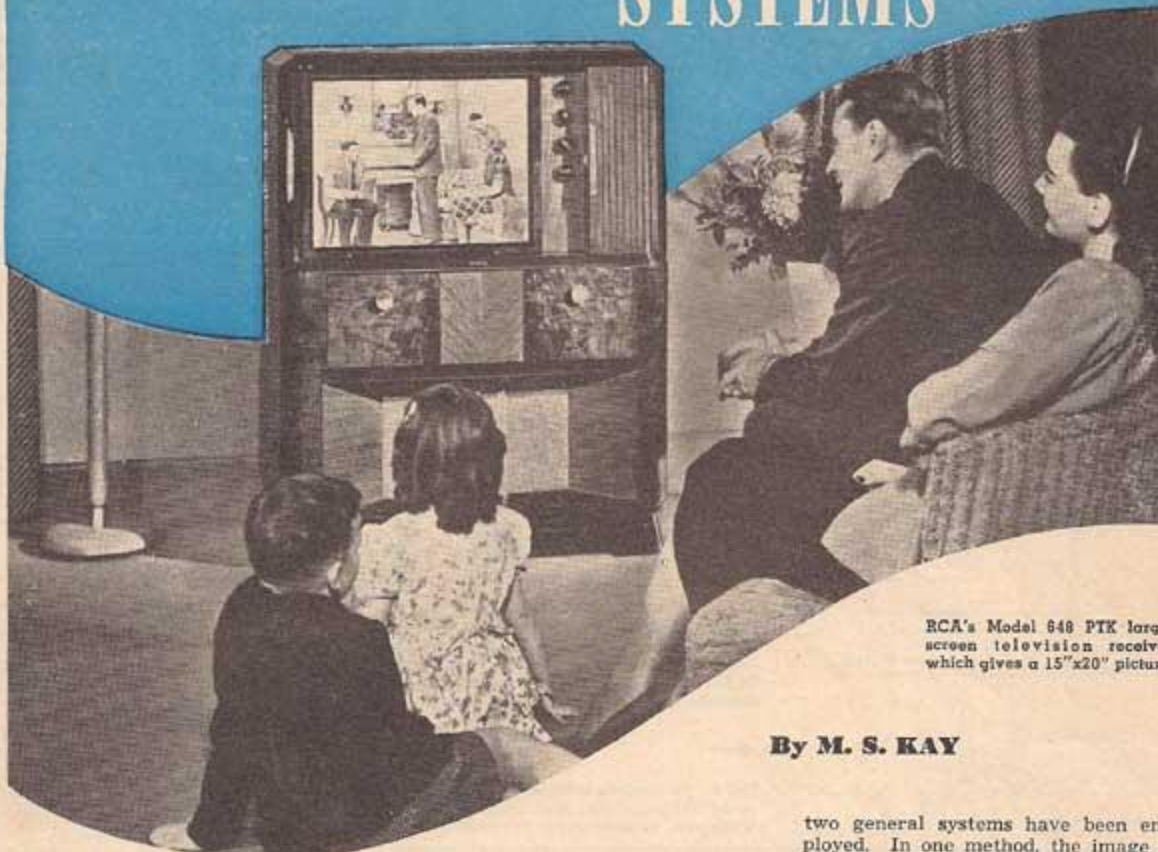
Television PROJECTION SYSTEMS



RCA's Model 648 PTK large-screen television receiver which gives a 15"x20" picture.

By M. S. KAY

Current developments in projection TV makes possible large images from relatively compact television sets.

THE desire for relatively large television pictures is a natural one. One immediate advantage is the ability to view the screen for long consecutive periods without fatigue. Secondly, a greater number of persons can more comfortably view a large area than say a 7- or 10-inch screen. This is particularly desirable in sets installed in public places, such as auditoriums, taverns, theaters, and retail establishments.

Large images can be obtained in two ways: by using cathode-ray tubes having large viewing surfaces, or by projection. In the first method, practical considerations limit the screen to diameters of 20 inches. A tube having a diameter of 20 inches possesses a large physical volume, is awkward to manipulate, and expensive. Difficulties with these tubes are encountered at all points. In manufacture, the machines required for evacuating and sealing must be considerable in size. This either results in a limited production or a large capital investment. The large bulk of the tube increases the storage and transportation costs to an amount far beyond a proportionate value for a smaller tube. Finally, in the home, the cabinet, which is no minor item in the final pricing of the set, must likewise be large. Because of these difficulties, tubes with screens greater than 20 inches have not been commercially attempted. Sets using viewing tubes with 12, 15, or 20-inch screens are readily available, however.

The other approach to large screen television is by projection and to date two general systems have been employed. In one method, the image is formed on the screen of a small cathode-ray tube and then enlarged, using several projection lenses similar to those employed in motion-picture equipment. The chief disadvantage of this method is its low efficiency. Specially treated lenses, having a large aperture and good transmission of light, deliver to the viewing screen only about 6 per-cent of the light available on the screen of the cathode-ray tube. Consequently, even with intense images developed on the cathode-ray screen, the final image is bound to be dim and difficult to see.

As an illustration, consider the 5-inch projection tube, with its image of 3" x 4". The total area here is 12 square inches. If the image is enlarged to fill a screen 15 x 20 inches, the total area becomes 300 square inches, and the light which was originally concentrated in an area of 12 square inches is now spread out to cover an area of 300 square inches. The brightness is thereby reduced by the ratio of 300/12 or 25 to 1. This is, of course, assuming 100 per-cent transmission. If now we take into ac-

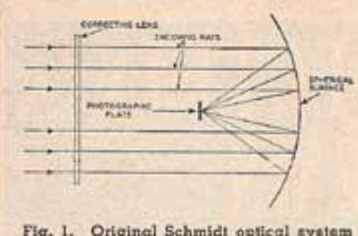


Fig. 1. Original Schmidt optical system as designed for astronomical telescopes.

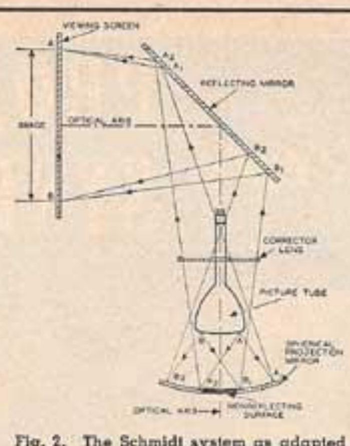


Fig. 2. The Schmidt system as adapted by G.E. and RCA for their television sets.

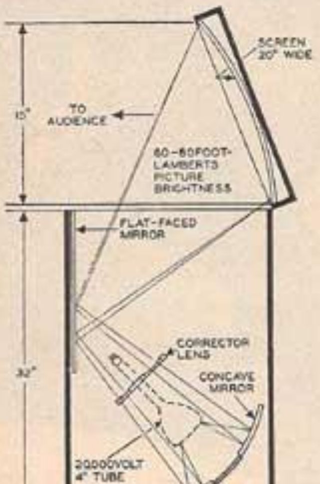


Fig. 3. The Philco projection system.

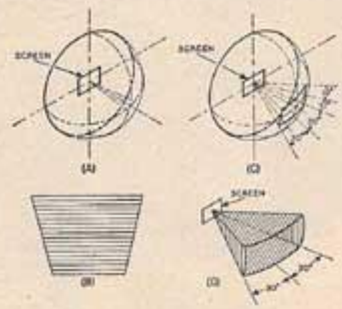


Fig. 4. (A) A non-directional screen will produce equal illumination at all equidistant points throughout a hemisphere. (B) A trapezoid. (C and D) The directional characteristics of Philco viewing screen.

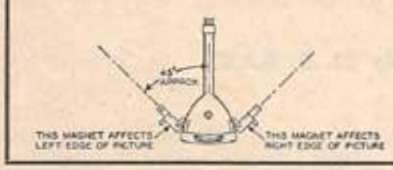


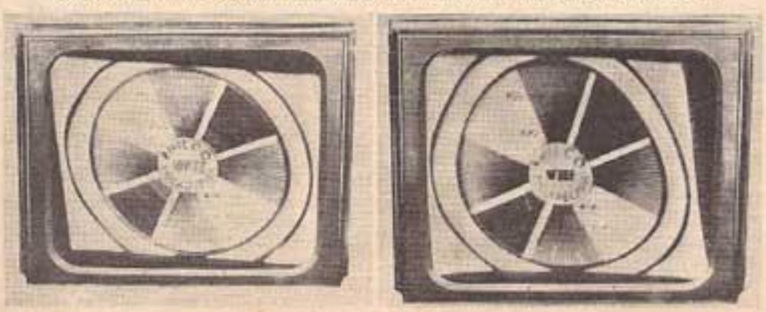
Fig. 5. To produce a trapezoidal image on the CRT face, the magnets are attached to the tube as indicated in the drawing.

count that the over-all efficiency is only 6 per-cent, then the brightness is decreased by a factor of approximately 400 to 1 rather than 25 to 1.

Increasing the brightness of the image developed on the tube screen would be one partial solution to this problem, but the cost involved can readily place the equipment in the same expensive class as large cathode-ray tubes. A second approach to the problem, and one which appears to have greater possibilities, is to increase the efficiency of the lens system.

The first attempt in this direction was tried with the same lenses mentioned above and several difficulties were immediately encountered. In order to capture as much light as possible being emitted from the screen, the projection lens should be as large as possible. However, as the lens becomes larger, the number of distortions or "aberrations" multiply. (There are principally six aberrations that must be corrected; namely, chromatic aberration, spherical aberration, coma, astigmatism, curvature of field, and distortion.) To correct for these aberrations in a fairly satisfactory manner, we require several lens elements, say possibly three. However, in a wide angle system, more than three lens elements should be used. As more elements are added, the cost of the system rises. The greater the number of lenses in a system, the greater the total loss of light at the intersecting surfaces and the lower the over-all efficiency. Finally, with large lenses, the elimination of some aberrations is accompanied by a greater accentuation in others.

Fig. 6. The visual effect of improper adjustment of the fixed magnets of Fig. 5.



This was the impasse that faced television engineers until the adaptation of the Schmidt reflective optical system to television. Schmidt, an instrument maker at the Hamburg Germany Observatory, invented his optical system in 1931. The system, originally designed for astronomical telescopes, was built around a large spherical reflecting surface or mirror. See Fig. 1. Use of this type of reflecting surface offered several immediate advantages:

1. Mirrors are completely free of chromatic aberrations.

2. Under comparable designs of focal distance and diameter, a spherical mirror has a spherical aberration one-eighth that of a single lens. The need for correction is still present, but the problem is now considerably simplified.

3. By placing a small aperture or opening at the center of curvature of a spherical mirror, all of the monochromatic aberrations (except spherical aberration) are eliminated.

We are thus left with essentially two problems to solve. One is spherical aberration and the other is curvature of the field. The latter is quite simply resolved by curving the screen of the projection tube to suit the curvature of the mirror. To eliminate spherical aberration, a special correcting lens is employed. The correcting lens introduces into the beam an amount of spherical aberration which is equal to that introduced by the mirror, but is opposite in sign. As a result, the two neutralize each other, effectively removing the last great defect of the spherical mirror. With this lens in place, we have an optical system possessing an efficiency of 25 per-cent with magnification of 5. Compare this to the meager 6 per-cent obtainable using a refractive lens system.

For use in television receivers, there are several modifications of the original Schmidt lens system as designed for astronomical use. In *RCA* and *G.E.* projection receivers, the optical mirror is mounted at the bottom of the cabinet with its axis vertical, projecting the image straight up and onto a flat mirror inclined at 45 degrees to the beam of light and throwing the image on a translucent screen. See Fig. 2. The throw or distance between the correcting lens and the viewing screen will depend upon the diameter of the correcting lens and the spherical mirror. To increase the size of the projected image, the distance or throw must increase, necessitating large cabinets, a larger mirror, and a larger correcting lens. Eventually the optical system becomes awkward and bulky. A compromise is thus necessary between the size of the final image and the cost and size of the set. For each different throw or magnification, we require a different correcting lens. This, it will be noted, differs from a refractive lens system where the size of the projected image can be increased merely by changing the position of the lenses and the screen.

In *Philco* projection television receivers the arrangement of the optical system components is slightly different as shown in Fig. 3. The distance between the corrector lens and the screen is 33½ inches and variations of plus or minus 10 per-cent are permissible without leading to any serious deterioration of image quality. Each of the reflecting plane mirrors in all these optical systems are front-surfaced mirrors to prevent ghosts which would occur from reflections at the surface of the glass of a rear-surfaced mirror.

The translucent screen upon which the final image is projected has, in itself, directional properties which concentrate the incoming beam in certain desired directions. If the screen was a perfect diffuser of light, it would produce illumination which was equally visible all over the room. Graphically this could be shown as indicated in Fig. 4A. At all points throughout a hemisphere, whose center coincides with the screen, equal illumination would be received from the screen. Since many of the extreme angles of this hemisphere are never (or very seldom) used for viewing, due to foreshortening, it is advantageous to concentrate the light that would normally go to these points toward those angles that are most used for viewing. To achieve this, the translucent screen is made directional in the vertical and horizontal directions. Not only does this cause the final image to be brighter than it would be using the perfect diffuser screen, but it also presents the added advantage of greatly reducing the susceptibility of the screen to any stray light from lamps located in the viewing room.

In the *Philco* projection receiver, the screen is designed to have a viewing sector which extends 60° horizontally and 20° vertically. See Fig. 4B. To achieve this directivity, the screen contains a large number of vertical grooves, random shaped. These vertical grooves are responsible for the horizontal directivity of the screen. To achieve the 20° vertical directivity,

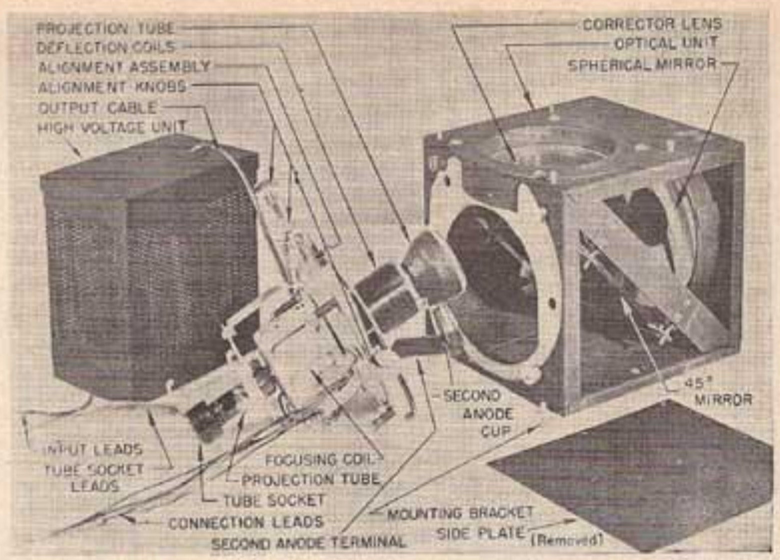


Fig. 7. The entire assembly, including the special power supply, as used in the North American Philips projection television system.

the screen surface is made concave. See Fig. 3. The screen, in addition to its directional properties, also possesses a great many minute or lenticular elements, each of which redistributes or diffuses the light reaching it uniformly throughout the desired sector. The over-all brightness of this screen is about 50 foot-lamberts.

Since the optical system is mounted at an angle and projects on the screen at an angle, a rectangular image projected from the face of the picture tube would appear on the screen as a trapezoid (the image would have sloping sides with the top larger than the bottom). See Fig. 4B. On the other hand, by projecting a trapezoidal image from the tube, we obtain a rectangular image on the screen. This latter method is the one used in the *Philco* system.

Formation of the trapezoid pattern is achieved by applying a magnetic field at right angles to the electron beam. To produce this magnetic field, two oppositely polarized permanent magnets are mounted opposite each other on the end of the projection tube. See Fig. 5. An iron pole piece, curved to fit the sides of the tube, is attached to each magnet and is used to produce a strong field for deflecting the electron beam upward near the tube face. The oppositely polarized ends of the magnets farthest from the tube face cause a lesser and downward deflection of the beam before it is deflected upward. The result is the same as that which would be produced if the face of the tube were tilted inward; the distance the beam travels to the bottom of the image is reduced and the distance to the top is increased. This creates the desired trapezoidal pattern. The magnets are adjusted for the proper keystoning pattern by moving them toward (parallel to the

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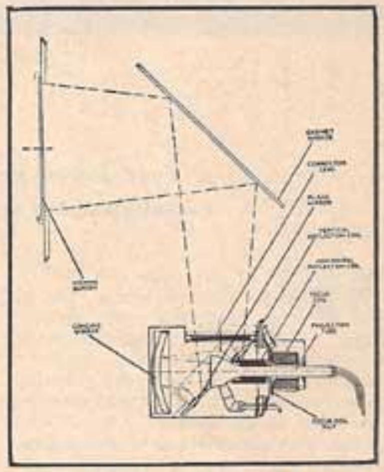

Fig. 8. The various components of the optical unit of the Philips projection set.

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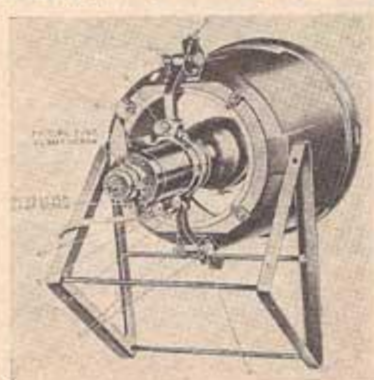
Fig. 9. The "optical barrel" in Philco and RCA receivers. The points lettered A through H are physical positioning adjustments.



Projection Television
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tube neck) or away from the tube (at right angles to the tube neck). The visual effects of improper positioning of the magnets are shown in Fig. 6.

In the *RCA* and *G.E.* projection receivers the additional bar magnets are not required because the translucent screen is not slanted and because it is perpendicular to the axis of the optical system. Hence, a rectangular image on the projection tube face appears as a rectangle on the screen. The translucent screen used in these sets is composed of two lucite sheets with a partial diffusing layer between them. The back sheet has a fresnel lens molded into its rear surface. The front sheet has vertical ribs molded into its outer surface. The fresnel lens functions to concentrate the light into a narrow viewing angle. The vertical ribs act to increase the horizontal viewing angle above that obtained with a flat surface. The diffusing layer eliminates interference patterns between the fresnel lens and the vertical ribs. The screen and lens combination give a gain of approximately five over that which would be obtained from a ground glass screen.

In the *RCA* and *Philco* receivers, the projection tube, the spherical mirror, and the correcting lens are all mounted in what is known as an "optical barrel." See Fig. 9. The spherical mirror is mounted in the bottom of the optical barrel and held against a knife edge by three sets of springs. The spring pressure is strong enough to hold the mirror securely against the knife edges, but not sufficient to distort the spherical mirror.

The 5TP4 is held in a retaining ring within the optical barrel, the face of which is approximately one-half way between the correction lens and the mirror. The tube is adjusted to position by controls on the side of the optical barrel. Optical focusing is accomplished by moving the picture tube up and down vertically. Other adjustments are needed to secure proper centering of the picture tube on the optical axis of the mirror. The correction lens is held in the ring on top of the barrel and secured by three spring fingers.

Another variation of the Schmidt optical system as adopted for television is that devised by *North American Philips*. The system, known by the tradename of "Protelgram," is an adaptation of the "folded" Schmidt system and occupies only half the space of a conventional arrangement. Since the light path is folded, it is possible to mount the projection tube with its optical system within a small metal box, thereby producing a compact and dustproof arrangement. The actual metal case measures only 8½" x 8½" x 9". It contains three optical elements: (1) a 6" spherical mirror, (2) an aspherical corrector lens, and (3) a special plane mirror to "fold" the light beam. See Fig. 8. These three elements form an optical triangle within the optical unit and are adjusted at the factory. They remain in adjustment under normal use. The optical unit is dustproof, with only the upper face of the corrector lens being exposed. It can be dusted with an ordinary cloth without scratching. The light emitted from the tube face is gathered by the spherical mirror, reflected to the plane mirror and then projected upwards through the corrector lens. At the center of the plane mirror there is a hole large enough to permit the projection tube face to be inserted through it. Behind the mirror ample room is provided for the deflection and focusing coils of the tube, plus whatever tube supports are required. There is no interference from the coils and the neck of the tube, since these are behind the plane mirror.

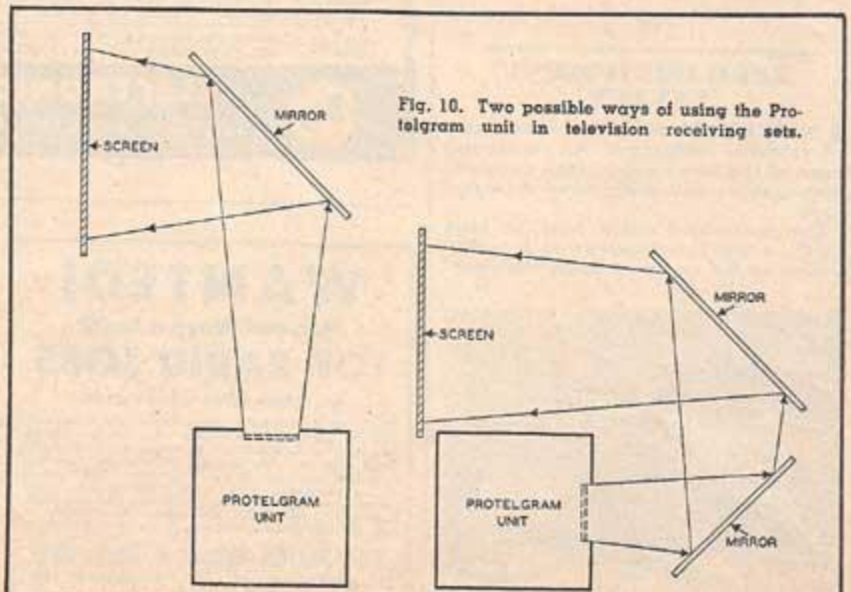

Fig. 10. Two possible ways of using the Protelgram unit in television receiving sets.

A throw distance of 31" from the corrector lens to the viewing screen is required to produce an image 12" x 16". Extending behind the tube face and for 7½" beyond the 9" dimension of the optical unit is the alignment assembly. This carries the tube and socket, focus, horizontal and vertical deflection coils and aligns the tube optically by means of three screws, which can be locked to insure good mechanical stability. Horizontal and vertical deflection coils are inside the optical unit; the focusing coil is outside. The tube is firmly seated in the plastic coil forms for the deflection coils, which are designed so that linear current will produce linear deflection over the full picture area.

A special small-size cathode-ray projection tube (3NP4) was designed for this unit. The tube screen diameter is 2.5 inches from which is obtained a 1.4 x 1.86 inch picture. 2.5 inches appears to be the smallest practical size from which an enlarged image can be obtained. The tube uses magnetic deflection, magnetic focusing and 25,000 volts for acceleration. The spot diameter at the tube face is 0.003 inches and this permits 450 line resolution to be obtained. The high-voltage anode terminal consists of a button in a glass cup sealed to the cone of the tube. The glass cup lengthens the external leakage path from the high-voltage contact to the coils thereby minimizing any tendency for arc-over to occur. The outside of the cone and part of the neck are covered with a conductive coating that can be grounded. This outer coating, together with the conductive coating inside the tube, forms a 300 $\mu\mu$fd. condenser which can be utilized for filtering of the high voltage. The neck of tube is quite narrow and, in conjunction with a deflection angle of only 40 degrees, permits full deflection to be achieved using only as much deflection current as ordinarily supplied to a 10BP4 direct-viewing tube operating at 9 kv.

A 25 kv. second anode is needed for the 3NP4 with better than average stability. Since existing types of high-voltage power supplies were found to be unsatisfactory, a new, compact unit was designed having low weight, small size, great stability and no r.f. radiation. See Fig. 7.

The flexibility of this particular design is illustrated by two possible arrangements, Fig. 10. In the left-hand illustration, the beam emerging from the corrector lens is folded once more by a second mirror tilted 45-degrees. For an even more compact arrangement, the beam can be folded twice after leaving the "Protelgram" unit.

For future projection television receivers, the immediate objectives are: greater light intensity on the viewing screen, better contrast, and increase in horizontal and vertical viewing angles.

Projection television, while presenting more problems must, nonetheless, keep pace with direct view receivers.

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