SPECIAL TV RECEIVER SYSTEMS

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STUDY SCHEDULE NO. 58

For each study step, read the assigned pages first at your usual speed, then reread slowly one or more times. Finish with one quick reading to fix the important facts firmly in your mind. Study each other step in this same way.

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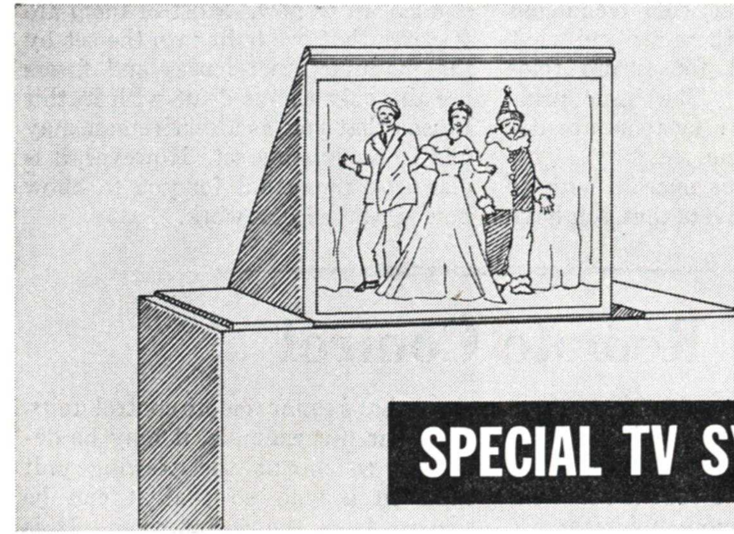


SPECIAL TV SYSTEMS

LESSONS up to now have covered all the sections of typical home television receivers that use direct-view picture tubes. Now we are ready to study ways in which the basic television circuits are sometimes modified to fit special viewing conditions or to meet commercial requirements. We shall also learn something about extra equipment often used with TV sets.

Since this Lesson covers a number of unrelated subjects, let's take a moment to learn what they are. First, we shall discuss sets in which provisions are made for controlling from a remote point. This isn't a new idea; remote control for radio receivers has been offered for years as a luxury item. There are people willing to pay extra for the ability to control a television set from a point other than right at the picture tube, so some manufacturers offer suitable equipment.

Another type of remote control consists of television duplicators—systems in which the program is picked up at one central point and is then fed to a number of reproducing units. Duplicators are of considerable importance in wired-in commercial systems like those used in schools, hospitals, and hotels. These, too, are described in this Lesson.

A larger picture is something that a great many set owners want. Because of lack of funds, many people buy sets having one of the smaller picture tubes; after a while, however, they often become dissatisfied with the small picture and obtain magnifying lenses to enlarge the image. Some people, too, want bigger pictures than even large direct-view sets can give; to satisfy this demand, a considerable number of projection television sets have been put on the market. Both lenses and projection systems will be discussed later in this Lesson.

A basic problem for the television viewer is the fact that light reflections from the surface of the picture tube or the protective cover glass will tend to degrade the image and reduce the contrast range appreciably. To eliminate such reflections, people purchase filters for installation in front of the cover glass. We shall discuss filters later on.

Finally, there are a number of laboratory efforts being made today to develop color television, and it is important for the practising technician to know just what these are and what they may foretell for future television possibilities. The basic principles of all modern systems are described in this Lesson.

All of these items operate with or from the basic receivers that you have studied up to now. Most of them are features that are built into the set by the manufacturer: lenses and filters are the only things dealt with in this Lesson that you, as a serviceman, may add to an existing set. However, it is of course important for you to know how all these items work.

Remote Control

There are two general forms of remote control: 1, a "convenience" type that makes it possible to tune in stations and adjust the contrast and the volume from a remote point; and 2, a "duplicator" system, in which more than one picture unit is controlled from a single point. Let's consider both these systems in order.

REMOTE CONTROL

Fig. 1 shows an example of remote control. The unit shown at the end of the sofa can be used to change stations or to adjust the contrast or the volume control settings. Such a system is at least a convenience; if the person operating the set is bedridden or otherwise disabled, it becomes practically a necessity.

There are numerous commercial or industrial applications that require somewhat similar remote control units. In a bar, for example, it may be desirable to mount the viewing unit high on a wall so that it can be viewed from the entire room. It is impractical to tune a set in this position. If the set is remotely controlled,

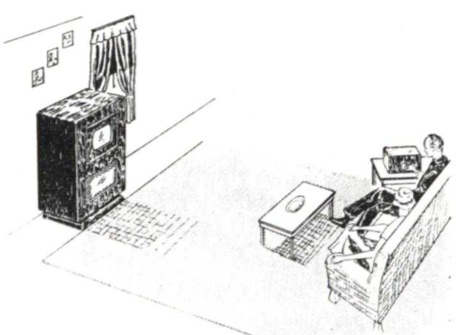


FIG. 1. The remote tuner beside the sofa permits adjustment of the picture unit which is located across the room.

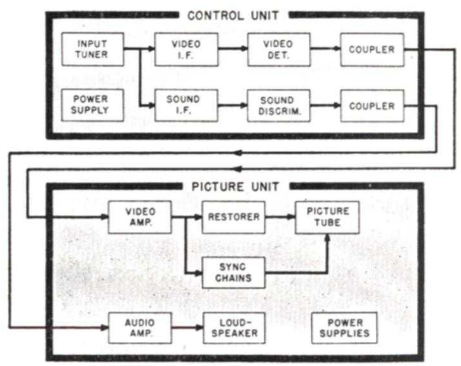
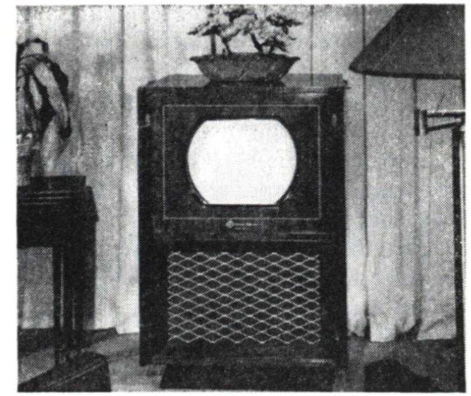


FIG. 2. Block diagram of stages in the control unit and the picture unit.

however, the control unit can be mounted where the bartender can operate it.

Many other similar practical applications can be thought of, all involving a control unit that can perform the normal functions of tuning and adjusting the set and that can be mounted conveniently at some point remote from the picture unit itself.

It would be possible to use some form of motorized control, but practically all the control units made now are actually the tuning portion of a television set. In other words, as shown in Fig. 2, the television set is split into two sections. The control unit contains the input tuner and parts of the video and sound channels. The video path in the control unit consists of the video i.f., the video detector, and a coupler stage that feeds the video signal through a coaxial cable to the separate picture unit. The sound path is similiarly divided: in the control unit we have the sound i.f., the discriminator, and a coupler unit that feeds a sound signal over its own cable to the audio amplifier and loudspeaker, which are in the picture unit.



Courtesy Industrial Television, Inc.
A picture unit or duplicator.

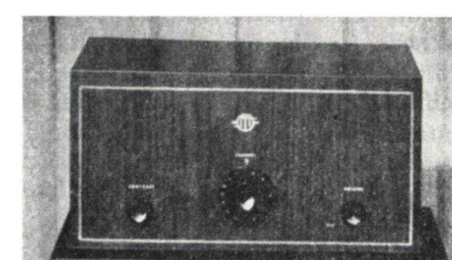
In the picture unit, the video signal goes through a video amplifier and a d.c. restorer to the picture tube. In addition, both the horizontal and vertical sync chains are contained in the picture unit. Suitable power supplies are in each unit, and of course the high-voltage supply is in the picture unit where it will be used with the picture tube.

Basically, therefore, in units of this kind, the television receiver with which we are familiar is split into two units, each of which has its own power supply. A relay is arranged so that when the control unit is turned on or off, the picture unit will also be turned on or off. The tuning, contrast, and sound volume controls (which are associated with the input tuner, the video i.f. amplifier, and the discriminator respectively) are part of the control unit.

At the picture unit will be found the brilliancy control, picture positioning controls, linearity controls, etc., which are usually associated with the sync and sweep chains. Since these controls require only occasional adjustment, they may well all be at the back of the picture unit. The picture unit may use any size of picture tube, but in most applications the installation will be at some distance from the viewers, so the larger sizes (15 inches or more) are most common.

Except for being in two sections, the only thing unusual about these remote control units is the coupler stage that is necessary to feed the video signal into the coaxial cable that connects the two units. A coaxial cable is necessary to prevent interference pick-up. It must have very low impedance so that it can handle the wide range of frequencies. (The video frequencies range from around 10 cycles out to 4 mc.) If the surge impedance of the cable is not low, shunting capacities will limit the frequency range.

If we tried to feed from the video detector directly into such a low impedance, there would be a severe loss of signal, because the line would make a very poor load. Hence, the coupler stage acts as an impedance matcher between the relatively high impedance



Courtesy Industrial Television, Inc.
A control unit for a remote-control system.

of the detector load (several thousand ohms) and the 50-to-90-ohm coaxial cable.

Video Coupler. Schematic diagrams of the control-unit coupling stage and of the input to the picture unit are shown in Figs. 3A and 3B.

The stage shown in Fig. 3A is a cathode follower. The arrangement is such that the signal from the video detector that appears across the detector load R_1 is coupled to the grid of tube VT_1 through the normal condenser - resistor coupling. However, this tube does not have a plate load resistance in the usual sense; resistor R_3 is a voltage adjuster, and condenser C_2 grounds the plate insofar as the signal is concerned.

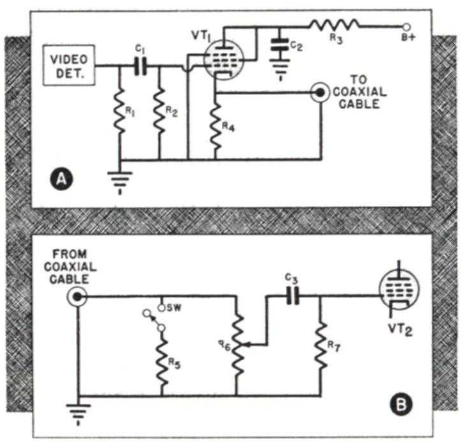


FIG. 3. The coupler stage at A feeds into the picture unit input as at B.

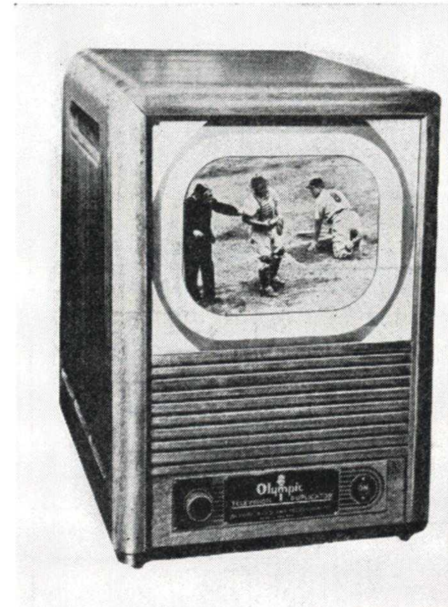
The "load" for the tube is in the cathode circuit, and consists of the terminating resistance of the coaxial cable (about 75 ohms in this case) in parallel with R_4 (about 500 ohms), making a total load of slightly under 75 ohms. Such an extremely low load does not require high-frequency compensation; in addition, the frequency response is improved by the degeneration that occurs because the load is in the cathode circuit.

Since the entire load signal is in the cathode circuit and is applied to the grid circuit, there is 100% degeneration. As a result, the tube acts as though its μ were less than 1, so there is a loss in signal level—the output is less than the input in such a cathode-coupled stage. However, the plate resistance of the tube used in the coupler stage equals $Y_p \div (\mu + 1)$, so it is far less than it would be in a more usual circuit. Also, notice that in Fig. 3A the tube is connected as a triode (screen grid and plate tied together) to give an even lower plate resistance; both these conditions produce an effective match between the tube resistance and the load. Hence, this cathode-coupled circuit makes a very good coupling network for this application; the signal loss is far less than would be caused by the mismatched coupling that would exist without it, and the frequency response is far superior to that of other couplings.

The coupling used at the picture unit is shown in Fig. 3B. The switch SW is provided so that a loading resistor R_5 can be connected as the terminating resistance for the coaxial cable. To prevent reflections, the coaxial cable must be matched at this end by an impedance exactly equal to the surge impedance of the cable.

If a 75-ohm coaxial cable is used, for example, resistor R_5 must have a resistance of 75 ohms. If there is only one picture unit involved, the switch will be closed so that this load resistor is connected directly across the cable.

In parallel with this may be a supplementary contrast control, such as resistor R_6. Alternatively, some means of varying the cathode bias of VT_2 or of a following video stage may be used to furnish a supplementary contrast control. It is desirable to have this supplementary control to set the limits



Courtesy Olympic Radio and Television Co.
A typical duplicator.

over which the one at the control unit will operate; in fact, it is almost necessary to have one if more than one picture unit is used, as we shall see in a moment.

The coupling from R_6 in Fig. 3B is through a standard R-C coupling network to the grid of VT_2, which is the first of the video amplifiers.

The sound coupler is much the same as the one we have just described—it is a cathode follower arranged to feed the sound cable. However, the far more restricted frequency range permits the use of a less expensive and easier matched higher-impedance line (500 ohms) instead of a coaxial cable.

TELEVISION DUPLICATORS

Hotels, schools, and hospitals may want units in different rooms, or there may be cases where more than one picture unit is wanted even in a home. In such cases, the basic remote control arrangement we have just described can be used for operating more than one picture unit. As shown in Fig. 4, all that is necessary is to run a coaxial line from picture unit to picture unit. The switch SW is provided in the circuit shown in Fig. 3B to make such multiple connections possible. Since the line must be loaded only at the end, the load resistor R_L in Fig. 4 is added at the unit C at the unit of the coaxial line, but it is disconnected for the units A and B. This arrangement lets the line be terminated in its own impedance; then the relatively high-impedance inputs of the picture units can be attached at other points along the line without upsetting the impedance matching of the line. If the resistor in each of these units were allowed to be across the line, on the other hand, the line would no longer be matched, because the combined resistance of the resistors in parallel would be far lower than is needed. Therefore, when several duplicators are connected to a single line, the last one must give the proper impedance match.

When more than one unit is connected to a line this way, it is very important that each unit have its own contrast control so that, for an initial setting of the contrast control on the control unit, the others can be properly adjusted to give the desired response. Usually only the control-unit contrast control would be used from then on, although the picture-unit

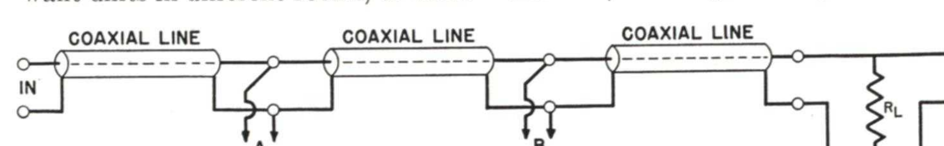


FIG. 4. How to connect a number of picture units to a coaxial line.

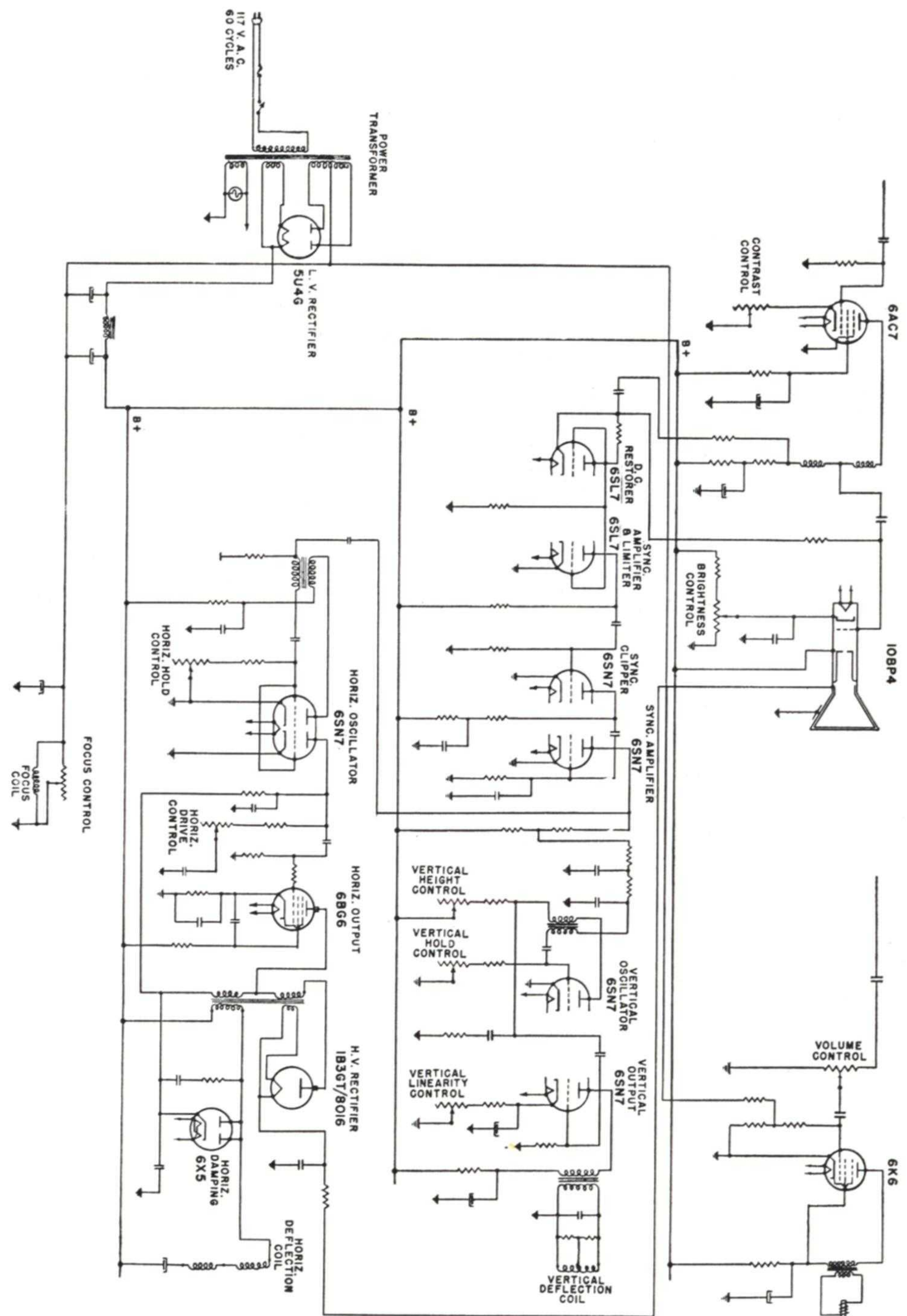


FIG. 5. Schematic of the Olympic Model RTU-3 duplicator.

contrast controls can be used if doing so proves desirable.

Connecting to Receivers. It is also possible to add duplicators to standard receivers, where more than one picture is desired. Fig. 5 shows a schematic diagram of a typical unit of this kind. This unit is designed to be attached to a standard TV set, which of course is a complete unit by itself.

The only modification necessary in the TV set to attach such a duplicator is to arrange for the picture to be picked up from the video output tube of the set. Cathode coupling is again necessary for impedance matching. In most receivers, the cathode of the video output tube is returned to the chassis either directly or through a bias resistor. To install a duplicator, the connection between the cathode of the output tube and the chassis must be opened, and the coaxial cable must then be connected to this point. The circuit is completed at the duplicator by a special plug-in arrangement that contains a matching resistor for the coaxial cable.

If more than one duplicator is to be used, the matching plug is removed and additional lengths of the coaxial cable are added from one unit to the next. The last one on the chain must have the resistor plug still in it, however, to match the coaxial cable and to complete the return circuit from cathode to ground for the output tube of the set. This particular arrangement does not upset the output tube characteristics to any great extent as long as sufficient resistance is in the circuit to give normal biasing. If not, it may be necessary to change the bias resistor; complete details on such changes are furnished by the duplicator manufacturers.

In the circuit shown in Fig. 5, the 6AC7 tube in the duplicator drives the picture tube. Remember that the signal is being picked from the cathode of the output tube of the set; therefore, an additional stage is necessary to get a video signal having the proper phase, and of course we need the gain to make up for the loss entailed in coupling to the cathode of the output tube of the set.

A d.c. restorer is used in this particular circuit. The restored signal is also applied to the sync amplifier and limiter stage. The sync signal then goes through a clipper and amplifier before being separated to drive standard vertical and horizontal sweep chains.

The audio signal is obtained from the primary of the output transformer on the receiver and is fed over a separate cable to drive the 6K6 power tube on the duplicator.

Whatever system of duplication is used, the sizes of the pictures at the main receiving point and at the duplicating points depend entirely upon the requirements. There is no reason at all why the main receiver cannot be a large-screen type and the duplicators even as small as 7 or 10 inches. The opposite is also feasible—it is possible to operate a duplicator with a large screen from a 7-inch tube set. You will notice that the duplicator contains its own sweep circuits and power supply, so it is independent of the receiver for everything except two signals, the combination video-sync signal and the sound signal. Duplicators of different sizes may be connected to the same coaxial line, if desired.

Getting Larger Pictures

Direct-view picture tubes are available today in sizes ranging from 7 inches to 20 inches in diameter. As you would expect, the larger the picture tube, the greater the cost of a set: not only does the tube price increase, but also larger sizes require

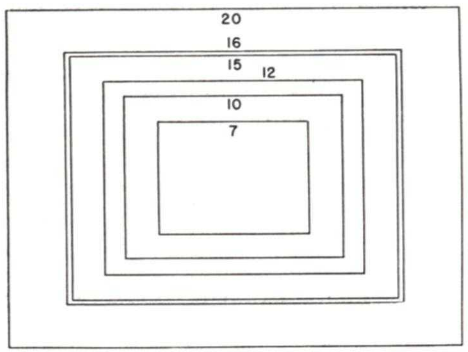


FIG. 6. This shows the relative areas on picture tube faces ranging from 7 to 20 inches in useful face diameter.

larger and more expensive cabinets, a higher voltage from the high-voltage supply, and usually a more powerful sweep output. (The use of two output tubes in parallel is common in the horizontal sweep for large tubes.)

Fig. 6 gives a relative comparison between the picture sizes that can be had on the popular tube diameters of 7, 10, 12, 15, 16, and 20 inches. It is obvious that the larger tubes give far more image area. However, since cost prevents many from getting these larger sizes, the manufacturers are attempting to make use of more of the picture tube screen area, and many people enlarge the images with lenses.

The television picture that is transmitted has an aspect ratio (ratio of width to height) of 4 to 3; this means that if the picture is four units wide, it will be three units tall. If the entire picture is to be reproduced on the face area of a direct-view tube, it must be included within the useful tube face area as shown in Fig. 7A. To get the image out near the edges of the usable screen area, the corners of this kind of mask are somewhat rounded, so the area in the original scene shown black in Fig. 7A is lost. The gray area represents the part of the picture tube face that is not used.

This type of mask was the only one used until recently. Then, a trend started in which somewhat larger picture areas were obtained from the same tube face by sacrificing slightly more of the corners of the image, as shown in Fig. 7B. Here, the width has been increased so that the width of the picture exactly equals the usable diameter of the tube face, and the height has been increased correspondingly to maintain the aspect ratio. This gives a picture having the area shown white, and the only thing lost is the area in the corners of the original picture that is shown here in black. Sacrificing these areas, in which very little of the interesting portion of the television image is ever

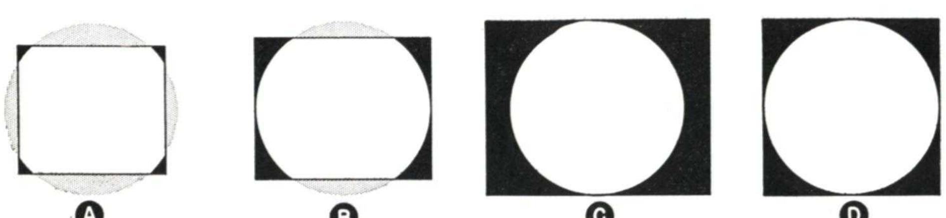
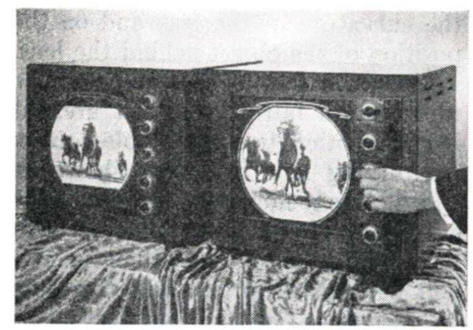


FIG. 7. Comparison of areas obtained with different picture masks.

present, makes it possible to increase the picture size somewhat for the same tube size. For example, with the mask shown in Fig. 7A, a 10-inch picture tube may have a useful area of about 52 square inches. An area of as much as 61 square inches can be obtained with the mask shown in Fig. 7B.

It is possible to carry this idea still further and to make use of the full screen area of the tube, providing we are willing either to sacrifice a considerable portion of the picture or to accept a distorted picture. Thus, if we expand both the height and width as shown in Fig. 7D so that the picture fills the entire screen area of the tube, we will have a square picture



Courtesy Westinghouse Elec. Corp.

FIG. 8. A zoom system enlarges the center of the picture as shown here.

that no longer has the aspect ratio of 4:3. Not very much of the picture is lost—just that in the corner areas that are blackened here—but the picture is distorted because the image produced is higher than is normal for its width. In other words, we are now getting a square picture from the rectangular picture that is actually transmitted.

If we maintain the proper aspect ratio, but enlarge the picture so that the height is equal to the useful screen diameter as shown in Fig. 7C, then we will get just the center portion of the picture. It will be undistorted, but all of the area that is shown in black here will be lost. It so happens that the chief object of interest on the television screen is often a single individual standing near the center of the picture area, in which case loss of the sides of the picture is unimportant. However, if the action spreads out, such as when a chorus line is dancing, for example, or if any other horizontal actions occurs, a great deal of the interesting part of the picture is lost.

For these reasons, the mask styles shown in Figs. 7A and 7B are the most popular. The useful areas are determined by the cut-out opening in the cabinet of the set; the size and drive controls on the set are adjusted until the picture image just fills this mask area.

ZOOM CONTROLS

Since the picture arrangement of Fig. 7C produces an enlarged center portion of a picture, and since this is satisfactory for certain subjects for intermittent viewing, some receivers are equipped with systems for changing instantly from one mask size to another. On such sets, the only physical mask is a circular one—the same size as the useful area of the particular tube screen. The receivers produce a smaller picture that does not fill this mask, like those shown in Fig. 7A or 7B, until the enlarging switch is thrown, at which time the picture size jumps to that of Fig. 7C. Fig. 8 shows a typical example. The "zoomed" or "opera-glass" enlarged picture produces an appreciably larger image of the scenes on which it can be used, but of course does not give an enlargement of the entire picture area unless the system is arranged to switch to the distorted style of image shown in Fig. 7D.

To switch the picture from one size to another, there are two sets of controls for the vertical and horizontal size controls, two sets for the linearity or shaping controls, and two brightness controls. Usually, a 5-pole, double-throw switch is used to change from one set of controls to the other. Fig. 9 shows two sections of such a switch. When it is thrown to the "normal" position, voltage is applied to the set of controls that is adjusted to give the normally masked image with the proper aspect ratio and with very little loss of the total picture area. When the switch is thrown to the other or "zoom" position, the other set of controls is switched in; the settings of these are such that the verti-

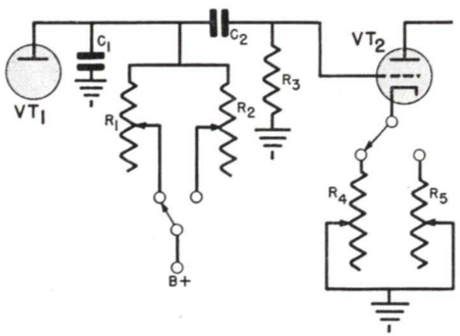


FIG. 9. Schematic showing dual controls for zoom purposes.

cal size, vertical linearity, horizontal drive, horizontal linearity, and the brightness are increased so much that the image makes full use of the entire screen area of the tube.

MAGNIFIERS

A way of getting a larger picture without making any change in the set is to use a magnifying lens in front of the tube. This blows up the whole picture to a larger size. Fig. 10 illustrates a typical installation.

As shown in Fig. 11, when an object is properly placed behind a double-convex magnifier lens, the light rays from the object are bent. To an observer, however, they appear to be coming in a straight line from a considerably larger image. In other words, the observer in Fig. 11 sees

Courtesy Celomat Corp.

FIG. 10. A typical lens magnifier.

an enlarged image of the object, rather than the object itself. The amount of magnification depends on the curvature of the lens and on the position of the object behind the lens.

Since the face of the picture tube represents a fairly large, flat area, it is not practical to use a double-convex magnifying lens like that shown in Fig. 12A to magnify it: because of the curvature of the lens, its center will be closer to the tube face than its ends will be, and distortion will therefore be produced. Instead, we use a lens that has one plane or flat surface as shown in Fig. 12B. Of course, if we take a double convex lens and cut it in half to get this shape, the distance behind the lens that an object must be placed to be brought to focus is greatly increased, because there is only one curved surface instead of two to give the enlargement. Therefore, it is necessary to use a relatively thick

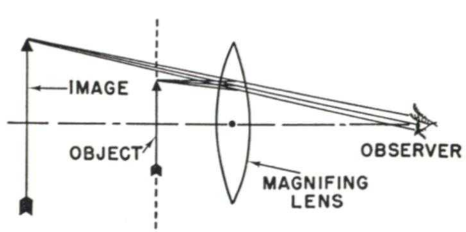


FIG. 11. How a magnifying lens produces a larger image.

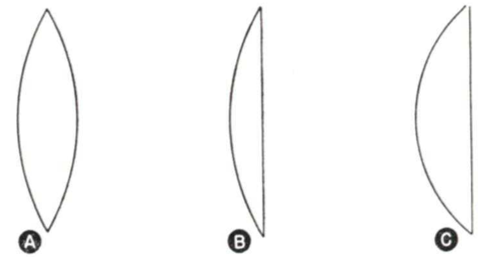


FIG. 12. Magnifying lens shapes.

plano-convex lens, as shown in Fig. 12C, to make it possible to keep the lens close to the face of the picture tube.

The lens used has to be larger than the picture tube face. Obviously, it would be very expensive to cut a glass lens of this size and grind and polish it to the proper shape. To reduce the cost, lenses are instead molded out of plastics, usually Lucite or Plexiglas.

Some of the earlier plastic lenses were solid plastic. However, it was discovered that it was far cheaper, and just as satisfactory, to mold a plastic "bubble" that could be filled with an oily liquid. Two styles of lenses of this kind are shown in Figs. 13A and 13B. In each case, the lens consists of a flat plate to which the molded curved portion is cemented. In the style shown in Fig. 13A, a small filler plug (1) is left open and the liquid is poured into the space between the flat plate and the curved face. Then the plug (which is in a portion of the lens that is not used to view the picture) is inserted. Ordinarily it is not possible to fill the lens absolutely full of liquid, so a small air bubble may be observable when the lens is in the position shown in Fig. 13A. However, when the lens is placed upright in its normal position in front of the picture tube, this air bubble moves out of the way (to the top of the lens).

In the lens style shown in Fig. 13B, the curved portion is filled with the liquid before it is cemented to the flat plate, or else a small filler opening is left at the joint (2).

Fig. 14 shows three ways of supporting the lens in the proper viewing position. In the sketch shown in Fig.

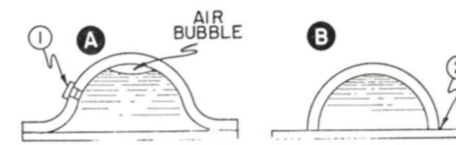


FIG. 13. Liquid-filled lens.

14A, the lens is held in front of the tube by a cord or strap that goes over the set cabinet and hooks at the rear. The lens is spaced out from the picture tube by small plastic bumpers behind the lens.

In the style shown in Fig. 14B, the lens is screwed right to the front of the cabinet. A third mount, shown in Fig. 14C, consists of a frame or bracket that slides underneath the set cabinet. The weight of the set then holds down the rear of the bracket so that the lens is supported in the proper posi-

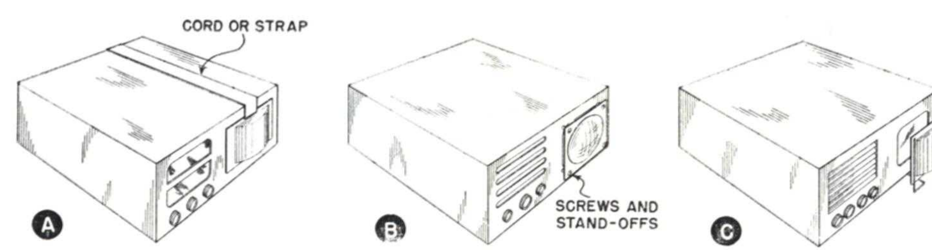


FIG. 14. Typical lens supports.

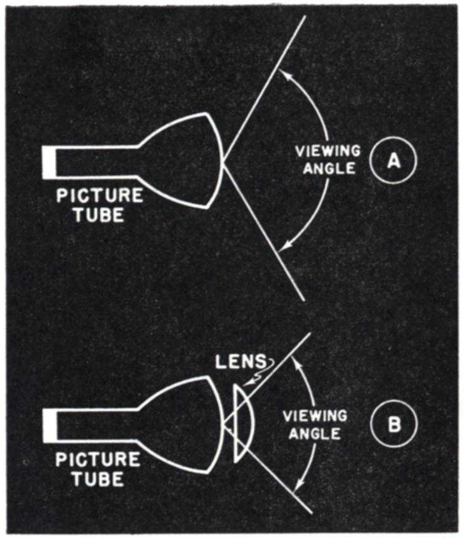


FIG. 15. A lens reduces the viewing angle.

tion. Most systems of this kind are arranged so that the lens can be slid up and down on the bracket to bring it into the proper position for the particular cabinet in question.

Associated with every lens is a distance called the focal length, which is the distance from the lens at which it brings parallel light rays to a focus. If the distance between the picture tube and the lens is less than the focal length, the lens will present a magnified image of the tube face to the viewer; and the farther apart the lens and the tube are, the larger this image will be. If the separation between the two becomes equal to the focal length, however, the magnification will become infinitely large, and the light rays coming through the lens will become parallel, thus making it impossible to see the image. At still greater separations, the image formed by the lens will be inverted and small. The lens must therefore always be separated from the picture tube by a distance that is less than the focal length.

As we said, increasing the separation between the lens and the tube increases the size of the image. However moving the lens away from the picture tube also greatly restricts the viewing angle. When no lens is used, it is possible for people to be at a rather sharp angle with respect to the face of the picture and still be able to see the picture, as shown in Fig. 15A. As soon as a lens is used, however, the people at the extremes of the sides cannot see all of the image. In other words, as Fig. 15B shows, the viewing angle is decreased by the addition of a lens.

This effect of decreasing the viewing angle is made worse as the lens is moved away from the tube to increase the magnification, as shown in Fig. 16. If the picture is enlarged very much, therefore, it may be impossible for more than one or two people to see it.

Some lenses give somewhat more magnification than others for a given viewing angle, depending on their size

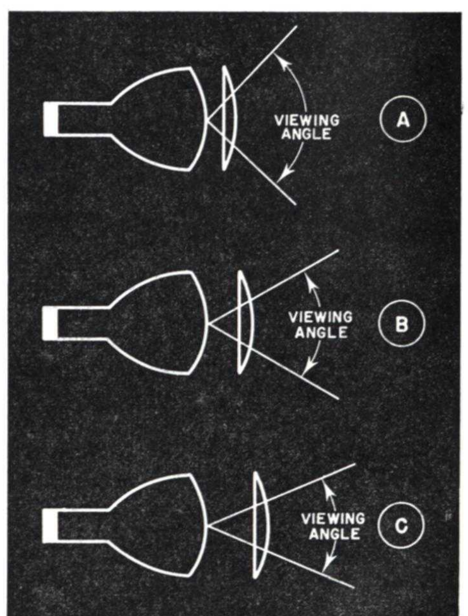


FIG. 16. As the lens is moved to increase the size of the image, the viewing angle is further decreased.

and shape. For this reason, you should check on the viewing angle and magnification of any lens to see if they are acceptable before buying it.

In an attempt to solve the viewing angle problem, some lenses are made as shown in Fig. 17. A rubber sheet

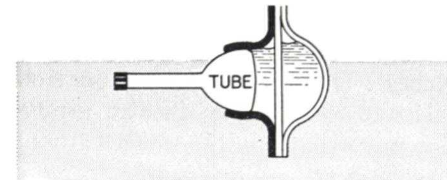


FIG. 17. A coupled liquid-filled lens.

or jacket that is secured to the lens makes a water-tight seal between the lens and the tube, and the space between the picture tube and lens is filled with the same kind of liquid that is in the lens. The result of directly coupling the lens to the tube in this manner is that the image seemingly appears to be on the face of the lens. As a result, this lens system gives a very wide viewing angle—practically the same as that obtainable without a lens at all.

A disadvantage of such a lens system is that it is much more difficult to install. It may be necessary to modify the cabinet to make it accept the lens if the masking opening on the cabinet will not permit the lens coupling to go in and be fastened around the tube. Such a modification of the cabinet may or may not be practical, depending on the conditions in each case. Further, the addition of the lens makes it rather difficult to replace the tube and to service the set, because the tube-lens assembly must be removed as a unit if the liquid is to remain within the sheath between the lens and the tube.

An entirely different method of making a lens is shown in Fig. 18. This lens, known as the "Fresnel" type, consists of a number of circular engravings on a flat sheet of plastic. As shown in the enlargement in Fig. 18B, each succeeding cut on the face of this plastic is at a different angle, so that the sum of their surfaces is equivalent to the surface of a lens having the thickness shown by the dashed line. Effectively, therefore, a thin sheet of plastic can be made to act just like a very thick plano-convex lens by shaping it this way.

If the plastic has a sufficient number of these cuts or ridges in it, and they are accurately cut, this system proves satisfactory. Because of its simplicity, and the small amount of material in it, such a lens is somewhat less expensive than some of the other types.

It is important that the lens be mounted accurately with respect to

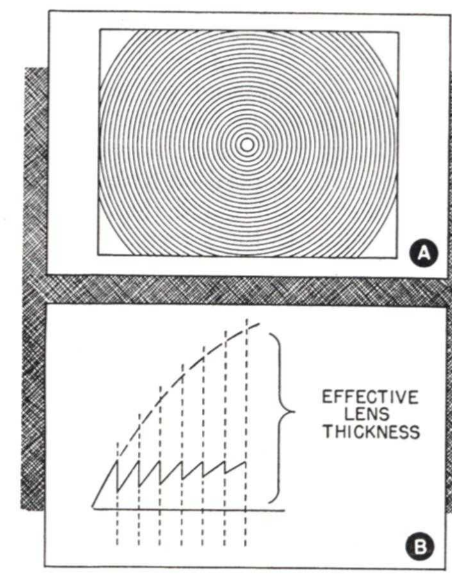


FIG. 18. A Fresnel lens.

the face of the picture tube—otherwise a very distorted image will be produced. In addition to its cost, the care needed to mount it, and the restriction in viewing angle that it causes, a lens has the disadvantage that it absorbs a considerable amount of the light traveling through it and therefore reduces the brightness of the image somewhat. Finally, the sharp curvature of the lens introduces problems because of glare due to reflections from light in the room. (We'll study glare in more detail later in this Lesson.) For these reasons, a lens is by no means a perfect solution to the problem of getting a larger picture. Nevertheless, a fairly large number of lenses are in use, particularly with 7-inch and 10-inch picture tubes. They are not very frequently used with the larger direct-view tubes because they cost so much in these sizes.

The direct-view tubes that are in use today are about as large as we can expect to go and still have them reasonable in cost, size, and weight. If larger images are desired, it is necessary to turn to projection systems. As a matter of fact, many home receivers use projection units that give images not much larger than some of the direct-view tubes (about 12 x 16 inches). Other units build on up from this size to the large theatre projection units that produce images around 18 x 24 feet!

Projection Systems

The most obvious projection system consists of using a projection lens (like those used in movie or slide projectors) in front of the picture tube to throw an enlarged picture on a screen as shown in Fig. 19. The size of the image on the screen depends on the lens used, its position with respect to the picture tube, and the distance from the lens to the screen.

The brilliancy of the picture on the ordinary picture tube is far too low for a projection system of this sort. There is a considerable loss of light in the directions A and B in Fig. 19, and, in addition, there is more loss in the transmission through the lens system itself. Finally, when even a rather brilliant small picture is spread over a much larger area in the projected picture, there is a drastic reduction in the amount of light per unit of area. Hence, even though a small direct-view tube may give a picture of sufficient brilliancy to be easily seen in a brightly lighted room, this same image projected on a screen and thus enlarged several times would be difficult to see even in the dark.

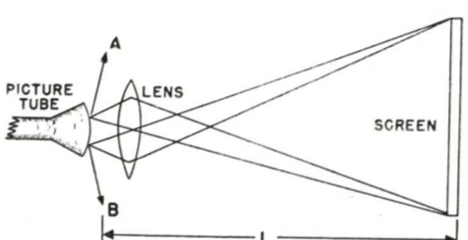
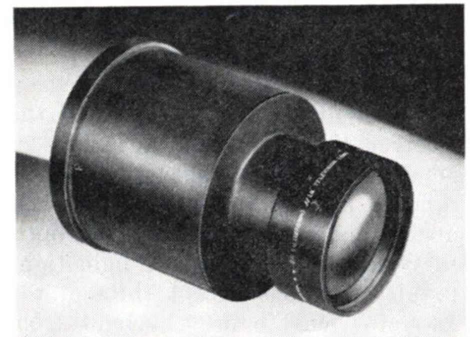


FIG. 19. Lens projection.

The practical solution to the last problem has been the development of special projection-type picture tubes. To begin with, it is desirable to have a tube of small diameter so that the original picture will be small; this simplifies the lens design and allows the use of a less expensive lens system. Then, a picture of very high brilliancy is produced on the face of the tube. This is done chiefly by using very high accelerating voltages (they range from 25,000 to 30,000 volts for home projection units and are as much as 80,000 volts in theatre systems), which produce an extremely bright spot. The brightness of the picture is further increased by using a tube having an aluminum backing behind the fluorescent screen to reflect forward through the face the light that would ordinarily be directed toward the back of the tube and lost. In this respect, a projection tube is like the "daylight" tubes used in many direct-view sets.

The basic "standard" receiver is used in such projection sets. The only modifications consist of using the projection tube, a higher voltage supply for the tube, and usually an increased sweep output.


Courtesy Bausch and Lomb Optical Co.
A TV projection lens.

Because the initial picture is very bright, a lens system can be used to project it on a viewing screen. Even so, in the larger screen sizes, the image is not as bright as that of a direct-view tube, but many people are willing to accept it anyway because of its large size.

Although the system is practical for theatre and club use where a very large image is desired, the system using an optical projection lens shown in Fig. 19 is not much used in home set-ups. One reason is that most of these systems require a fair amount of space; another is that the room in which the set is used must be kept rather dark, much as it must be for home movies. For these reasons, a somewhat different projection system is more commonly used in home installations.

This latter projection system, which was borrowed from the astronomers, makes use of a spherical mirror instead of a projection lens. The particular arrangement of elements in this system is such that more efficient light gathering is obtained, with the result that the image is somewhat brighter than that obtained by the use of a comparable projection lens. Furthermore, this system is more desirable for homes because it is far less costly and much more compact than the lens system.

MIRROR PROJECTION

Fig. 20 shows the basic details of the projection system that is used today in most home receivers and also in many of the large commercial systems. Briefly, the projection tube faces a spherical mirror, and the image from the mirror is brought to focus on a screen at the proper distance away. As long as the projection tube is placed within the focal distance of the spherical mirror, the image at the remote point will be an enlarged one. Whereas the efficiency of a lens system is only about 5% to 10%, mirrors such as this have efficiencies much nearer 30%, so that a considerably brighter image can be obtained.

The spherical mirror by itself will not bring the image to a proper focus. It is necessary either to grind the mirror to a special shape, which would make it extremely costly, or to use a corrector lens. The corrector lens itself has a rather peculiar shape and would be costly if it were ground from glass. However, these corrector lenses are today molded from plastic mate-

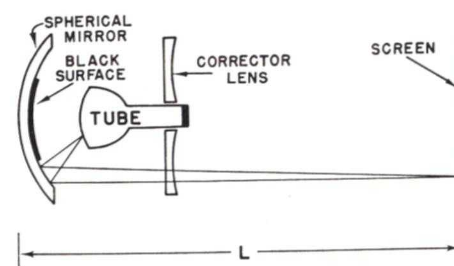


FIG. 20. Spherical mirror projection.

rial so that they are relatively inexpensive.

Fig. 21 shows why the corrector lens is needed. Let's assume that the point O in this figure is a particular spot that is illuminated on the face of the projection tube. Notice that light

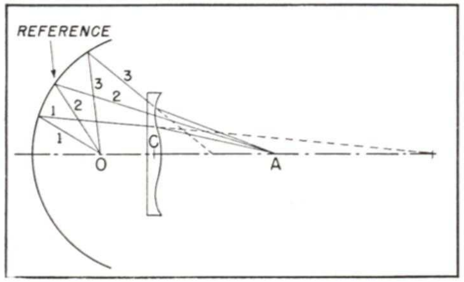


FIG. 21. How the corrector lens works.

originating at this point will be reflected to different points along the axis line O-A if the spherical mirror alone is used (follow the dotted lines).

Thus, light that follows path 1 strikes the axis at a point far removed from the place where light would fall if it traveled along path 3. Let's say that we want all the light rays to strike the axis at the same point A as the ray following path 2 does. We can produce this effect by using a corrector lens having the shape shown, which will bend the rays traveling along paths 1 and 3 so that they come together with that from path 2 at point A. In fact, if we use a corrector lens of the proper shape, we can bring all the light rays from the spherical mirror to a focus at the desired point.

The exact shape needed for the corrector lens depends on where it is placed in the light path. This lens does not enlarge the image or otherwise change it—all it does is bend the various rays of light so that they all come to the same focal point. The magnification that is obtainable in the system depends entirely on the size of the spherical mirror and its position with respect to the projection tube and the screen.

The combination of the spherical mirror and corrector lens to produce an enlarged image was first developed by an astronomer named Schmidt for use in telescopes. For this reason, you will sometimes find that a projection television system of this sort is called a Schmidt lens system.

If the image is to be projected on a screen at some distance from the receiver, the system shown in Fig. 20 is used much as it is shown here. The tube is mounted with the spherical mirror and corrector lens in an optical "barrel" that is made light-tight in all directions except through the corrector lens to prevent light from external sources from getting in. The system is focused by moving the tube away from or closer to the spherical mirror, and the entire barrel, including the spherical mirror, can be moved with respect to the screen to determine the size of the image.

Notice that there is a black surface directly in front of the picture tube on the spherical mirror. This section is designed so as not to reflect light at all. This is necessary so that light coming from the tube will not be reflected directly back on the face of the tube; if this were to happen, the contrast of the image would be reduced. The rest of the spherical mirror surface reflects the light from the picture tube through the corrector lens rather than back at the tube.

Care of Mirrors. The spherical mirror used in this optical system is unusual in that the reflecting surface is on the face of the mirror rather than on its back. The ordinary home mirror has the silvered surface on the back of the mirror, so that the glass acts as a protection for it. If a back-silvered mirror were used in a system such as this, however, the light rays from the projection tube would have

to go through the glass, strike the reflective coating, and then come back through the glass, with the results that they would be bent at the points of entering and leaving the glass, and that light would be lost in traveling through the glass. Therefore, the silvering is placed on the top surface of the mirror, where it faces the tube itself. It is very important that you never touch the mirror surface either with your hands or tools, because the oil and acids normally present on the skin will attack the mirror. This will result in discoloration and corrosion of the surface with consequent loss of reflecting ability. If it is necessary to handle such a mirror, be sure to touch it only on its rear surface or on the extreme edges where it is not coated for reflection.

To prevent dust from collecting on the mirror, the optical barrel is usually made dust-tight. Should there ever be any need for cleaning such a mirror, a small, soft, camel's-hair brush can be used to pick up the dust. It is important to avoid the use of water and other cleaning compounds on these mirrors. Should you by accident touch a mirror, refer to the instructions accompanying the set, because sometimes the manufacturer will recommend a particular cleaner that can be used safely. If you find no such recommendation, however, contact the distributor for instructions rather than damage the mirror by attempting to clean it.

The corrector lens is made of soft plastic material and is very easily scratched; even rubbing it with a cloth may mar it. Again cleaning fluid should be avoided, since the chemicals in some of them may eat away plastic. Use a camel's-hair brush for dusting; for cleaning, again consult the manufacturer's instructions.

There are two basic screen arrangements that may be used. In one, the screen is just like a movie screen, and the image is viewed from the side on which it is projected. In others, the screen is a translucent material on which the image is projected from the rear. Many of these screens are ground glass, although other materials (to be described late) are sometimes used.

THE RCA SYSTEM

Many television receivers use a projection system to give a large image on a screen that is a part of the cabinet. The light path of the system shown in Fig. 20 must be bent for it to be used this way in a cabinet of reasonable depth. In the RCA line of projection receivers, and in all others that are adapted from this line, the system is basically that shown in Fig. 22. Here, a flat plane mirror is mounted at a 45° angle behind a view-

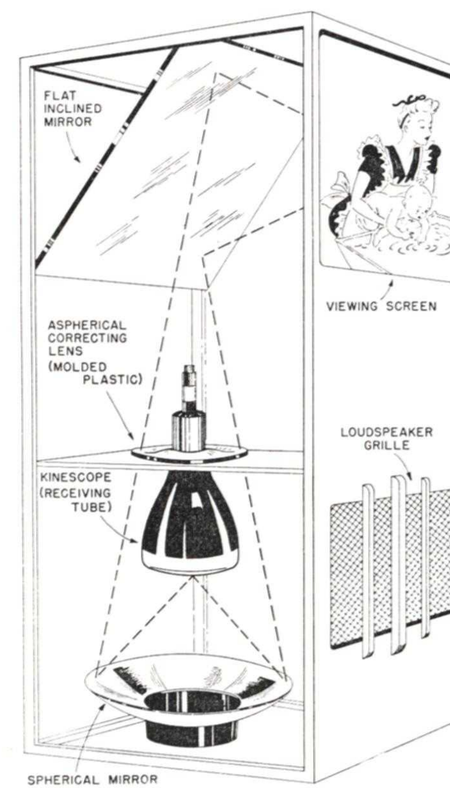


FIG. 22. The RCA projection system.

ing screen, and the image is reflected from this mirror to the screen. Mounting the tube in this way and then bending the optical path with the flat mirror makes it possible to use a cabinet of ordinary depth and not an unusual height to get the enlarged image. The viewing screen commonly

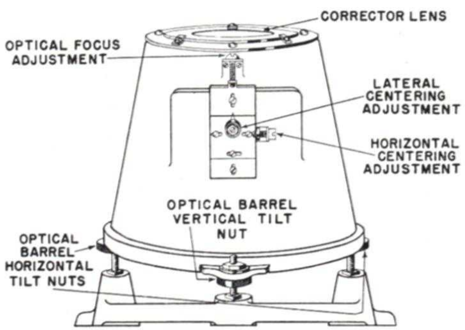


FIG. 23. The RCA optical barrel.

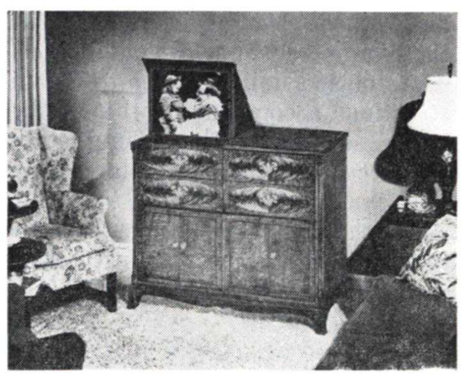
used on cabinets of this kind depends on the design of the cabinet. Common sizes are 16 x 20 inches or 18 x 24 inches—either of them larger than the picture obtainable even on a 20-inch direct-view tube.

A drawing of a typical optical barrel is shown in Fig. 23. The adjustments on the side of the barrel focus and center the image by raising or lowering the tube or by moving it from side to side. The corrector lens acts as the top of the barrel and keeps dust out of it. To keep dust off the top face of the corrector lens, the space between the lens and the plane mirror is usually enclosed in a cloth jacket.

The connecting leads going to the base of the picture tube and to the deflection coils come out through a cable. Although these leads pass through the light path, they do not block any of the image because light from every point on the spherical mirror is used at any one moment to illuminate a point on the screen corresponding to the point illuminated on the face of the picture tube. Therefore, no shadow is cast by these leads. They do reduce the total amount of light reaching the screen, but the loss is very slight.

The cabinet can be kept reasonably low by arranging it as shown in Fig. 24. The screen of this set is secured in a vertical track so that it can be hidden inside the cabinet when the set is not in use but can be brought up to viewing position by raising the lid. In a system of this kind, the lid must come up to exactly the right angle, because the flat mirror is on the lid. Therefore, stops are used in the cabinet to fix the position in which the lid remains when it is lifted.

As we mentioned, the screen itself must be translucent because the image is projected on it from behind and is viewed through it. Ground glass has often been used, but some receivers have a screen that consists of several layers of plastic. The center layer is a diffusing layer. The back sheet of the combination screen is cut to be a



Courtesy RCA

FIG. 24. A typical projection set.

Fresnel lens like the one described earlier. This lens concentrates the light so that it goes directly through the screen. The front layer of the combination has vertical ribs cut in it so that the image can be seen from a somewhat wider viewing angle. This

combination screen and lens transfers several times more light than an ordinary ground-glass screen does and also offers a somewhat wider viewing angle. Even so, however, the image on such a screen is bright and clear only within a restricted angle; if one gets too far to the side, the image will practically disappear.

Incidentally, it is not easy to adjust the contrast and brilliancy properly when you are right next to a screen of this kind, so some projection sets have remote control equipment that permits the contrast and brilliancy to be adjusted from the normal viewing position. Such a control does not provide tuning; it is still necessary to operate the tuning control at the set itself.

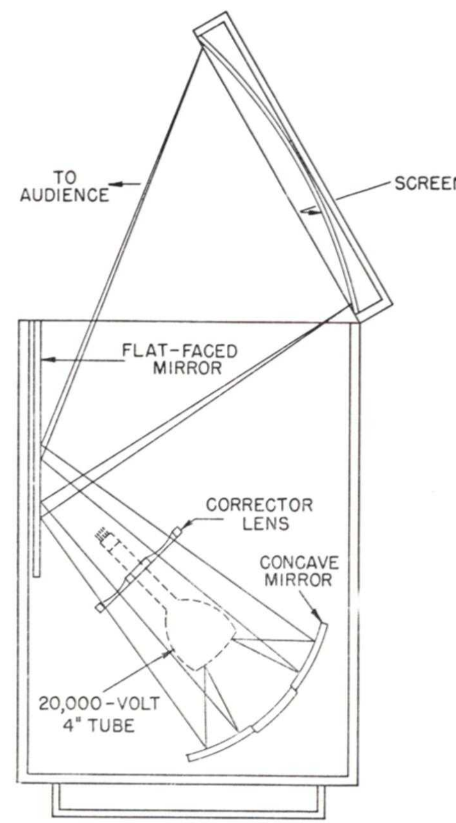


FIG. 25. The Philco system.

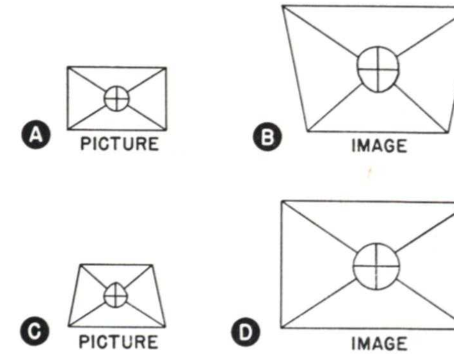


FIG. 26. Keystoning and its correction.

THE PHILCO SYSTEM

Instead of using a translucent screen and projecting the image on the rear of it, the Philco system is arranged so that the image appears on the front of the viewing screen. The shape and reflecting qualities of the viewing screen are such that this system gives somewhat greater light transfer than does rear projection. However, a rather special arrangement is necessary within the set to avoid distortion of the image.

The basic light path is shown in Fig. 25. A projection tube is used in a Schmidt lens system very similar to that of the RCA receivers. The image is reflected from a spherical mirror through a corrector lens to a flat mirror, which then reflects the image onto the front of the viewing screen. In this case the viewing screen is mounted on the lid of the cabinet and is raised to an angle of about 67½° for normal viewing from the front of the cabinet.

The basic difficulty with this system is the fact that the optical barrel is not at an angle of 45° with respect to the plane mirror and that the light path is not at right angles to the viewing screen. As a result, a rectangular picture (Fig. 26A) on the face of the picture tube will produce an image on the viewing screen having the shape shown in Fig. 26B, in which the top of the image is wider than the bottom. (This is called a "keystone" image because its shape is the same as that of the keystone of a stone arch.)

This difficulty can be avoided by distorting the picture on the face of the picture tube so that it has the trapezoidal shape shown in Fig. 26C. Then

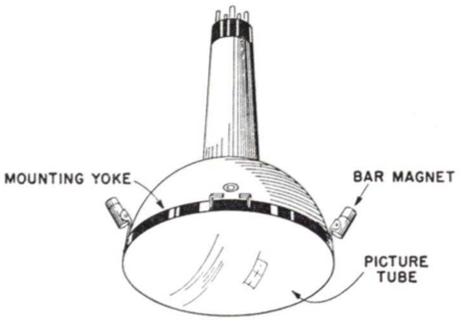


FIG. 27. Keystoning magnets in place.

the distortion in the picture will exactly cancel the distortion introduced by the optical system, and the resulting image will appear in the correct proportions (Fig. 26D).

The required distortion of the initial picture is easily obtained by using a magnetic field to bend the electron beams. Two bar magnets are placed on opposite sides of the tube face as shown in Fig. 27. The magnets are held by a yoke that surrounds the edge of the tube. The positions of these bar magnets can be adjusted to produce a picture on the tube that will be distorted in just the right way to cancel the distortion in the optical system. Because these magnets give the initial picture a keystone shape, they are known as keystoning magnets.

Since the image is formed on the front of the viewing screen, the screen is designed to reflect light rather than to transmit it. It is curved slightly to decrease the vertical viewing angle. This arrangement increases the brightness of the image, because light that would otherwise be directed up or down is concentrated by the curved screen into the forward direction. The screen has vertical ridges in it that are intended to increase the width of the viewing angle somewhat and to decrease glare caused by light that strikes the screen from the side.

This viewing screen is mounted on the inside of the lid of the cabinet, so that the lid must be raised to make the picture visible. There is a special stop arrangement on the lid that allows it to be brought up to the proper position for viewing but no farther.

THE PROTELGRAM SYSTEM

As Fig. 23 showed, the optical barrel in the Schmidt lens system described so far is somewhat bulky. For this reason, a fairly large cabinet is needed to house such a system.

The Protelgram system developed by the North American Philips Company, however, has an optical barrel small enough to be housed in a table-

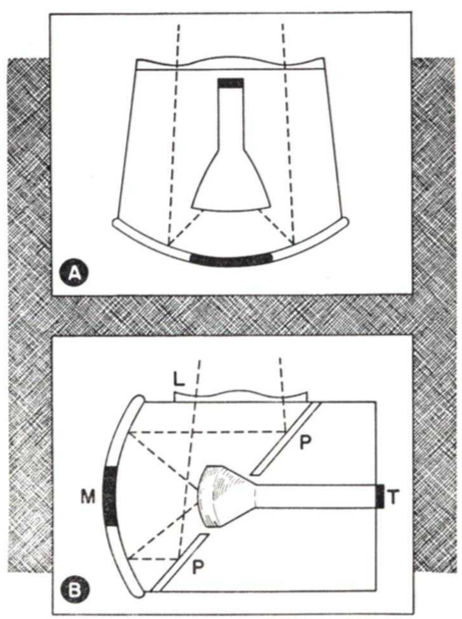
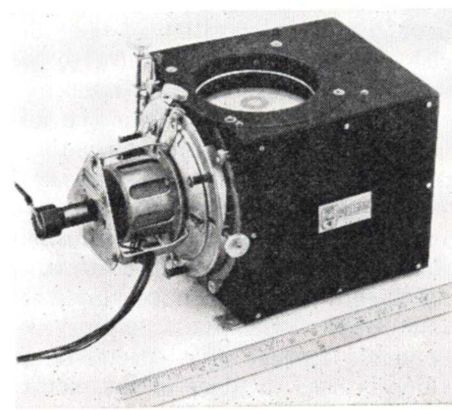


FIG. 28. The Protelgram box compared to a standard barrel.

model receiver. This reduction in size is produced by using a "folded" Schmidt lens system and a 2½-inch projection tube. The basic difference between this and the system used by RCA and Philco is shown in Fig. 28.

As you can see, the tube is inserted in the box in front of the curved mirror M in much the same manner as in the other systems. However, the light path from this mirror M is to a plane mirror P mounted at a 45° angle, which reflects the light up through the correcting lens L and thus out of the box. The projection tube T is inserted through a hole in the



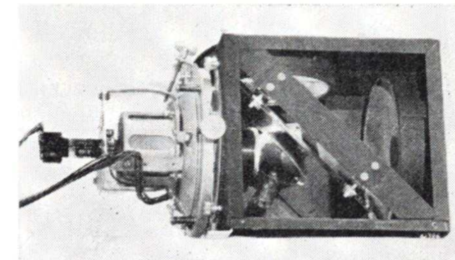
Courtesy North American Philips Co.

FIG. 29. An external view of a Protelgram unit.

the tube except its face is taken completely out of the light path—the center of the plane mirror P. All of focusing coils, wiring, socket, etc., are not in the way at all. This eliminates some of the light losses experienced in the other systems.

The use of a small picture tube, which makes it possible for the spherical mirror to be small also, and the use of the plane mirror to bend the light path, result in a compact optical unit. A general idea of this optical unit's appearance can be obtained from Figs. 29 and 30. In Fig. 29, the tube and the deflection coils are shown projecting out of the box. In the opened view of Fig. 30, you can see the spherical mirror, the inclined plane mirror, and the corrector lens at the top of the box. Notice how just the tube face protrudes through the plane mirror.

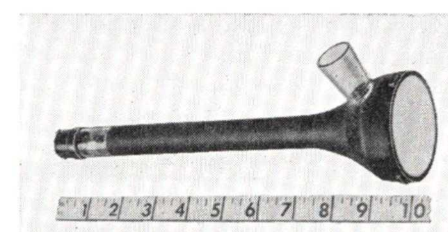
Fig. 31 shows the tube itself. As you can see, it is very small in size.



Courtesy North American Philips Co.

FIG. 30. A cut-away view of Protelgram box.

The glass cup on the bell of the tube near the face is used to insulate the high-voltage connection from the outside of the tube, which is completely covered by a grounded conductive coating. When the high-voltage connection is made inside this glass cup, the leakage path from this connection to the outside conductive coating is the total path up the inside wall of the cup and down the outside. Hence, this cup acts as an insulator.



Courtesy North American Philips Co.

FIG. 31. A projection tube.

As shown at the left in Fig. 32, the Protelgram optical unit can be installed in a console cabinet if desired. Because of its small size, it is also possible to lay the unit on its side, as shown at the right in this figure, and use an additional mirror to get a very compact unit that will fit into a table cabinet. Either of these arrangements in cabinets of the size indicated in Fig. 32 will give a picture of 12 x 16 inches. In addition, this unit can be used for projection onto a screen on the wall,

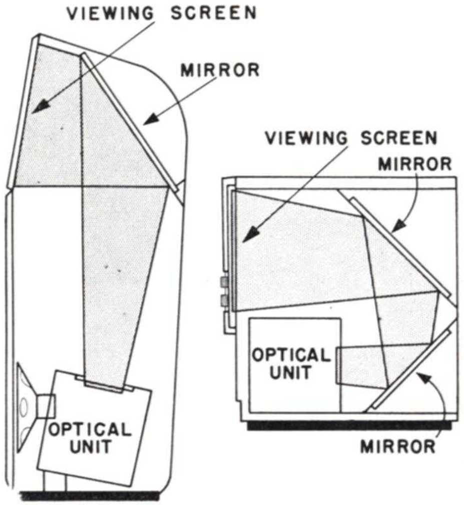


FIG. 32. Two ways of mounting a Protelgram unit.

in which case it can be made to give a picture as large as 3 x 4 feet.

SUMMARY

From the foregoing details, you can see that projection sets are basically much like direct-view sets. The same receiver chassis can be used in either —the only basic differences are that the former use a projection tube and a higher-voltage power supply and sometimes need a greater sweep voltage. Also, it may be desirable to use a somewhat higher signal on the grid of some projection tubes, in which case the contrast control setting may be at a higher level or an additional amplifying stage may be used in the video amplifier. In general, a projection receiver is otherwise identical with a comparable direct-view set.

You will, therefore, find the usual TV controls on a projection receiver. In addition, there will be the controls that are necessary for proper focusing and picture centering of the projection unit. These controls are physical, rather than electrical; that is, they move the actual position of the tube with respect to the mirror (or to the lens in a lens system). A later text will give more details about the adjustment of these controls. Since there are several variations on the basic systems we have described, it is wise to consult the manufacturer's information for exact details before attempting to adjust one. For example, in some systems the manufacturer recommends the use of a special lamp, which is used in place of the picture tube, to get the optical system lined up. Once the optical system has been brought to a proper focus, the lamp is removed and the picture tube is installed in its place. In other systems, the optical system is lined up with the picture tube already installed.

Eye-Strain and Glare Filters

An important factor affecting the quality of a television picture is its contrast range. By "contrast," in this case, we mean the brightness range between the lightest and the darkest part of the picture. Illumination experts consider that a good picture, whether film, painting, television, or engraving, should appear to the eye to have a contrast range of approximately 30 to 1. This means that the highlights or brightest portions of such pictures, when viewed with normal surrounding illumination, should be about 30 times as bright as the darkest shade obtainable.

With paintings or photographs, this is not too difficult a range to obtain, because dyes, paints, and printing inks used for black are extremely light-absorbent. The black level, therefore, is very low, so a highlight 30 times as bright can readily be secured by using good paper or white pigments.

In the television and motion pictures, however, the "black" is actually just the absence of light, so we can have no true black. The darkest shade we can get is determined by the amount of the surrounding light that is reflected from the screen surface. Therefore, if we start out with a "black" that is actually well up in the gray region, the highlight brightness must be very high if we are to get our desired contrast range. In the case of motion pictures, it is not practical to get such extremely bright levels; for this reason, motion pictures must be viewed in the dark so that the dark elements of the scene will be more nearly black, making it possible for a reasonable light level to represent the lighter portions of the scene.

There are two reasons that make it undesirable to view a television picture in complete darkness—first, it is often inconvenient to try to make a room dark enough, and secondly, viewing such an image in the dark tends to produce eye strain. This strain results from the fact that the eye becomes tired in attempting to accommodate for both the bright picture and the surrounding blackness.

For these reasons, it is desirable to view a television image in a room that is at least reasonably well lit. As a matter of fact, it is the opinion of lighting experts that the amount of light on the surrounding walls should be approximately equal to the highlight brightness in the pictures that are to be seen. This means that the room should be almost normally illuminated for most television picture viewing.

As soon as we introduce such light levels, however, we are back to our original problem of a "gray" black and may even encounter cases of a "mirror" reflection or of glare. Let's see what can be done to avoid these difficulties.

SCREEN ILLUMINATION

As a practical example of the effects of the ambient (surrounding) illumination, let us first assume that we can have a television picture having the optimum range of contrast of 30 to 1. This means that if the brightest point in the scene has a brightness of 30 foot-lamberts (a foot-lambert is a unit of brightness used by lighting engineers), the darkest portion of the scene must have a brightness of only about 1 foot-lambert.

Now, let us suppose that we light up the surrounding room to a brightness of 20 foot-lamberts, which is the level that may be found in a fairly brightly lighted living room. The viewing screen is necessarily also lighted to the same level. The viewing screen is not a perfect reflector, but it may easily reflect half the light falling on it, so now the lowest level of brightness of the screen is 1 plus 10, or is 11 foot-lamberts. Since the minimum blackness we can get is equal to the lowest light level that the screen can reach, our "black" level is now 11 foot-lamberts.

This same 10 foot-lamberts is added to the highlight brightness also, making the highlight brightness now 30 plus 10, or 40 foot-lamberts. However, notice what has happened to our contrast range. It is now 40 to 11 (instead of 30 to 1) or only about 3.6 to 1. Effectively, we now have a washed-out grayish-white image.

To get back the proper 30-to-1 contrast range, the contrast and brightness controls on the receiver would have to be turned up to make the highlight brightness 30 times 11 or 330 foot-lamberts. This would be far too bright a picture for any degree of comfort; in fact, it is a higher light level than the average receiver can produce.

Obviously, therefore, there are only two things that can be done if we are going to get anywhere near the optimum contrast range. One is to greatly reduce the surrounding light, with its attendant problems of being inconvenient and perhaps causing eye strain; the other is to reduce the amount of light that is reflected from the viewing screen. The latter idea brings up the use of light filters. Let's take our example and see just what a filter will do.

In Fig. 33A, we have the screen that is transmitting a highlight brightness of 30 foot-lamberts and a "black" brightness of 1 foot-lambert. Let's assume that the screen has a 50% reflectivity—that is, that it reflects 50% of the light falling on it. If the light from the room falling on this screen is 20 foot-lamberts, the screen will reflect a total of 10 foot-lamberts. Our maximum possible contrast range is now in the ratio of 40 to 11, or about 3.6 to 1.

Now, let's place a light filter in front of this television screen (Fig. 33B). This filter is a light gray sheet of cellophane or similar material of such a nature that it will pass only part of the light that is trying to go through it. Let's first assume that it passes half the light. In this case, the 30-foot-lambert highlight brightness of the picture is reduced to 15 foot-lamberts, and the "black" brightness will be reduced to 0.5 foot-lambert. However, notice what happens to the surrounding (ambient) light. This light must go through the filter to fall on the screen and then must come back through the filter a second time to come out. Therefore, if we have a surrounding light of 20, it is reduced to a value of about 10 before it strikes the viewing screen. Since the screen reflects half the light falling on it, this 10 will return to the filter as 5 foot-lamberts and will be reduced in half again (to 2.5) in passing through the filter a second time. Therefore, our minimum light level has been reduced to 2.5 + .5 or to 3 foot-lamberts. With no change in the original picture brightness, we now have a ratio of 17.5 (15 + 2.5) to 3, which is 5.8 to 1 instead of our original 3.6 to 1.

Of course, we started with an original picture highlight brightness of 30 foot-lamberts. If this represents the highlight brightness that we desire, and if the set has sufficient range, we now can increase the original picture highlight brightness to let us say 60 foot-lamberts, increasing the black brightness to 2 foot-lamberts at the same time. This will be reduced in half by the filter so that the highlight brightness on the viewing side of the filter will be only 30, but we will now have a range of (30 + 2.5) to (1 + 2.5) which is 32.5 to 3.5, or 9.3 to 1. Notice that we obtain this increased range with no increase in the actual brightness of the final picture.

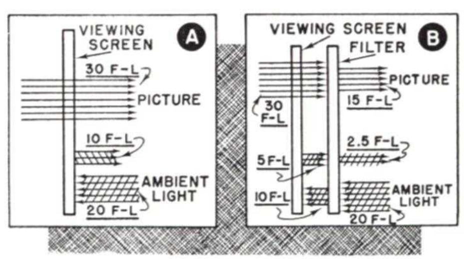


FIG. 33. How a light filter reduces reflection.

Of course, we could have increased our illumination to 60 in the first case (without the filter) and thus could have nearly doubled the contrast range, but this would have been at the expense of producing an excessively bright scene.

Fig. 34 shows what happens if the filter cuts out even more of the light —if it only transmits, let us say, 20% of the light. We now need 150 foot-lamberts from the screen to give us a highlight brightness of 30, but our 20 foot-lamberts of ambient light goes through the filter to appear as only 4 on the screen. This is reflected as 2 and comes through the filter the second time as only .4 foot-lambert. This gives a contrast range of 30.4 to 1.4 or 21.6 to 1, which closely approaches the desired 30 to 1.

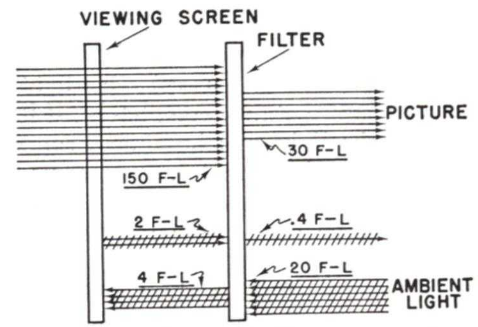


FIG. 34. A filter with 20% transmission.

You can see, then, that it is possible to get an increased contrast ratio in a room that is normally lighted by using a filter in front of the face of the viewing screen, whether this viewing screen be a direct-view picture tube or the screen on a projection system. It is necessary to run the picture at a higher initial brightness level to achieve this, however, and if the set is not capable of producing a sufficiently bright picture, the filter is not as effective. For this reason, filters are less commonly used on projection sets than on direct-view types.

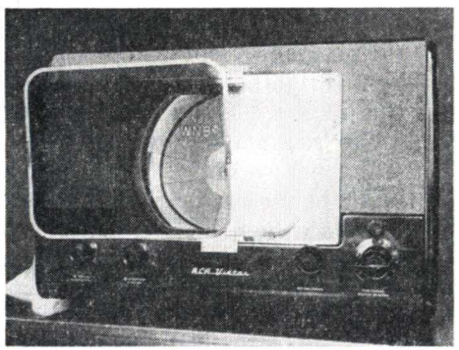
It is important to realize that this filter improves the contrast only by reducing the effect of ambient light. It can do nothing whatever about limited contrast ranges in the pictures themselves. Many television pictures have low contrast ranges, and these may be further compressed by improper adjustment of the contrast and brightness controls on the receiver. Therefore, it is well to be cautious about statements that a filter will increase the contrast in the picture, because this may not necessarily be so at all. The filter merely makes it *possible* for a full contrast range to be visible when there would be such a range in the picture on the tube if it were not for the ambient light.

Notice that the filter will work satisfactorily only when it is in front of the picture screen so that the room light falling on the screen will be doubly cut down. Holding such a filter directly in front of one's face will do nothing except cut down the highlight brightness of the picture. For this reason, goggles or spectacles made like sun glasses will not work in the manner we have described. Of course, if the picture brightness is run up to a very high level so as to get the highlight brightness as far from the minimum level as possible, then such goggles will cut down the terrific brightness that would be harmful to the eyes, but this is not as effective as the use of the filter on the viewing screen itself.

Filters designed for improving the contrast by reducing the reflections from the viewing screen are usually neutral gray filters having light transmission abilities ranging between 20% and perhaps 35%. Some of these filters, however, are tinted blue. These filters are considered desirable by some because the image produced by many picture tubes has a yellowish or brownish cast instead of being a pure black and white picture. This may come about because the fluorescent screen materials do not produce a good white, or because the tube has aged and the screen has become slightly burned, or because the high voltage is somewhat below normal. The use of a blue filter will tend to wipe out this color cast and to make the picture appear more truly black and white.

Since people may object to the effects of filters on the color or appearance of the picture, it is always well to be cautious in recommending the use of filters except on a trial basis.

A Polaroid filter recently put on the market uses the phenomenon of polarization of light to eliminate reflections from the picture tube. As you know, ordinary light consists of electromagnetic waves (like radio waves, but much higher in frequency)



Courtesy Polaroid Corp.

This view shows how a Polaroid filter cuts down glare. A set is facing a window reflecting a strong light, and the filter is shown covering half of the tube face.

that vibrate in all directions at right angles to the direction of propagation. Certain natural crystals have the property of passing practically all the light that vibrates in one plane, and of absorbing light that vibrates in other planes, with a maximum absorption of vibrations that are 90° from the plane that is passed. Such crystals are called "polarizers," because the light they pass is polarized (that is, it vibrates in only one plane).

Polaroid is a material that is made by embedding vast numbers of tiny polarizing crystals in a sheet of plastic. It acts as an efficient polarizer: about 50% of a beam of unpolarized light that strikes a sheet of Polaroid will pass through it, emerging as a polarized beam. The rest of the beam will be absorbed. Its action on polarized light depends upon the angle between the plane of polarization of the light and the polarizing plane of the Polaroid. If this angle is 0° (that is, if the light is polarized in the plane that the Polaroid passes), the light will be passed almost completely; if it is 90°, the light will be almost completely absorbed; and if it is somewhere between 0° and 90°, part of the light will be passed, the rest will be absorbed.

In this new filter, a sheet of Polaroid is bonded to another material that has the effect of producing a 45° rotation of the plane of polarization of any light that passes through it. The filter should be placed on a TV set so that the Polaroid side is farther from the tube. When this is done, it will be impossible for ambient light to be reflected from the face of the tube. Let's see why.

The light from an ordinary source, such as an electric light bulb, is unpolarized. When such light strikes the filter, half of it passes through the Polaroid, emerging as polarized light. The plane of polarization of this light is then rotated 45° by the other material in the filter. Next, the light is reflected from the face of the tube back toward the filter. This time, it strikes the rotating material first, so its plane of polarization is rotated 45° more, making a total of 90°, before it reaches the Polaroid again. Since its plane is now 90° from the plane that the Polaroid passes, the light is almost completely absorbed. Thus, no light is able to pass through the filter, be reflected from the tube, and pass out through the filter again.

Half the light from the tube face, however, which is initially unpolarized, is able to pass out through the filter. Thus, the filter acts as a 50% filter as far as the light from the tube is concerned and as virtually a 100% filter for ambient light.

ROOM ILLUMINATION

You can see from what we have said that it is desirable to have normal room illumination, but it is not desirable to have too much light. If the light level is too high, it is practically impossible to get the highlight brightness of the picture high enough to overcome the surrounding level. It is all but impossible to see the picture if direct sunlight is allowed to fall on the screen, for example.

As a further point, it is of course undesirable to have the set placed next to a bright source of light. If you can see a strong light at the same time you are attempting to watch the screen, your eyes will become tired from trying to accommodate intermittently between the strong light and the less brilliant screen, just as they would for the opposite condition of a bright screen and dark surroundings. That is why it is undesirable to place the television set next to a window through which sunlight may come.

In general, therefore, it is desirable to light the room to a normal level, preferably by the use of indirect or shaded lights during evening hours, and, in the daytime, to cut down somewhat on the amount of sunlight present by drawing the blinds at least part way. Strong light should not be allowed to shine directly on the screen nor to be right beside it.

To make it easier to watch a TV picture, the lights in the room must be properly arranged with respect to the set. Glare can be caused by excessive illumination at the wrong angles to the viewing screen. As a matter of fact, the screen is so mirror-like that it is even possible to get reflections and to see the light source in the screen if the former is placed in the wrong position. In general, therefore, it is not desirable to have lights directly behind the viewer so that the light, viewer, and viewing screens are on the same line, and not to have the lights beside the set. The light from all sources in the room should be practically at right angles with respect to the line formed by the television set and the viewer. Under these conditions, with the normal relatively flat-faced viewing screen, the light source may produce some glare but not at least a mirror reflection.

If a magnifier lens is used in front of the set, the problem is quite severe, because the curved surface of the magnifier is practically certain at some point to be of the right shape to produce a mirror reflection.

Color Television

Ever since the beginning of the idea of a television system, many engineers have been working on television in color. Because it is so desirable from the standpoint of natural rendition of a scene, color television is almost certainly the system that will eventually be put into use providing a practical system that is not too expensive can be developed. Involved in this cost problem is not only the initial cost of the receiving equipment, but also the extra costs at the transmitting end, both in original material and in operation.

Of course, a color system, to be practical, must be as reliable in maintaining synchronization as is the modern black-and-white process. As yet, there has been no standardization on color systems because no one system has yet been adopted. In the following, we shall describe four or five basic color systems that are at least in the laboratory developmental stage, so that you will have a general understanding of the problem and can see the direction of thinking of the engineers that are working on this problem. We shall primarily discuss receiving equipment. You can assume that in all cases, the transmitter must use corresponding units to pick up the image.

We cannot say that any one of these particular systems will ever be the one that is finally developed—but from the emphasis on color development in the laboratories today, and from the great public demand for color television, it seems quite possible that the next few years will see a practical system placed on the market. It is even possible that more than one system may come into use if the standards for picture transmission can be set to permit this.

Before we go on to learn about these basic systems, however, let's briefly review a few facts about light.

LIGHT FILTERS

What we know of as white light is actually a combination of all colors in such proportions as to give the effect of white to the eye. However, we need not have *all* colors to produce white, because of the way in which the "primary" light colors blue, red, and green will add together. As Fig. 35 shows, the proper admixture of these three will produce white. Also, it is possible to get white light by combining the complementary colors. Thus, blue and red combined will give magenta, and magenta with green will give white. Similarly, blue and green will give peacock blue, which when added to red will give white. Finally, red and green light combined will give yellow, which when added to blue will give white. Since the three primary light colors can be combined to give all the colors plus white, we can reproduce a full color image if we can have a system that will break down the original image into these three primary colors at the transmitter and recombine them correctly at the receiver.

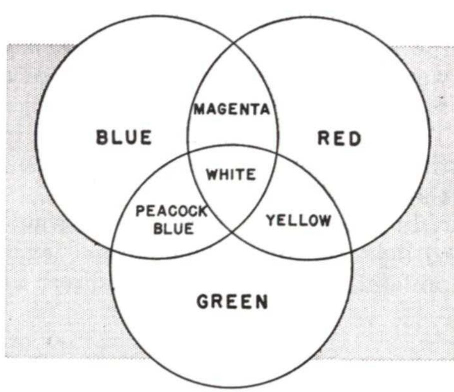


FIG. 35. The effect of mixing various colored lights.

The process of adding colored lights together must not be confused with that of mixing paints or dyes, which is a subtractive process rather than an additive process. For example, when yellow and blue *lights* are mixed, the added colors give white as a result. On the other hand, if you mix yellow and blue *paint*, you will get green paint as a result. The difference lies in the fact that the color you see when you look at paint is the color of light that the paint reflects or transmits; all other colors that may be in the light that strikes the paint are absorbed by it.

Suppose, for example, that a yellow paint is illuminated by white light. The paint will absorb or remove from the white light the blue, purple, and red components; it will reflect primarily yellow, plus some green and orange. It will therefore appear yellow to your eyes, which see only the light reflected from it. Similarly, blue paint will absorb and remove from white light the yellow, orange, and red, reflecting primarily blue and some green and purple. If we mix these two paints together, green is the only color not absorbed by either paint, and it is therefore the only color reflected to your eyes.

Basically, therefore, from a lighting standpoint, color television can be obtained simply by taking pictures of the red, green, and blue components of the image to be transmitted, and then, at the receiving end, reproducing each of these three color images and superimposing them upon each other on the viewing screen to form the composite full color scene. Two major problems are involved: first, the separation of the scene into primary colors; and secondly, the recombination of the different images at the receiver. It is necessary that these images be combined at a rapid enough rate to prevent flicker, and the overlapping of the images must be carefully controlled so as to produce the illusion of a solid colored scene. Fundamentally, therefore, instead of dealing with one scene at a time, we are actually trying to handle three.

IMAGE TRANSMISSION

There are two basic methods of sending the colored images as a transmitted signal. First, the respective color images may be sent one after another in sequence, or secondly, they can all be sent simultaneously by using each to modulate a different carrier.

Sequential Scanning. In the sequential system, a line may be scanned for the red values in it, for example, then scanned a second time for the green values, and finally for the blue, after which the process is repeated for the next line. In such a case, the red image is sent as a line; the next line corresponds to the green image; and the next line corresponds to the blue image (see Fig. 36A). When all three images corresponding to a single line of the original scene have been obtained, the next line of the scene is scanned in the same sequence.

If the separate *frames* can be combined at a rate fast enough, it is possible to make this sequential scanning that of a complete frame or picture, instead of lines. Thus, the entire picture could be scanned first to get a red image, scanned again to get a green image, and scanned yet again to get a blue image. Then all three of these images for the complete frame could be recombined. If this is done, it is necessary to transmit at a much higher frame rate, because the color images must all be recombined at a fast enough rate to avoid flicker. This means that about 20 frames per second for each color is about the slowest

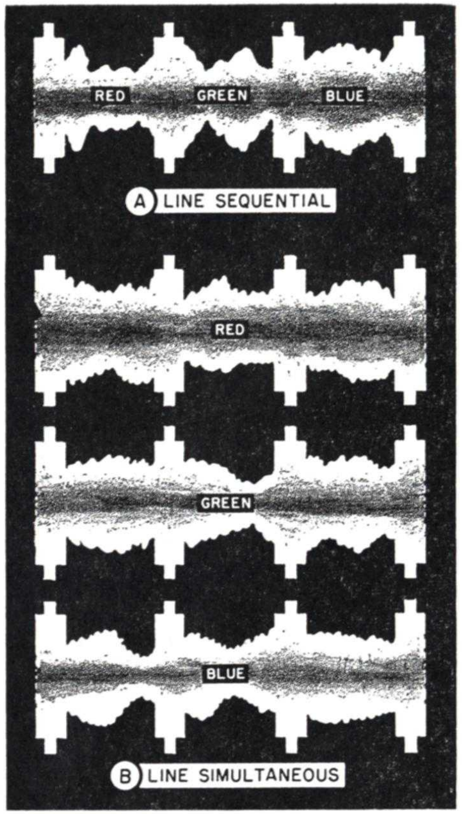


FIG. 36. Scanning methods.

we can expect, and we would probably have to go to 24 or more. Since there are three colors, the number of frames per second would have to be at least three times the lowest number that was found acceptable.

On the other hand, if each line is scanned three times before the next line is scanned, the same number of frames may be used; but now we have three times as many lines. Therefore, no matter how it is done, a sequential scanning system would differ from present-day standards either in the number of frames or in the number of lines, or perhaps even in both. Hence, either a frequency channel wider than the present 6-mc. one must be used, or the image detail must be degraded by reducing the line resolution (a reduction in the detail because of the loss of high frequencies). Whether a poorer color image should be accepted or a channel about 9-mc. wide should be used has not yet been settled.

Simultaneous Scanning. The simultaneous scanning system is one in which we have three different signals produced by three different pickup tubes, each of which scans the scene all the time. One tube picks up the red image, another the green, and the third the blue. The three signals are then modulated on three separate carriers, or on sub-carriers that are combined into one. Since we have three entirely separate images from beginning to end, it is possible to use the black-and-white standards for lines and frames. However, we must use nearly three times as wide a channel to transmit the whole image if today's standards are maintained. Thus, if a 6-mc. channel is necessary today for black and white, a simultaneous system using the same standards for each of the three colors would require an 18-mc. channel. Of course, it isn't quite as bad as this—one or more of the colors could perhaps be sent in a narrower channel, and there is only one sound channel for the entire picture, so a range of from 14 to 16 mc. would handle such an image. In fact, it would be possible to handle the image in a 16 mc. channel by using multiplexing or other tricks of modulation.

The wide frequency spectrum needed is one of the stumbling blocks that has prevented the introduction of this kind of color system. The Federal Communications Commission has insisted that any color system it is to approve for commercial use must be less wasteful of the frequency spectrum.

Another important question not yet settled is whether a color system should exist as an entirely separate service, or whether it should be able to produce an acceptable image on a black-and-white receiver as well. In the case of the simultaneous systems, any one of the three images can be used as a black-and-white image. For example, the green image of a simultaneous system, if it were transmitted according to present day standards, would produce a satisfactory black-and-white picture representing the complete scene. The receiver in this case would just ignore the other two color images, which would be suppressed by its tuned circuits. The sequential systems, however, can be received only on a set designed for the color image. The ability to operate both kinds of receivers has always been one of the strong points in favor of simultaneous transmission; in fact, it may eventually outweigh the objection that a wide frequency band is necessary for such a system.

Incidentally, you may wonder how a color image could be reproduced as black and white. It is very important to notice in the following discussion that in all cases we are merely using a filter in front of the camera to filter out lights of all but the desired color, so that only light of this color is registered by the camera tube. However, the camera tube is the same type as that used today, so the image of any color that is transmitted consists of a voltage variation that corresponds to the varying brightness level of the elements of the scene as far as light of that color is concerned. At the receiver, if there is no corresponding color filter, the pickup tube will be actuated to reproduce a black-and-white picture corresponding to the voltage variations in the transmitted signal. Of course, the contrast of this black-and-white picture produced by a color signal may not be the same as it would be if white light from the scene were picked up by the camera; however, the black-and-white picture produced by, say, the green signal should be acceptable, if not perfect.

Each of the systems to be described holds promise of being workable. The eventual choice will depend upon cost considerations and other factors that we shall mention.

MECHANICAL SYSTEMS

A mechanical means of getting a color image has been known and experimented with for a long time. In fact, the use of a mechanical disc or drum goes back to black-and-white systems that were in use before the development of the electronic picture tube.

A simple form of this system is shown in Fig. 37. The reproduced television image appears on the face of a standard cathode-ray tube as an ordinary black-and-white image. However, the light from this tube must pass through a color filter before being projected on the viewing screen. A color filter is made up of a disc of separate filters for red, green, and blue light. The disc may have six, nine, twelve, or more segments if desired, but the number of segments must be a multiple of three if a three-color system is used.

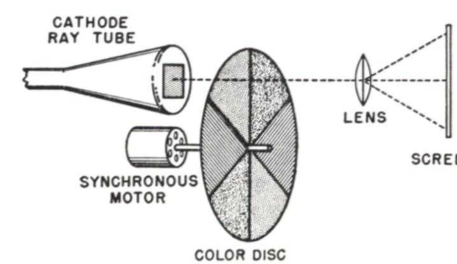


FIG. 37. A mechanical color scanner.

The disc is rotated by a synchronous motor so that the color segment in front of the picture tube at any time is the proper one for the color that is to be reproduced at that time.

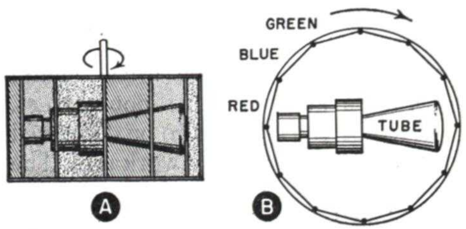


FIG. 38. Another possible mechanical color scanner.

This system must be used with the sequential method of transmitting the color information; to keep the speed of rotation of the filter disc at some reasonable figure, it is necessary to use frame rather than line sequences.

In operation, the color disc is rotated continuously. Its size and speed of rotation are such, however, that one color segment remains in front of the image for one entire frame so that a complete color frame is produced. Then, when the next frame starts, the next color of the disc is interposed between the picture-tube image and the screen. Finally, when the third frame is reproduced, the third color of the disc is interposed. Thus, three separate color images are reproduced in sequence on the same screen area. The rate at which they are produced is so fast that the eye blends them all together as a single image.

One of the disadvantages of this kind of system is that light is lost in passing through the filters. This can be made up for by the use of projection-type tubes. A more important difficulty is that of keeping the synchronous motor exactly in step with the one that is used at the transmitter. Naturally, the color discs at the receiver and the transmitter must be exactly in step at all times—otherwise a color that is transmitted as blue might appear as red or green at the receiver, and so on.

A final disadvantage is the fact that this is a mechanical system—it uses devices that become worn out with use and therefore require maintenance and repair.

The problem of getting the synchronous motor to rotate at the correct speed and to put the right color disc in front of the image at the proper time is not insurmountable. A special synchronizing signal can be sent along with the television image and be applied to the motor circuit through a regulating network that will keep the motor running at the proper speed.

This is basically quite a simple system. If the objections to the use of a mechanical system can be overcome, it may eventually become successful.

Color Drum. A somewhat modified form of the system is shown in Fig. 38. Here, a large drum is used instead of a segmented color disc. A short picture tube is mounted within the drum, and the color filters are mounted so that each will pass in front of the tube in turn as the entire drum rotates. This construction permits a great many filters to be used, which makes it possible to reduce the speed of rotation of the drum.

THREE-TUBE ELECTRONIC SYSTEM

A completely electronic system for reproducing television in color has long been the goal of television engineers. The most basic arrangement of this kind is shown in Fig. 39.

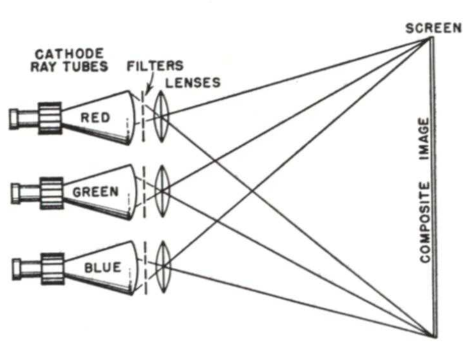


FIG. 39. A three-tube color system.

Basically, this system uses three separate receivers, each feeding a signal representing the light value of a particular color to its black-and-white picture tube. Light from each image then passes through a filter of the right color, after which it is focused by a lens on a viewing screen. The three tubes are arranged so that the three images overlap each other properly to produce a composite image that has the correct color at every point.

Obviously, a device that requires the use of three separate receivers would be very expensive. However, a single receiver can be used if it is specially designed to have r.f. and i.f. systems of the proper wide band width and to incorporate electrical filters to separate the signals of the three images from each other. Three picture tubes are still needed, however.

In this electronic system, we use the same filters used in the mechanical system, but they are now fixed—they do not need to rotate, because the tubes are either operated from entirely separate signals or operated in sequence so that the proper tube behind the proper filter is illuminated at a particular instant.

Although this basic electronic system does work, its cost is too high. Several modified forms of the system have been developed, however, in which a single tube is used. These are considerably less expensive.

SINGLE PICTURE-TUBE ELECTRONIC COLOR SYSTEMS

The system shown in Fig. 40A is one that uses a single picture tube to produce color electronically. In this particular system, the color image is broken up into separate small pictures that all appear on the tube face during a single vertical scan. In other words, when the electron beam completes one vertical scan of the picture tube face, three separate small, black-and-white pictures will have been formed, one corresponding to the red image, another to the green, and the third to the blue. Light from each image passes through an appropriate color filter; then, by means of a prismatic optical system, the three single-color images are combined into a single natural-color image that is projected onto a screen.

To produce these different pictures an optical system at the pick-up camera splits the light from the scene into three parts, each of which is filtered to produce a single-colored beam. Each beam is brought to a focus on a particular area of the mosaic of the picture tube. Thus, three separate images, one in each of the primary colors, are produced on the mosaic. When the mosaic is scanned by the electron beam of the pick-up tube, all three images are converted into electrical signals for transmission.

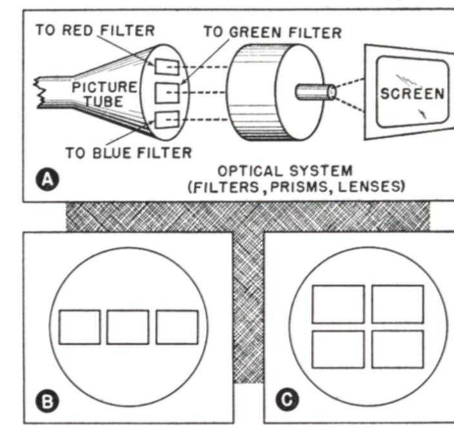


FIG. 40. A single-tube color system.

The optical system at the pick-up camera can be made to arrange the three images one above the other or side by side on the mosaic of the pick-up tube; they will appear in the same orientation on the face of the picture tube (see Figs. 40A and 40B). It is also possible to use an optical system that will produce the image arrangement shown in Fig. 40C. Either three or four images can be produced: if only three are formed, one will be on one line and two on the other.

The chief advantage of the arrangement shown in Fig. 40C is that it permits the individual images to be larger than does either the horizontal

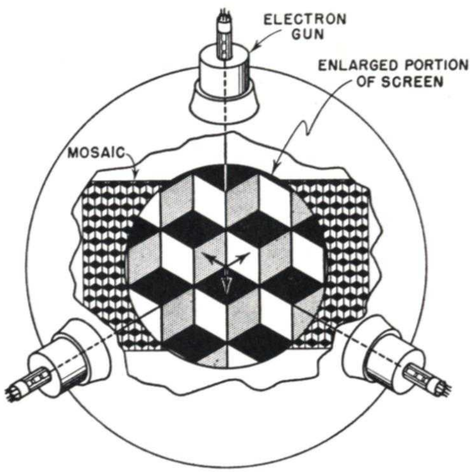


FIG. 41. The tri-Chromoscope.

or the vertical arrangement. Further, it makes it possible to use a fourth color—yellow, say—if it is found that use of a fourth color will improve the appearance of the final image.

A good feature of this color system is that it uses only one picture tube to produce a full-color image electronically. On the other hand, very little of the face of the picture tube is actually used, and a fairly expensive optical system must be used to recombine the images. However, this arrangement does offer one possible approach to the problem of getting color television without the use of mechanical moving parts.

COLOR SCREENS

A basic attack on the problem of getting color pictures is an exploration into materials that can be made to fluoresce directly in different colors. The original cathode-ray tubes used screens that produced green images, and it was soon discovered that other fluorescent materials could be made to produce yellow or blue images directly. As a matter of fact, our present-day white image is the result of a combination of several of these fluorescent materials so that the blue and yellow lights balance to produce white.

Therefore, since it is possible with materials known today to get a green and a blue, attempts are being made to find a material that will fluoresce red. Unfortunately, even the green and blue images produced have mostly been pastel rather than brilliant colors, but it is quite possible that a chemist will some day come up with fluorescent materials that will give brilliant primary colors. When such materials have been found, some method must be devised to make the electron beams of the picture tube strike the proper screen at the right time. There are two basic arrangements that have been suggested for this.

The Tri-Chromoscope. One of these systems, shown in Fig. 41, uses a single screen and three separate electron guns. Each of the guns is modulated separately by the signal corresponding to one of the colors, and each scans the screen or mosaic on the face of the tube from a different angle. Magnetic deflection yokes on all three guns are driven in series from one single deflection generator so that the three beams can be held in synchronism.

The mosaic screen surface is made in a series of three-sided pyramids. The surfaces of the pyramids are arranged so that the beam from any one gun strikes only one side of each pyramid. All of the sides facing in one direction are coated with the same

color phosphor; but, of course, there is a different phosphor on each of the three sides of any one pyramid.

Thus, each pyramid on the mosaic screen of the picture tube consists of three separate areas of different materials of such a nature that each will glow with a different color. To prevent secondary electrons from one phosphor from exciting adjacent phosphors of different colors, a metallic backing is applied over the phosphors.

In manufacturing the tube, the pyramidal shapes are molded into the back surface of the glass face of the tube. The different color phosphors are then settled into place one at a time. When one phosphor is to be settled, the tube is oriented so that all the pyramid faces on which that phosphor is to be deposited are horizontal. A solution containing the phosphor is then poured into the tube, the phosphor is allowed to settle out of solution, and the remaining liquid is poured out. The phosphor adheres only to the horizontal faces. The tube is then rotated 120°, and the next color phosphor is applied in the same manner.

In this system, the colors are reproduced directly on the screen surface of the picture tube. It is therefore a direct color system and involves no expense for filters or lenses of any sort. However, the tube used is relatively expensive, since three complete gun structures are necessary, and the special mosaic must be carefully made.

The Chromoscope. Another approach to the same basic idea is that shown in Fig. 42. This tube is much more like the standard tubes with which we are familiar in that it has only one electron gun. Instead of having just one screen, however, the tube has four. Three of them are coated with phosphors that will produce the primary colors. The fourth screen—the one nearest the gun—is purely a guard screen and may be just a metal backing on the others.

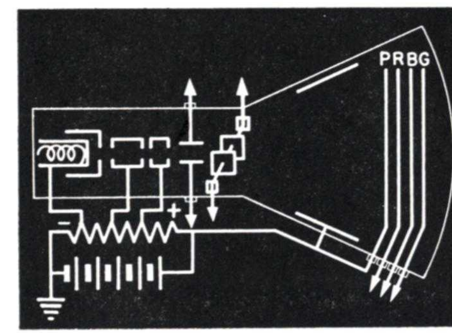


FIG. 42. The Chromoscope.

The color screens are made on a mesh material similar to screen wire, the openings in the meshes being large enough to pass light. Each screen is coated by a very thin coating of fluorescent material. A different material is used for each screen, of course, so that the proper color will come from each.

When this tube is in operation, a high positive potential is applied to the various screens in sequence. At any instant, the high potential is applied to one screen and the others are kept at low potentials. The electron beam strikes all three simultaneously through the openings in each succeeding screen. However, electrons are slowed down by low potentials and speeded up by high potentials. Therefore, electrons will have sufficient velocity to excite (cause light from) the screen that has the high positive voltage on it, but will be slowed down and produce but little light from the other screens. Therefore, the proper colors can be produced by arranging for the proper screen to be connected to the high-voltage supply at the right time.

A tube of this kind uses the same gun structure as the present-day types and differs from them only in the screen. Therefore, the cost of this tube should not be much greater than present ones, providing the fluorescent materials are not overly expensive and no great difficulty is encountered in depositing them on the screens and in subsequently assembling the screens.

The difficulty in designing a set to use this tube will be mostly in obtaining a voltage switching system and a suitable control pulse to actuate it. This arrangement is most readily adapted to a frame sequential system.

We have been able to do little more than describe in brief form the possible color television systems, because none of them has yet been made commercially available. However, as soon as one or more of the systems can be produced economically (with respect to both the transmitter and the receiver), and as soon as it is decided whether to permit color systems to require separate receivers or to insist that they be capable of producing a picture on a black-and-white receiver, we can expect a spurt of further development in these fields.

Lesson Questions

Be sure to number your Answer Sheet 58RH-3.

Place your Student Number on *every* Answer Sheet.

***Send in your set of answers for this Lesson immediately after you finish them,* as instructed in the Study Schedule. This will give you the greatest possible benefit from our speedy personal grading service.**

1. In a remote control system, why is it necessary to use a coupler stage to feed the signal from the video detector to the coaxial line connecting the control unit to the picture unit?

2. When a number of duplicators are connected to the same video-frequency coaxial line, which one uses the line-matching resistance?

3. If the full screen area of a picture tube is to be used to reproduce an image, what compromise must be made?

4. What two effects are produced when a magnifying lens is moved farther away from the face of a picture tube, assuming that the separation between the lens and the tube is kept less than the focal length of the lens?

5. What is the purpose of the corrector lens in a Schmidt lens system?

6. Why is the center of the spherical mirror in a Schmidt system made non-reflective (black)?

7. Why is the reflective coating placed on the face of a spherical mirror instead of on the back as in an ordinary home mirror?

8. Why should cleaning fluids be avoided when cleaning a plastic correcting lens in a projection system?

9. If a light filter in front of a picture tube reduces the light passing through it by half, why does it reduce the ambient light reflection to one quarter?

10. If the present 6-mc. black and white channel is to be used for color, and either the number of frames or the number of lines are increased, what must be sacrificed?

Be sure to fill out a Lesson Label and send it along with your answers.

COMPETITION

When a competitor opens a shop in your neighborhood, your first reactions are probably the same as those of most people—you feel that he is "cutting in" on your trade and that, by fair or foul means, he may run you out of business. However, there is another view to take of this problem.

First, forget your fears! A mind frozen by mistrust and hate is incapable of reasoning; it will lead you to the very downfall you fear. Face the facts: someone else is in the same business, so you must make your services so much *better* than his that you get your share of the work.

Welcome the competition as a spur—something to force you to your best efforts—something to make you become more careful, more efficient, more alert. You will find that honest competition adds enjoyment to your work.

And, another thing, force your competitor to rise to *your* level to survive—don't stoop to his. Do your best work and you'll find that your fears were not justified—there is plenty of business for the man who can deliver the goods!

J. E. Smith