

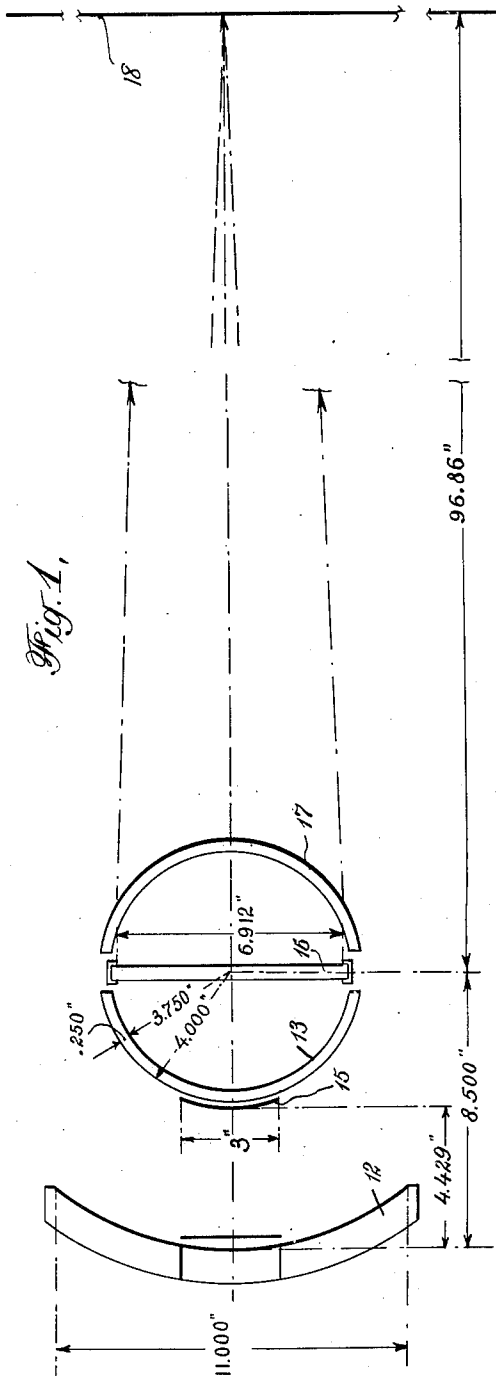
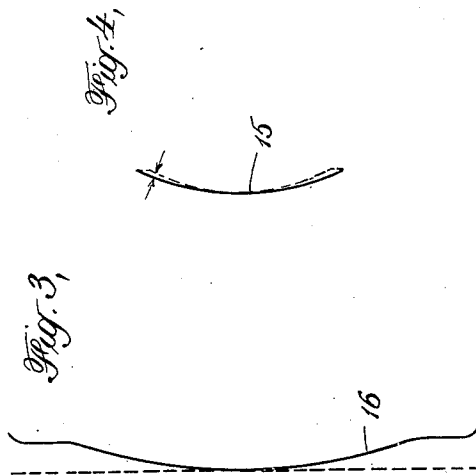
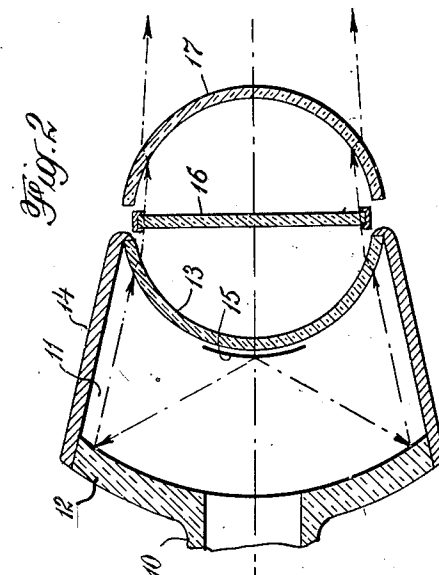
Dec. 13, 1949

J. G. BAKER ET AL
SCHMIDT TELEVISION PROJECTOR WITH SPHERICAL
ABERRATION CORRECTOR

2,491,072

Filed June 19, 1945

2 Sheets-Sheet 1



INVENTORS
James T. Baker
Constantin S. Szeghe
BY
Percy H. Mason, Edmunds
ATTORNEYS

Dec. 13, 1949

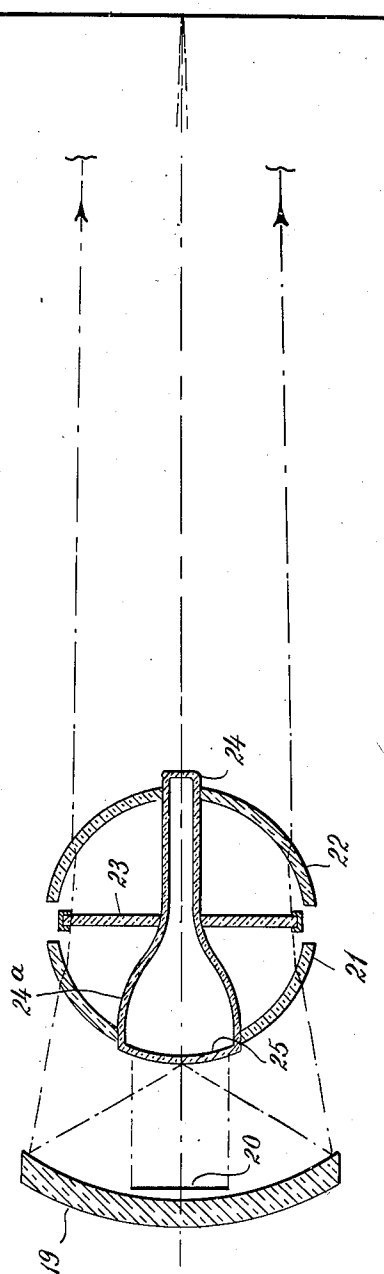
J. G. BAKER ET AL
SCHMIDT TELEVISION PROJECTOR WITH SPHERICAL
ABERRATION CORRECTOR

2,491,072

Filed June 19, 1945

2 Sheets-Sheet 2

Fig. 5.



INVENTORS
James F. Baker
BY Constantine S. Szegho
Percy Davis, Marion Edmunds
ATTORNEYS

UNITED STATES PATENT OFFICE

2,491,072

SCHMIDT TELEVISION PROJECTOR WITH
SPHERICAL ABERRATION CORRECTOR

James G. Baker, Waban, Mass., and Constantin S. Szegho, Chicago, Ill., assignors of one-half to The Perkin-Elmer Corporation, Glenbrook, Conn., a corporation of New York, and one-half to The Rauland Corporation, Chicago, Ill., a corporation of Illinois

Application June 19, 1945, Serial No. 600,257

13 Claims. (Cl. 178—7.5)

1

This invention relates to television receivers employing a cathode ray tube and is concerned more particularly with a new television receiver which includes an optical system for the purpose of projecting upon a viewing screen an enlarged image of that appearing on the fluorescent screen of the tube. The optical system of the television receiver of the invention, while of the Schmidt type, offers numerous advantages over an ordinary Schmidt system in that it may be constructed to permit an increase in speed or aperture without loss of definition or to give better definition at the same speed or aperture. Also, in the new receiver, elements of the optical system may be incorporated in the cathode ray tube envelope in such manner that there is less loss of light.

The use of optical systems in television receivers, employing a cathode ray tube, for the purpose of projecting upon a viewing screen an enlarged image of that appearing on the fluorescent screen of the tube is not new, and systems of various kinds utilizing lenses or spherical mirrors have been proposed for the purpose. The combination of a spherical mirror and an aspheric correcting plate counteracting the spherical aberration of the mirror, which was devised by Schmidt, is an optical system that is obviously desirable for television purposes, because the Schmidt system has long been known to afford clarity of definition at speeds, and fields of view at such speeds, that are not obtainable with refracting systems. However, the previous applications of the Schmidt system to television projection use, with which I am familiar, are open to a number of objections and are also subject to limitations in performance which restrict their use.

In one such prior television receiver, the cathode ray tube projects through an opening in the correcting plate toward the mirror and the light is radiated from the rear surface of the fluorescent screen to the mirror. As the fluorescent screen radiates the major portion of its light in the forward hemisphere, the arrangement described operates at an initial disadvantage. The interposition of the fluorescent screen in such a system blocks off a large portion of the aperture and, in order that this lost light may not illuminate the fluorescent screen with consequent loss of contrast in the final image, it is necessary to prevent such action. The desired result has been achieved either by forming the mirror with a central hole of the size and shape of the fluorescent screen or by applying an opaque disc of suitable size and shape to the central area of the mirror. The use of such expedients results in a loss of ad-

2

ditional light by vignetting and this effect is enhanced by the formation of the central opening in the correcting plate and mounting the tube to extend through the opening. Because of the factors mentioned, the prior system in a commercial form is constructed to operate at a speed of about $F/0.74$, equivalent to an effective speed of about $F/0.85$, and with a field of about 45 degrees.

The present invention is directed to the provision of a novel television receiver containing an optical system, which, at considerable field angles, gives markedly superior definition to that of an ordinary Schmidt system of the same F -number, or, for the same definition as that given by an ordinary Schmidt system, permits an increase in speed or aperture. The optical system of the new receiver may be constructed to operate at a speed of $F/0.60$ and, at that speed, gives considerably better definition than the prior system, above referred to, operating at $F/0.74$. In addition, in television use, the light lost in the new system because of silhouetting and vignetting is substantially less than the loss in the prior system.

The optical system of the new receiver includes a spherical mirror, a pair of thin shells with concentric radii and concentric on either side of the center of curvature of the mirror, and a correcting plate. Each of the shells adds a properly chosen amount of negative spherical aberration to the system with a resultant drastic reduction of the positive spherical aberration of the mirror. The mirror and the two concentric shells form a perfectly symmetrical system and the spherical aberration of this system is considerably less than that of the mirror alone. The correcting plate is, therefore, weaker or flatter than that required in an ordinary Schmidt system of equal speed and the performance at a given field-angle is correspondingly improved.

While the use of two shells as above described gives the best results, it is possible to obtain part of the advantages of the invention by employing a single shell. In such an arrangement, a heavier burden is placed upon the correcting plate and, because of that, the plate must be steeper, so that definition is sacrificed at a given speed, or, for a given standard of definition, there is a reduction in speed or aperture. However, the use of the single shell with the mirror and correcting plate produces a system which is superior to an ordinary Schmidt system.

In the preferred form of the new television receiver, elements of the optical system are incorporated in the tube to form part of the tube

3

envelope. Thus, one of the shells may form the end of the tube adjacent which the fluorescent screen is mounted and the mirror may form part of the wall of the enlargement of the tube within which the screen lies. When the mirror and shell are used in the manner described, they must be made of materials selected to withstand the temperatures to which they will be exposed in the processing and operation of the tube.

For a better understanding of the invention, reference may be made to the accompanying drawings, in which

Fig. 1 is a diagrammatic view of the elements of the optical system of one form of the new television receiver;

Fig. 2 is a longitudinal sectional view through the optical elements and part of the cathode ray tube of one form of the new receiver;

Fig. 3 is a diagrammatic view showing the curvature of one face of the correcting plate of the optical system of the new receiver, the horizontal dimensions of the plate being multiplied.

Fig. 4 is a diagrammatic sectional view of the fluorescent screen of the cathode ray tube of Fig. 2; and

Fig. 5 is a longitudinal sectional view showing another form of the new receiver.

One form of the new television receiver, in which elements of the optical system form parts of the tube envelope, is illustrated in Fig. 2 and the dimensions of a specific system suitable for such use are shown in Fig. 1.

The cathode ray tube of Fig. 2 has an envelope formed with a neck 10, in one end of which are mounted the usual cathode serving as a source of electrons, the means for forming the electrons into a beam, the control and focusing electrodes, and the beam-deflecting device. At its other end, the neck opens into an enlargement 11, one wall of which is formed by a spherical mirror 12 silvered on its concave surface. The opposite wall of the enlargement is formed by an optical shell 13 which is concentric with the mirror. The edge of the shell is connected to the outer edge of the mirror by a frusto-conical glass section 14 and the neck, mirror, section, and shell form an envelope which is vacuum-tight. A fluorescent screen 15 is mounted within the envelope and has a convex surface facing the mirror.

A correcting plate 16 is mounted outside the envelope at the center of curvature of the mirror and, although the plate has been illustrated as having flat parallel faces, it is of such curvature as to perform correcting function. The plate is, in effect, a convex lens with asphericity superimposed on both faces, and the cross-sectional shape of one face of the plate, with the horizontal dimensions enlarged twenty times, is shown in Fig. 3. Beyond the plate is a second optical shell 17 which is concentric with the mirror and disposed with its concave surface facing the plate.

The dimensions of the optical system of a typical television receiver of the invention are given in Fig. 1, where it will be seen that the mirror has a radius of 8.500" and a clear aperture of 11.000". The shell 13 is made of the glass known commercially as "Pyrex," because of the heat that it must withstand, and it has an outer radius of 4.000" and an inner radius of 3.750" so that its thickness is .250". The shell is concentric with the mirror. The correcting plate 16 is of the glass referred to commercially as DBC-1 and it has a clear aperture of 6.912". It is figured as needed from a basic radius of 249" for each face. The fluorescent screen has a diameter of 3" and

4

its radius of curvature is 4.261". The screen is not concentric with the mirror and the distance between its forward face and the mirror is 4.429". The opening at the center of the mirror is circular and of at least the same diameter as the diameter of the area of the screen projected on straight lines. The shell 17 has the same dimensions as the shell 13, but it is made of the glass known commercially as BSC-2. With the system of the dimensions above given, the picture diameter on the projection screen 18 is 76.772", the distance from the correcting plate to the projection screen is 96.86", and the magnification is 23.79 times.

As pointed out above, the purpose of the shells is to introduce a properly chosen amount of negative spherical aberration into the system, so that the positive spherical aberration of the mirror is drastically reduced and the work to be performed by the correcting plate is also greatly reduced. It is well known that the nearer the correcting plate in an ordinary Schmidt system is to flatness, the better is the performance at a given field-angle. As the correcting plate in the optical system of the new receiver is weaker or flatter than that required in an ordinary Schmidt system of equal speed, the definition of the optical system of the new receiver is markedly superior to that of an ordinary Schmidt system of the same F-number at considerable field angles. Conversely, for the same definition in the projected image, the speed or aperture of the system of the receiver of the invention can be increased over that of a conventional Schmidt system. Another advantage in using the shells is that the color correction for most zones is better than in an ordinary Schmidt system, since the positive curve on the correction plate is always acting against the negative contributions of the shells.

The shells may vary in thickness, and as their thickness increases, the burden on the correcting plate is reduced and a flatter plate may be used. The shell thickness adopted represents a compromise between the size of the mirror and the correction burden on the correcting plate. Increasing the thickness of the shells reduces the burden on the plate and increases the mirror size for a given focal length of the system. For a system operating at a speed of F/0.60, the permissible upper limit in thickness of the shells is $\frac{1}{8}$ of the equivalent focal length, that is, $\frac{1}{8}$ of the distance between the center of curvature of the mirror and the focal point. For systems to operate at lower speeds, the thickness of the shells may be greater, as, for example, for a system to operate at F/1, the shells may have a thickness up to $\frac{1}{2}$ the equivalent focal length. With shells of that maximum thickness, no correcting plate is required. However, shells or less thickness are preferred and with shells of a thickness of .25" in the example of the system described, variations in correction over the aperture are minimized. The shells need not be identical in thickness, but if one is thicker than the other, the overall correction by zones is impaired. The radius of the shells should be as long as possible and the maximum radius is, of course, that at which the surface of one shell is in direct contact with the fluorescent screen.

The glass used for the shells may have a mean index of refraction (n_D) varying from about 1.4 to 1.8 and it is advantageous to employ a glass having as low a dispersion, that is, as high a v -value, as possible. The shells introduce negative color which is corrected by the plate. By

making the shells of glass of low dispersion, less burden is imposed upon the plate. The achromatism of the shells can be overcome by causing them to depart from concentricity with the mirror but, for a given standard of definition, this results in a reduction in the field angle.

The fluorescent screen in the new receiver, which corresponds to the photographic film in an ordinary Schmidt camera, is approximately spherical and concentric with the mirror. The departures from sphericity and also from concentricity are obviously necessary, because the projection screen is at a finite distance, whereas in the Schmidt camera, the corresponding distance is infinity. The shape and position of the fluorescent screen will vary, therefore, with the distance between the correcting plate and the projection screen but may be readily determined. For most projection purposes, a screen of spherical shape is suitable but for highest precision, the screen will be formed with the slight zone indicated by dotted lines in Fig. 4. The greatest depth of the zone will be 0.0035" in a screen of three inch diameter.

In the foregoing, I have described a form of the new television receiver in which elements of the optical system are incorporated in the envelope of the cathode ray tube of the receiver to form walls bounding the evacuated space. This form of receiver is preferred, since the light striking the mirror comes from the forward zone of the screen. In some instances, however, it may be desirable to construct the receiver with the optical system wholly independent of the cathode ray tube and such an arrangement is shown in Fig. 5. In the Fig. 5 form of the new receiver, the spherical mirror 19 is provided with a central opening or else the central area is covered by an opaque black baffle 20. The shells 21, 22 and the correcting plate 23 are formed with central openings through which the cathode ray tube 24 may be inserted with the enlarged end 24a of the tube facing the mirror. The fluorescent screen 25 within the end of the tube is disposed at the proper distance from the mirror by reason of the position of the tube. The light striking the mirror comes from the back surface of the screen and passes through the wall of the tube envelope on its way to the mirror. The correcting plate must, accordingly, be designed to correct for the spherical aberration of the mirror as modified by the shells as well as for the error introduced by the tube end wall, as will be obvious. The diameter of the baffle is substantially the same as that of the screen projected in straight lines parallel to the axis of the system.

As pointed out above, the materials employed for the shells and correcting plate in the optical system of the new receiver should be selected in order that chromatic aberration may be reduced as much as possible, but, in some applications, other requirements must be fulfilled. Thus, in a system, such as that shown in Fig. 2, in which the mirror and one shell form parts of the envelope of the cathode ray tube, the mirror and shell should be made of a material capable of withstanding the temperatures to which they are exposed in the processing and operation of the tube. The materials used in the correcting plate and second shell will then be chosen to obtain the desired chromatic effects, in view of the limitation on the choice of the material for the first shell. The selection of the materials will be clear to one skilled in the art of optical design and the color removal conditions can be ex-

pressed in an equation relating the lens power of the shells and correcting plate to their desired dispersions for any specific example of the system.

We claim:

1. An image projection device comprising a cathode ray tube having a fluorescent screen on which a light image is produced, and an axially aligned optical system comprising a spherical reflector placed to receive light from the screen on its concave surface, a spherical shell concentric with the reflector, the shell adding negative spherical aberration to the system to reduce the positive spherical aberration of the reflector, and an aspheric correcting plate lying outside the envelope at the center of curvature of the reflector and shell in the path of rays passing from the reflector through the shell and figured to correct for the residual spherical aberration of the combination of the reflector and shell.

2. An image projection device comprising a cathode ray tube having a fluorescent screen on which a light image is produced, and an axially aligned optical system comprising a spherical reflector forming part of the tube envelope, the reflector being placed to receive light from the screen on its concave surface, a pair of spherical shells concentric with the reflector and lying outside the tube envelope and with their concave faces opposed, the shells adding negative spherical aberration to the system to reduce the positive spherical aberration of the reflector, and an aspheric correcting plate lying between the shells and figured to correct for the residual spherical aberration of the combination of the reflector and shells.

3. An image projection device comprising a cathode ray tube, the envelope of which has an end wall formed of a shell of spherical curvature with its concave surface facing outwardly and with a curved fluorescent screen mounted inside the envelope adjacent the convex surface of said end wall, and an optical system aligned with the screen and comprising a spherical reflector concentric with said end wall and receiving light from the screen, the tube end wall adding negative spherical aberration to the system to reduce the positive spherical aberration of the reflector, and an aspheric correcting plate lying outside the tube in the path of rays passing from the reflector through the shell and figured to correct for the residual spherical aberration of the combination of the reflector and the tube end wall.

4. An image projection device comprising a cathode ray tube, the envelope of which has an end wall of spherical curvature with its concave surface facing outwardly with a curved fluorescent screen mounted inside the envelope adjacent the convex surface of said end wall, and an optical system aligned with the screen and comprising a spherical reflector concentric with said end wall and forming part of the envelope, the reflector receiving light from the screen, a spherical shell concentric outside the tube with the reflector and lying beyond the center of curvature thereof with its concave face opposed to that of the end wall, the shell and end wall adding negative spherical aberration to the system to reduce the positive spherical aberration of the reflector, and an aspheric correcting plate lying outside the tube between the end wall and shell and figured to correct for the residual spherical aberration of the combination of the reflector, the end wall, and the shell.

5. An image projection device comprising a cathode ray tube and an aligned optical system, the tube having an envelope, including a neck and an enlargement at the end of the neck, and a fluorescent screen within the enlargement, and the system including a spherical shell forming the end wall of the envelope enlargement and a spherical reflector forming the wall of the enlargement surrounding the neck, the shell and reflector being concentric about a center of curvature outside the envelope and the reflector receiving light from the screen and reflecting it through the shell, the shell adding negative spherical aberration to the system to reduce the positive spherical aberration of the reflector, and an aspheric correcting plate lying outside the envelope in the path of rays passing from the reflector through the shell and figured to correct for the residual spherical aberration of the combination of the shell and the reflector.

6. An image projection device comprising a cathode ray tube and an aligned optical system, the tube having an envelope, including a neck and an enlargement at the end of the neck, and a fluorescent screen within the enlargement, and the system including a spherical shell forming the end wall of the envelope enlargement and a spherical reflector forming the wall of the enlargement surrounding the neck, the shell and reflector being concentric about a center of curvature outside the envelope and the reflector receiving light from the screen and reflecting it through the shell, a second shell concentric with the first and lying at the opposite side of said center of curvature, the shells having their concave surfaces opposed and adding negative spherical aberration to the system to reduce the positive spherical aberration of the reflector, and an aspheric correcting plate lying between the shells and figured to correct for the residual spherical aberration of the combination of the shells and the reflector.

7. An image projection device as defined in claim 5, in which the correcting plate lies at the center of curvature of the shell and reflector.

8. An image projection device as defined in claim 5, in which the fluorescent screen is aligned with the tube neck and the opening in the reflector is not substantially smaller in area than the area of the screen projected by parallel lines.

9. In an image projection device including a cathode ray tube having a fluorescent screen adjacent the inner surface of its end wall, the combination of a spherical reflector receiving light from the screen, a spherical shell concentric with the reflector and lying at one side of the center of curvature thereof, and an aspheric correcting plate lying outside the tube at the center of curvature of the reflector and shell and in the path of rays passing from the reflector through the shell and figured to correct for the residual spherical aberration of the combination of the shell and reflector and for the error introduced by the thickness of the end wall of the tube.

10. In an image projection device including a cathode ray tube having a fluorescent screen adjacent the inner surface of its end wall, the combination of a spherical reflector receiving light from the screen, a pair of spherical shells concentric with the reflector and lying on opposite sides of the center of curvature thereof with

their concave faces opposed, at least one of the shells lying outside the tube, and an aspheric correcting plate lying outside the tube at the center of curvature of the reflector and shells and figured to correct for the residual spherical aberration of the combination of the shells and reflector and for the error introduced by the thickness of the end wall of the tube.

11. An image projection device as defined in claim 9, in which the tube extends through aligned openings in the shell and plate and the reflector has a central non-reflecting area aligned with the screen and of an area not substantially less than that of the screen projected by parallel lines.

12. In an image projection system, a cathode ray tube having an envelope comprising a neck and an enlargement connected thereto, the enlargement having an inwardly convex end wall facing the neck, a spherical reflector forming the wall of the enlargement surrounding the neck and facing the end wall, said end wall being transparent and having inner and outer spherical surfaces which are substantially concentric with one another and with the reflector, and a screen on the inside of the end wall facing the neck and reflector.

13. An image projection device comprising a cathode ray tube having a fluorescent screen on which a light image is produced, and an axially aligned optical system comprising a spherical reflector placed to receive light from the screen on its concave surface, a pair of spherical shells concentric with the reflector and lying on opposite sides of the center of curvature thereof with their concave faces opposed, at least one of the shells lying outside the tube, and an aspheric correcting plate lying outside the tube between the shells and figured to correct for the residual spherical aberration of the combination of the shells and reflector.

JAMES G. BAKER.

CONSTANTIN S. SZEGHO.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,170,979	Straubel	Aug. 29, 1939
2,229,302	Martin et al.	Jan. 21, 1941
2,273,801	Landis	Feb. 17, 1942
2,295,779	Epstein	Sept. 15, 1942
2,298,808	Ramberg	Oct. 13, 1942
2,305,855	Epstein	Dec. 22, 1942
2,344,756	Warmisham	Mar. 21, 1944
2,440,735	Cawein	May 4, 1948

FOREIGN PATENTS

Number	Country	Date
883,937	France	Apr. 5, 1943
477,406	Great Britain	Dec. 28, 1937
487,241	Great Britain	June 16, 1938
541,650	Great Britain	Dec. 5, 1941
544,694	Great Britain	Apr. 23, 1942
557,771	Great Britain	Dec. 3, 1943

OTHER REFERENCES

Maksutov, "Journ. Opt. Soc. Amer." vol. 34, No. 5, May 1944, pp. 270-284.