meniscus and said eighth element being biconvex, and a positive meniscus ninth element;*
a collimator component including
a negative biconcave tenth element, and
a positive meniscus eleventh element; and
a prime lens component including
a positive biconvex twelfth element,
a negative biconcave thirteenth element,
fourteenth and fifteenth elements arranged into a positive doublet,
said fourteenth element being a negative meniscus and said fifteenth element being biconvex, and 20 *a positive sixteenth element;*
all of said elements being located on a common optical axis and following one another in the order set forth; said focusing component being movable for focusing said optical system over said first range portion; said variator component being movable for variation of the focal length of said optical system; said compensator component being movable relative to said variator component for focusing of said optical system over said second range portion.
5. *An optical system for a variable focal length lens* 30 *which is focusable over an extended range defined by a first range portion for normal object distances and a second range portion for shorter object distances, said optical system comprising:*
a focusing component including 35 *first and second elements arranged into a positive doublet, and a positive third element;*
a variator component including
a negative fourth element, and 40 *fifth and sixth elements arranged into a negative doublet;*
a compensator component including
seventh and eighth elements arranged into a positive doublet, and
a positive ninth element;
a collimator component including

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a negative tenth element, and
a positive eleventh element; and
a prime lens component including
a positive twelfth element,
a negative thirteenth element,
fourteenth and fifteenth elements arranged into a positive doublet, and
a positive sixteenth element;
all of said elements being located on a common optical axis and following one another in the order set forth.
6. *An optical system for a variable focal length lens which is focusable over an extended range defined by a first range portion for normal object distances and a second range portion for shorter object distances, said optical system comprising:*
15 *a focusing component including*
first and second elements arranged into a positive doublet,
said first element being a negative meniscus and said second element being biconvex, and
a positive meniscus third element;
a variator component including
a negative meniscus fourth element, and
fifth and sixth elements arranged into a negative doublet,
said fifth element being biconcave and said sixth element being a positive meniscus;
a compensator component including
seventh and eighth elements arranged into a positive doublet,
said seventh element being a negative meniscus and said eighth element being biconvex, and
a positive meniscus ninth element;
a collimator component including
a negative biconcave tenth element, and
a positive meniscus eleventh element; and
a prime lens component including
a positive biconvex twelfth element,
a negative biconcave thirteenth element,
fourteenth and fifteenth elements arranged into a positive doublet,
said fourteenth element being a negative meniscus and said fifteenth element being biconvex, and
a positive sixteenth element;
45 *all of said elements being located on a common optical axis and following one another in the order set forth.*
* * * * *

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**UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION**

PATENT NO. : Re. 30,592

DATED : April 28, 1981

INVENTOR(S) : Andor A. Fleischman

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Cover Sheet, Column 2, last line, change "33" to --17--;

Column 6, line 3, change "5893 A" to --5893 Å--;

Column 6, line 4, change "6563 A" to --6563 Å--;

Column 6, line 5, change "4861 A" to --4861 Å--;

Claim 1, Column 7, line 18, change "ELF" to --EFL--;

Claim 1, Column 7, line 21, change "(.7579)" to --(.7579 in.)--;

Claim 1, Column 8, line 13, change "ELF" to --EFL--;

Claim 1, Column 8, line 16, change "(.7579)" to --(.7579 in.)--;

Claim 1, Column 8, line 22, change $S_{12}=2.556$ " to -- $S_{12}=3.556$ --.

Signed and Sealed this

Twelfth Day of January 1982

[SEAL]

Attest:

GERALD J. MOSSINGHOFF

Attesting Officer

Commissioner of Patents and Trademarks