

**HOW THE TV  
PICTURE TUBE WORKS**

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## STUDY SCHEDULE NO. 51

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.

- 1. **Producing the Electron Stream** . . . . . Pages 1-8  
Introduction to the picture tube; electron guns; emitters; equipotential lines.
- 2. **Concentrating the Electron Beam** . . . . . Pages 8-13  
The fundamentals of electronic optics; how an electronic lens works; baffles.
- 3. **Focusing the Electron Beam** . . . . . Pages 13-17  
Electrostatic focusing; magnetic focusing.
- 4. **Deflecting the Electron Beam** . . . . . Pages 18-30  
Electrostatic deflection; electromagnetic deflection; the ion spot; ion traps; ion-trap adjustment.
- 5. **Fluorescent Screens and Tube Envelopes** . . . . . Pages 30-36  
Fluorescent screens; Daylight tubes; halation; special screens and filter glass; face shapes; metal tubes; safety rules.
- 6. **Answer Lesson Questions, and Mail your Answers to NRI for Grading.**
- 7. **Start Studying the Next Lesson.**

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**I**N THE SOUND section of a TV system, a microphone changes the sound into electrical signals that vary in amplitude. These signals are then changed into frequency variations (FM) and are sent out on the TV sound carrier. In the receiver, the discriminator-type second detector changes the frequency variations into amplitude variations, and after amplification, the loudspeaker changes them back to the original sound that was picked up by the microphone. This portion of a TV system is just like that of a standard radio system.

Let us now compare the operation of the video section of a television system with that of the sound section. In the upper left corner of Fig. 1 is shown an artist whose picture is to be transmitted. The light that is reflected from her face is collected by the lens system and focused on the plate of the television camera tube. This plate is covered with a mosaic composed of an innumerable quantity of minute photoelectric cells. The camera tube also has an electron gun similar to that used in a standard picture tube. The scanning, in this case, is accomplished by deflecting the electron beam electromagnetically by means of the coils around the neck of the tube. These coils are fed with signals that cause

the point of impact of the electron beam to move across the mosaic in approximately a horizontal line at a uniform speed, then fly back and scan another line, and so on until the entire mosaic has been scanned by 525 lines in the desired sequence. This complete scanning is repeated at a rate of 30 times per second. As the electron beam sweeps over the mosaic, each element transfers its charge, which varies according to the illumination of that portion of the scene, to an amplifier. The resulting voltage pulses, called video signals, are amplified and combined with special signals for controlling the timing of the camera-tube electron beam during the return time. The resulting composite signal is then used to modulate a high-frequency transmitter.

In the TV receiver, the video program is treated like any other amplitude-modulated signal. It is amplified by the r.f. stage and then fed to the mixer stage where it is mixed with a signal from the local oscillator to produce the i.f. signal frequency. The signal is then amplified by the i.f. stages, and is fed to the second detector where the carrier is stripped from the composite video signal. The video signal is then amplified by the video amplifier which corresponds to the



audio amplifier in a sound receiver.

The TV video signal is then ready to be changed back into a scene. As you already know, this is accomplished by use of a picture tube. The application of the video voltage variations to the grid-cathode of the picture tube results in variations of the electron-beam intensity and causes corresponding variations in the brightness of the spot that is formed on the screen of the picture tube. To duplicate the scene that caused the electrical variations on the camera-tube mosaic, these spot-brightness variations must occur at the right place on the screen. This is accomplished by sweeping the electron beam across the face of the picture tube in step (synchronized) with the camera-tube beam. The sync signals that were separated from the video signals, are used to synchronize the horizontal and vertical sweeps of the

TV receiver with the horizontal and vertical sweeps of the camera tube.

Now that you have a basic understanding of all the TV stages and sections and their operation, you are ready to study them in greater detail. Let's start in this Lesson with a study of the picture tube, and learn how the electron beam is formed, how it is focused to a pin point on the fluorescent screen, and how it is swept across the screen. Then you will have a full understanding of how the video signal is converted into a scene.

Picture tubes are made in various sizes and types. However, all picture tubes are fundamentally the same, and every tube has the following basic elements:

1. A source of electrons in the form of a cathode.
2. A filament to heat the cathode so that it will emit electrons.

3. A control grid to vary the number of electrons passing through it.
4. A means of concentrating the electrons leaving the cathode into a beam.
5. A fluorescent coating on the screen that glows upon the impact of the electron beam.
6. A means of focusing the electron beam into a small spot on the tube screen.
7. A high-voltage anode to accelerate the electrons in the beam.
8. A means of deflecting the electron beam in any desired direction.

### ELECTRON GUNS

The electron gun is the complete electrode assembly in picture tubes that produces and focuses a beam of electrons as a pin point on the viewing screen. Let's study its elements in order.

**Electron Emitter.** In a picture tube, the source of electrons is a cathode that is heated by a filament that is electrically insulated from it. This filament is wound non-inductively so that no stray fields are produced by the alternating current flowing through the filament.

Fig. 2 shows the arrangement of the elements in a typical electron emitter. A cap made of nickel is heated from the inside by the filament. The end of this cap is coated with a special chemical oxide mixture that emits electrons freely when it is heated. Since a thin pencil of electrons is desired, only the end of the nickel cap is coated with the oxide mixture. The electrons leave the cathode more or less at right angles to the surface, and consequently these electrons start traveling over paths essentially parallel to the principal axis of the picture tube. But electrons have negative

charges and repel each other, so when they are emitted from the end of the cathode, if left to their own devices they would quickly spread out, and all beaming action would be lost. How this is avoided will be described shortly.

Electron emission should take place in a vacuum for two important reasons. First, the absence of air particles in the vicinity of the cathode makes it easier for electrons to jump away from the cathode. Second, in a vac-

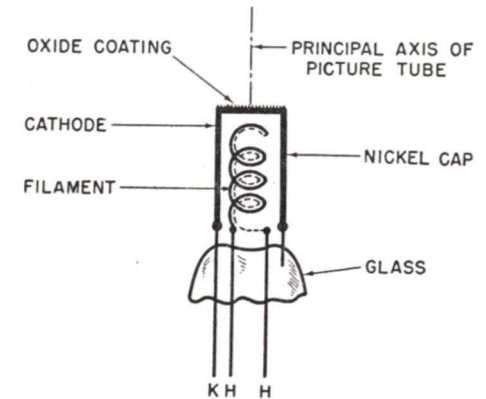


FIG. 2. Arrangement of the elements in the electron emitter of a picture tube.

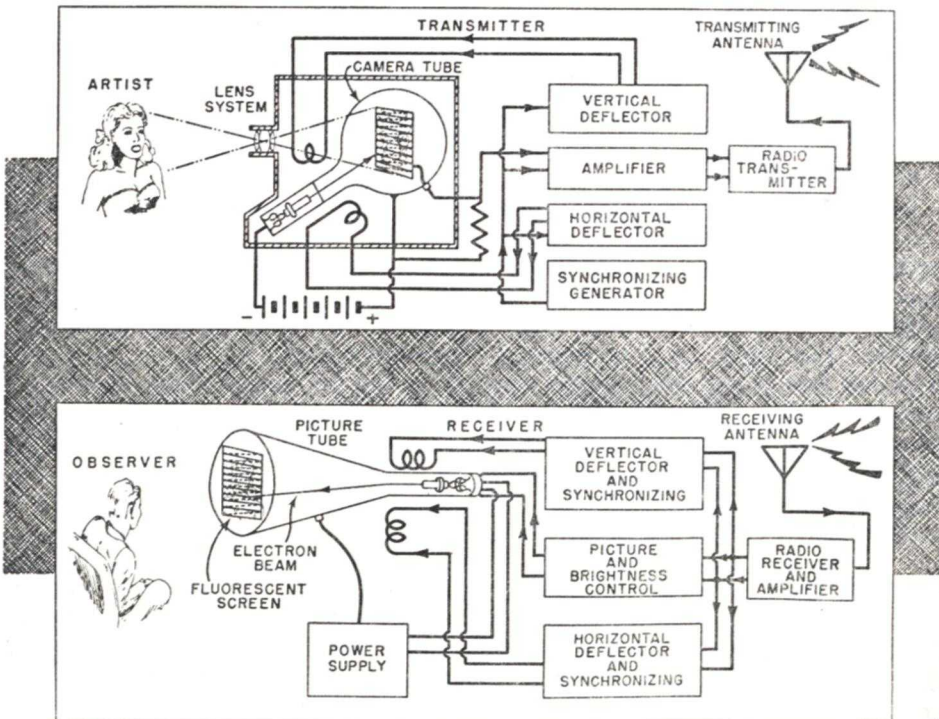
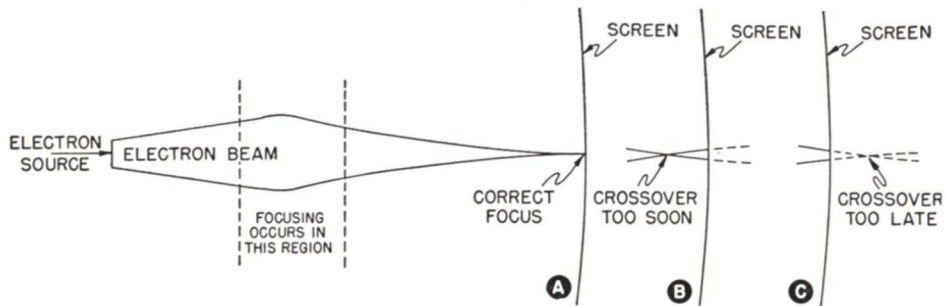


FIG. 1. Block diagram of the video portion of a television system.





**FIG. 3.** The electron beam is correctly focused when it crosses over at the point where it strikes the screen.

As a rule, the oxide coating is sprayed on the end of the cathode in the form of a liquid. While the picture tube is being evacuated, an intense heat is applied to the cathode (usually by inducing strong eddy currents in the nickel cap), changing the sprayed-on materials to the desired active oxides.

**Other Gun Elements.** As stated previously, the electrons leaving the end of the cathode will, due to their repelling action on each other, tend to spread out so that they will not reach the screen as a small compact beam. To avoid this, specially-constructed electrodes are used to accelerate the electrons to a high speed so that they will not have time to spread out. Even so, a spot the size of the coated portion of the cathode would be entirely too large, therefore the beam must be reduced to a very small diameter at the point of impact on the screen. Since the electrons are leaving all parts of the cathode in a more or less straight line, it is possible to make these individual lines cross over one another by varying the electrode voltages or by the use of a magnetic field. Just how this is accomplished will be described later.

Fig. 3A shows that as the electrons cross over, the beam becomes a fine pin point and, if properly focused, this crossover can be made to occur just where the beam strikes the screen.

Figs. 3B and 3C show what happens if the beam is improperly focused. If the crossover occurs too soon or too late, the spot will be a large circle on the screen instead of the desired pin point, the details will be lost, and the picture will be blurred.

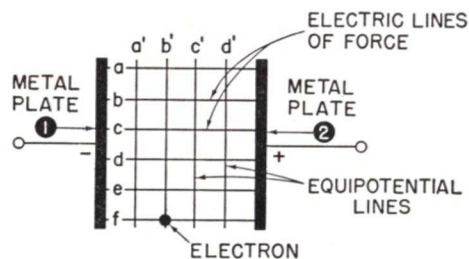
Not only is it necessary to focus the spot on the screen, but also the number of electrons in the stream must be controlled by the video signal in order to vary the brilliancy of the spot. An element called the "control grid" is used for this purpose. This element is entirely different in appearance from the tube grid with which you are familiar and operates on a somewhat different principle. This difference is based upon the behavior of an electron in an electrostatic field, as we will show.

By making use of the electronic-optic principle of electrostatic focusing, it is possible to bundle these emitted electrons into a small-diameter stream, and make them form a small brilliant spot on the screen that will vary in brightness with the applied video signal. Only the cathode-ray tube designer is interested in the actual shapes of the electrodes, their arrangement, and the voltages applied to each. However, the serviceman who understands the problems of cathode-ray tube design, and knows how the desired effects are accomplished, is in a

better position to service, install, and adjust cathode-ray tube equipment.

### EQUIPOTENTIAL LINES

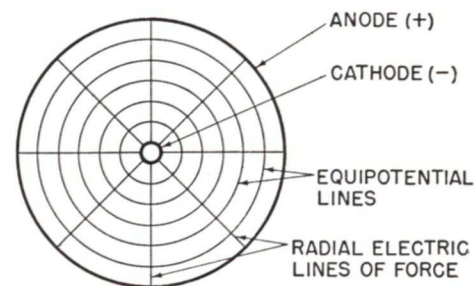
The underlying principles of electronic optics are not difficult to understand. An electron is always attracted to a positively charged electrode; it is the path that the electron takes in getting there that requires study. You know that electric lines of force exist between any two differently charged bodies, such as between the emitter (source of electrons) and the anode of a cathode-ray tube; it is along these lines of force that electrons travel. It is easier, however, to predict how electrons will move by referring to what are called equipotential surfaces, for these are simpler to locate in actual practice than electric lines of force, and electrons moving from one equipotential surface to another always behave in a definite manner. The first electronic-optics principle to be studied is the relation between electric lines of force and equipotential surfaces.



**FIG. 4.** Cross-sectional view showing electric lines of force and equipotential lines between two charged parallel plates.

Fig. 4 represents a cross-sectional view of two parallel metallic surfaces, with surface 2 positively charged with respect to surface 1 (which can be a cathode). Electrons are urged from 1 to 2 along lines a, b, c, etc., which represent electric lines of force. An electron moving from surface 1 to

surface 2 starts from rest (zero speed) at surface 1, gaining speed as it moves. All along the path it gains energy, because the energy of a moving body of constant mass increases with its



**FIG. 5.** Cross-sectional view showing electric lines of force and equipotential lines between two charged coaxial cylinders.

speed. Other electrons starting from rest at various points on plate 1 gain speed at the same rate, so that all electrons moving between the plates possess the same energy at any given distance from plate 1. We can indicate this on Fig. 4 by putting in lines a', b', c', and d', drawn at right angles to the electric lines of force. These lines represent positions of equal potential or energy level, and are called equipotential lines or surfaces. (Equipotential lines on a cross-sectional view actually represent equipotential surfaces, just as the heavy lines 1 and 2 in Fig. 4 represent plates.)

Fig. 5 illustrates the electric lines of force (radial) and equipotential lines (concentric) as you will find them in a simple electronic tube having a cylindrical cathode inside a cylindrical plate. Although the drawing gives only one cross-sectional view of the tube, all other cross sections are alike. Electrons going from the cathode to the anode will travel along the electric lines of force, and will therefore move at right angles to the equipotential lines shown.



A free electron that is traveling along the path of an electric line of force between two bodies in the direction of increasing potential (toward the highest positive body) will gain velocity. A gain in velocity is the same as a gain in potential, for this is the way of assigning a definite velocity to the electron. Since the electron has mass, it is also gaining energy as it travels along the path in the direction of increasing potential (a rock traveling down to earth from a height of twenty feet will have far more energy at the bottom of its fall than would a rock dropped from a height of five feet.) This means that when an electron travels through an electric field in a direction of increasing potential, it will receive energy (or potential, or velocity, as you prefer) from the electric field.

An electron traveling in a direction of decreasing potential (toward the lower potential body) will be retarded, and will lose some of its energy, potential, or velocity. An electron moving along an equipotential line will neither gain nor lose velocity, energy, or potential.

An equipotential line passes through all points having the same potential. Any number of equipotential lines, each corresponding to a different potential, can be drawn between two charged bodies; some will have low potentials and some will have high potentials. When an electron moves from a low equipotential line to a high equipotential line, its velocity is increased. An electron moving from a high to a low equipotential line will lose velocity.

An electron traveling at right angles to equipotential lines is speeded up or retarded, as the case may be, but is not diverted from its straight path of travel. Only when an electron is traveling through an electric field at an

angle other than  $90^\circ$  to the equipotential line is its direction, as well as its velocity changed. This change in the direction of travel of an electron merits further study, for it is the fundamental action of electrostatic focusing systems in picture tubes.

Equipotential lines are straight and parallel only when the charged bodies are two large, parallel, metal plates; the lines are then parallel to the flat plates. In all other cases, equipotential lines will be curved. In picture tubes, we deal almost entirely with curved equipotential lines.

Let us consider first the condition shown in Fig. 6A, where electron "e" is traveling at an angle to the principal axis of a picture tube and is passing from a low potential region to a high potential region. The change in potential along the path of the electron is actually quite gradual, there being no definite boundary for a region, but we can simplify our study greatly by assuming that the curved equipotential line shown here represents the boundary between regions of different potential. The results obtained with this assumption will be sufficiently accurate for our purposes.

In the low-potential region in Fig. 6A, electron e has velocity  $P_1$ , that may be broken up into two components  $P_{T1}$ , tangential to the equipotential line and  $P_{P1}$  perpendicular to the equipotential line.

The tangential velocity component  $P_{T1}$  remains unchanged as the electron moves from a low- to a high-potential region, for this component represents motion along the equipotential line. The velocity component that is perpendicular to the equipotential line increases as the electron crosses this line, so that the velocity that is perpendicular to the line in the high-potential region is  $P_{P2}$ . Combining the two velocity components again after the elec-

tron has crossed the equipotential line, we get  $P_2$  as the new electron velocity. This is larger than the original electron velocity  $P_1$  and is bent closer to the principal axis.

The passage of an electron from a low-potential region to a high-potential region, under the conditions in Fig. 6A, results in increased electron velocity and a travel path that is more normally parallel to the principal axis. By repeating this process for three other conditions of electron travel, as indicated in Figs. 6B, 6C, and 6D, we can determine the nature of the bending in each case.

All four diagrams in Fig. 6 are reversible; that is, the indicated electron paths are correct for either direction of electron travel along the path.

If we limit ourselves to equipotential lines that are portions of circles having their centers on the principal axis, we can summarize the results of

the diagrams in Fig. 6 as follows:

1. Electrons approaching a concave equipotential line, moving away from the principal axis, and passing from a low- to a high-potential field are bent back toward the principal axis.

2. Electrons approaching a concave equipotential line, moving toward the principal axis, and passing from a low- to a high-potential field are bent away from the principal axis.

3. Electrons approaching a concave equipotential line, moving away from the principal axis and passing from a high- to a low-potential field are bent away from the principal axis.

4. Electrons approaching a concave equipotential line, moving toward the principal axis, and passing from a high- to a low-potential field are bent toward the principal axis.

5. Electrons approaching a convex equipotential line (traveling in a direction opposite to that in Fig. 6)

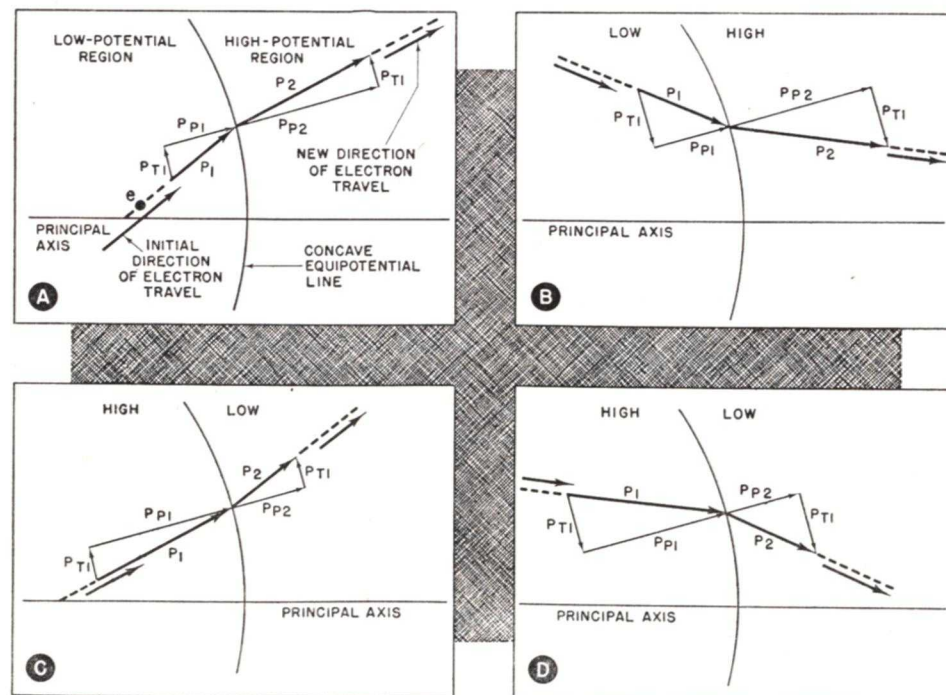


FIG. 6. How the path of an electron is changed as it moves at various angles through regions of differing potentials.



moving toward the principal axis, and passing from a high- to a low-potential field are bent toward the principal axis.

6. Electrons approaching a convex equipotential line, moving away from the principal axis, and passing from a high- to a low-potential field are bent away from the principal axis.

7. Electrons approaching a convex equipotential line, moving toward the principal axis, and passing from a

low- to a high-potential field are bent away from the principal axis.

8. Electrons approaching a convex equipotential line, moving away from the principal axis, and passing from a low- to a high-potential field are bent toward the axis.

Although these eight statements take care of all conditions in picture tubes, it is far easier and better to remember the method shown in Fig. 6 for deriving these facts than to memorize the eight statements.

## Concentrating the Electron Beam

In a practical picture tube, a beam of electrons that focuses to a small spot on the fluorescent screen is produced by two distinct sections: 1, a hot cathode and an electrode system that converges the emitted electrons to a point quite near the cathode on the principal axis of the tube; 2, one or more electronic lens systems located between the first converging point and the fluorescent screen, to produce equipotential lines that will converge the electron beam to a small spot on the fluorescent screen. This second section will now be considered in its simplest form as a bi-potential electronic lens.

### ELECTRONIC LENS

In the electronic lens, the bending is continuous throughout the electric field that forms the lens (since there is an infinite number of equipotential lines at which bending can occur).

Expert mathematicians can calculate the positions of equipotential surfaces by a long, tedious process, but only for simple electrode shapes. The usual, and quite practical procedure involves making a large accurately scaled model of the electrodes, im-

mersing this model in a conductive liquid, and applying voltages to the electrodes. A test probe that is completely insulated except for a tiny metal ball point at its tip is connected to a vacuum-tube voltmeter. This probe is then moved around in the liquid between the electrodes to search out points of equal potential. These points are plotted on a cross-sectional diagram of the electrodes, and connected together by smooth curves to give the equipotential lines for that electrode arrangement.

In Fig. 7A is shown a cross-sectional view of a simple bi-potential lens made up of two metallic cylinders placed end to end on a common principal axis. The smaller cylinder has a lower positive potential than the larger cylinder, and the difference in potential between the cylinders results in equipotential lines distributed as shown in Fig. 7A for any lengthwise cross-section of the cylinders.

Point 0 can be considered as the point source for the electronic lens in Fig. 7A, as electrons are concentrated at this point by the first section of the picture tube gun (by the cathode and its associated focusing system). Since

the two metal cylinders produce the same electric field for any cross-section, electrons leaving 0 in all directions at any given angle with the principal axis will be acted upon in a similar manner by this electronic lens.

Notice that electrons traveling to the right from point 0 first encounter convex equipotential lines. These lines gradually straighten out, then become concave inside the larger cylinder. Let us see what happens to electrons as they pass through one convex equipotential line and one concave equipotential line.

An electron traveling from point 0 through the 1100-volt convex equipotential line (shown by itself for clearness in Fig. 7B) is bent toward the principal axis. If this were the only equipotential line acting upon electrons, the beam would be focused to point X on the principal axis. In passing through the 4400-volt concave equipotential line, however, the electron beam is bent away from the principal axis, so that it now focuses

at a point farther away along the principal axis, at Y.

Returning to Fig. 7A we see that the convex equipotential lines having potentials from 1020 volts to 2200 volts will progressively bend the electron beam toward the principal axis, and at the same time will increase the velocity of the electrons. The concave equipotential lines from 2200 volts to 4580 volts will gradually straighten out the electron beam until it is almost parallel with the principal axis and is converged to a spot of the desired size at point I on the fluorescent screen. Line 1 in Fig. 7A represents the path taken by electrons leaving the point source 0 at angle  $\theta_1$  with the principal axis. Electrons leaving point 0 along the principal axis will be accelerated but not bent, since these electrons will travel at right angles to all equipotential lines.

### ELECTRONIC BAFFLES

There is a practical limit to the angle at which electrons can leave point 0 and still be focused to a point

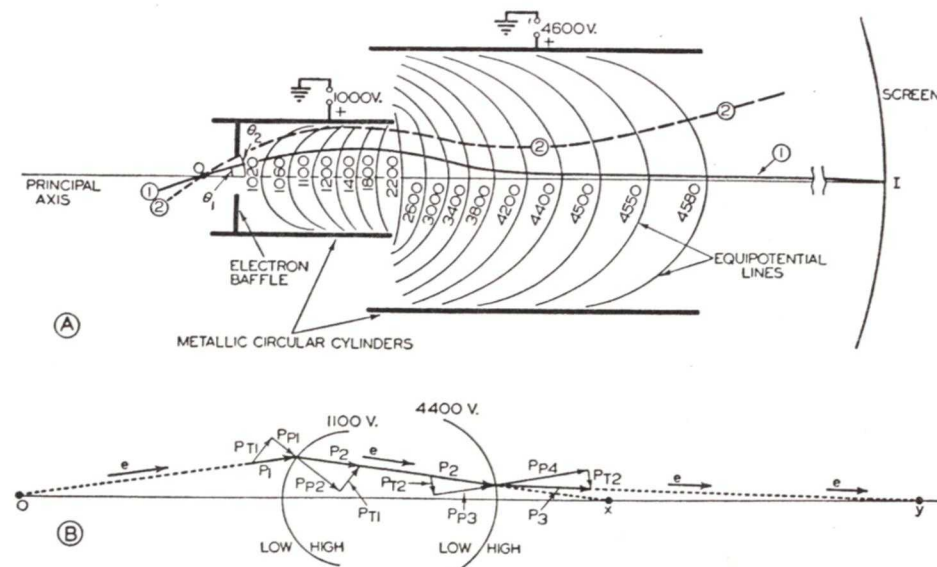


FIG. 7. Electron paths through a bi-potential electronic lens.



on the screen. For example, electrons leaving point O at angle  $\theta_2$  are acted upon by the electronic lens in such a way that they take path 2, and this would cause undesirable spreading of the beam. To overcome this, one or more electron baffles (each a disc with a hole in its center) is used in a picture tube to block all electrons that do not converge to the desired narrow beam along the principal axis.

### THE FIRST LENS

As has been previously pointed out, there are two electrostatic lens systems in a picture tube. The first one is near the cathode, and is used to bring the emitted electrons to a more or less sharp point that can act as a source of electrons for the second lens. The first lens is essentially produced by the control grid, which is a cylinder with one or more baffle plates located in front of the cathode. This first lens is known as the cathode lens or immersion lens (any electrostatic lens in which the object or source of electrons is inside or immersed in the lens is an immersion lens). The grid cylinder is usually given a negative bias with respect to the cathode, and is excited

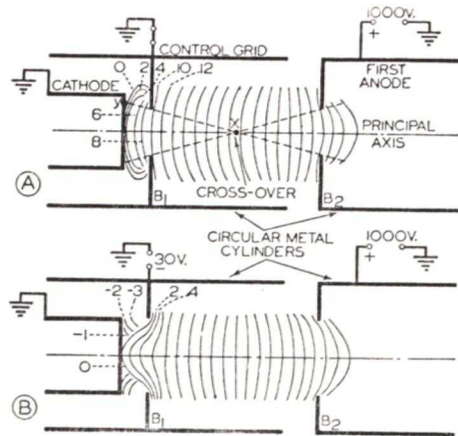


FIG. 8. Equipotential lines within an immersion lens when there is no bias (A) and when there is a 30-volt bias (B) applied to the control grid.

by the TV signal, thus serving as the control electrode.

The cross-sectional diagram in Fig. 8A shows a typical arrangement of the electrodes that are located near the cathode of the picture tube. These electrodes are metal cylinders. The equipotential lines in Fig. 8A are shown for the condition where the control electrode is at zero potential with respect to the cathode, a condition corresponding to maximum brilliancy of the spot on the screen.

Since the first anode is at a high positive potential with respect to the cathode, positive equipotential lines exist right up to the cathode as shown in Fig. 8A.

Along the surface of the cathode, the positive potentials pull electrons away from the heated electron-emitting surface. Those electrons that are traveling along the principal axis are accelerated, but not bent as they move toward the first anode, because they are moving perpendicularly to the equipotential lines.

An electron leaving the cathode at a point away from the principal axis, such as at point Y, will encounter convex equipotential lines of increasing potential; these will force the electron to take the indicated path from Y to the cross-over point X, and at the same time will accelerate the electron.

Any electrons traveling from point Y away from the principal axis will follow an equipotential line without accelerating, until they are redirected toward the principal axis again. They are then attracted by the first anode, and are accelerated along with the other electrons in the beam. Stray electrons may form an electron cloud around the cathode, outside the zero equipotential line. This electron cloud will tend to repel electrons back to the principal axis, and force them to go through the cross-over point X.

Most of the electrons that make up the final beam will be pulled out from the center of the cathode, and will be accelerated rapidly with a minimum change in direction. Electrons emitted at such angles that they could not possibly go through the cross-over point are blocked by electron baffle  $B_1$ . The first anode has another electron baffle ( $B_2$ ) that also blocks electrons that are outside the desired beam.

When the control electrode has a negative bias of 30 volts with respect to the cathode (a condition corresponding to a low-brilliancy spot on the picture-tube screen), the equipotential lines will be arranged as shown in Fig. 8B. The negative charge on the control electrode has the effect of making the positive equipotential lines sharply convex for electrons leaving the cathode; in addition to this, the positive potential increases rather slowly near the control electrode.

We also have negative equipotential lines in the vicinity of the cathode shown in Fig. 8B. Many of the electrons that would normally leave the cathode because of the potential that is given them by the heat of the filament cannot overcome the repelling force of these lines, and consequently are kept at the cathode. The result is that only electrons near the principal axis are pulled away from the cathode by the first anode. We thus see that a negative charge on the control grid reduces the number of electrons that can enter the electron beam.

The control electrode has its greatest effect in the region between the cathode and the electron baffle  $B_1$ . The electrostatic field between the electron baffles  $B_1$  and  $B_2$  is essentially constant for a definite first-anode voltage. With proper electrode design, the equipotential lines in this region will be so shaped that there will be

convex lines for focusing the electrons to cross-over point X, and concave lines for narrowing the beam again as the electrons spread after leaving point X.

### A COMPLETE ELECTRON GUN

The general arrangement of the electron gun elements in a picture tube is shown in Fig. 9. Since we have already considered the action of

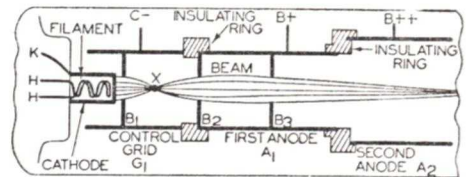


FIG. 9. General arrangement of the elements in the electron gun of a picture tube.

each component in the system, we will now review the action of the entire system.

Cathode K serves as the primary source of electrons. The control electrode  $G_1$  produces between baffle  $B_1$  and the cathode an electrostatic field that controls the number of electrons in the beam. The first anode  $A_1$  provides between it and  $G_1$  an electrostatic field that focuses the emitted electrons to cross-over point X. The first and second anodes,  $A_1$  and  $A_2$ , together form a bi-potential electronic lens that converges the electron beam back into a narrow straight stream and focuses the stream or beam of electrons to a spot of the desired size on the fluorescent screen. Electron baffles  $B_1$ ,  $B_2$ , and  $B_3$  block any electrons that tend to widen the final electron beam.

The number of electrons in the beam will vary at different points, for the baffles will divert some electrons to the positive supply leads. If milliammeters are inserted in the  $B+$  and  $B++$  leads, the sum of their readings

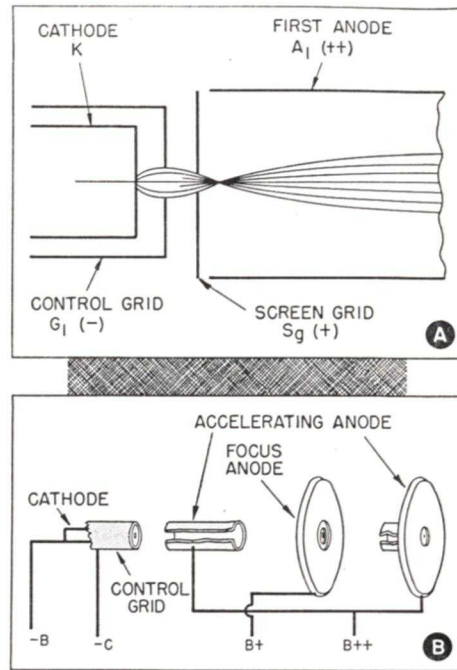


will be approximately equal to the electron currents at cross-over point X. The current in the second anode supply lead is a better indication of screen spot brightness, however. The beam current is very small, varying from approximately 50 to 250 microamperes, depending on the type of tube and the anode voltage employed.

### SECONDARY EMISSION

When the electron beam strikes the fluorescent screen it causes secondary electrons to be emitted from the screen. If these secondary electrons are not removed they will accumulate and form an electron cloud in front of the screen that will interfere with the normal operation of the tube, tending to slow down the beam and making it spread.

To prevent this electron cloud from forming, the inside of the glass envelope in practically all picture tubes is coated with a conductive material such as carbon or powdered graphite. This coating is called aquadag, and is similar to the coating found on resistance strips of volume controls. The coating usually extends from the neck of the funnel-shaped part of the glass envelope to within an inch or so of the fluorescent screen. One end of the aquadag coating is connected to the second or accelerating anode through spring clips, and hence has a high positive potential so that it will attract secondary electrons that are emitted from the fluorescent screen during bombardment by the beam. This prevents a large accumulation of secondary electrons in front of the screen. In some picture tubes, no metallic accelerating anode is provided, and the aquadag coating, in addition to collecting secondary electrons from the screen, also acts as the accelerating or high-voltage anode of the tube.



**FIG. 10. Methods of reducing interaction between the control grid and the focusing anode.**

On many magnetic-deflection tubes the outer portion of the glass envelope also has a conductive coating that is grounded. The glass between the inner and outer conductive coatings acts as a dielectric, and in this way a condenser is formed that has considerable storage capacity. The condenser so formed acts as a portion of the filter system for the second anode high-voltage supply.

In the gun shown in Fig. 9 there is considerable interaction between the control grid and focusing anode No. 1. Variations in control grid voltage will vary the number of electrons striking baffles  $B_2$  and  $B_3$ , thus undesirably changing the first anode voltage with respect to the second anode voltage, and defocusing the beam.

In some early tubes, this was avoided by using an element called the "screen grid" between the control grid and the first anode as shown in

Fig. 10A. More recently, however, the second anode has been split; one part, electrically connected to the second anode, now is inserted between the control grid and the focusing anode as shown in Fig. 10B. Not only does splitting the second anode cause rapid acceleration of the electrons, but also interlocking between the adjustment of the control grid voltage and the focusing anode voltage is thus elim-

inated. The arrangement in Fig. 10B also allows a simpler power supply than that in Fig. 10A.

In the terminology of some picture-tube manufacturers, the control grid is designated as  $G_1$ , the first section of the accelerating anode in Fig. 10B is designated as  $G_2$ , the focus anode as  $G_3$ , and the other section of the accelerating anode as  $G_4$ ;  $G_2$  and  $G_4$ , of course, being tied together.

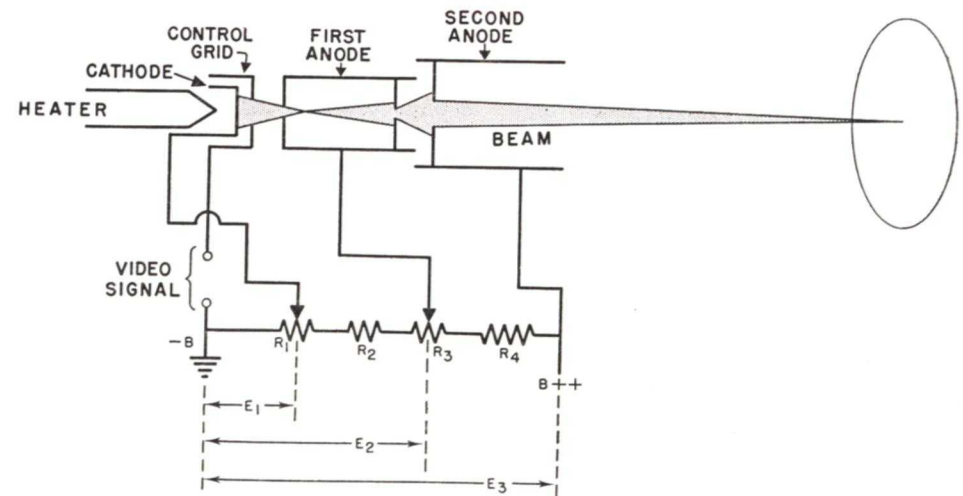
## Focusing the Electron Beam

The technician's primary interest in a picture tube is the effects that variations in electrode voltages have upon the spot size and the spot brilliancy. However, there are two types of picture tubes; one uses electrostatic focusing and deflection, while the other uses electromagnetic means for both these purposes. We shall study both, beginning with the electrostatic type.

### ELECTROSTATIC FOCUSING

The schematic circuit diagram for

a typical electrostatic picture tube and its operating voltage supply is shown in Fig. 11. The voltages applied to the various electrodes in the picture tube depend upon the size of the tube. For example, in a tube having a face diameter of 7 inches, the highest a.c. supply voltage  $E_3$ , applied between the second anode and  $B-$ , may be as much as 6000 volts. The first anode may have a potential of 1500 to 2500 volts. The cathode may be positive with respect to ground (the control



**FIG. 11. Schematic diagram of the voltage distribution system used with a typical electrostatic tube.**



grid return) by 30 or 40 volts, so that the control electrode is always negative. The exact d.c. voltage between the cathode and the control grid depends upon the setting of  $R_1$  which serves as the brilliancy control. Now let us see how the spot size and the spot brilliancy will vary as the voltages are varied.

Let's assume first that the control grid is highly negative, with the spot brilliancy correspondingly low. Electrons under this condition are flowing into the first anode in a narrow cone with the result that the beam is focused to a small spot. As the control grid is driven in a positive direction by the video signal or by reducing the bias set by  $R_1$ , more and more electrons enter the stream, and the spot brilliancy increases. At the same time the electrons in the stream repel each other more than before, and the spot size is therefore increased when the control grid is driven more positive. By careful tube design, the spot diameter can be maintained within reasonable limits for normal variations in the control grid voltage. This variation will not greatly affect line definition if the largest spot diameter is less than the width of a line.

Raising voltages  $E_1$ ,  $E_2$ , and  $E_3$  will increase spot brilliancy. Conversely, reducing these voltages will reduce spot brilliancy. To see how these voltages affect spot size, we may consider each electrode by itself. Increasing the first anode voltage causes electrons to be drawn from a larger area on the cathode, giving more electrons in the beam and a larger cone at the cross-over. The result is a beam with less effective focusing, due to the greater repelling action among electrons in the beam. These factors together cause spot size to be increased when the first anode voltage is increased.

Provisions are always made for varying the first anode voltage in electrostatic picture tubes because this provides a simple way of focusing the electron beam to a spot. Increasing  $E_2$  without increasing  $E_3$  reduces the potential difference between the first and second anodes. The equipotential lines then become flatter (less convex and less concave), with the result that there is less bending as the electrons pass through the second electrostatic lens, and the point of focus (the point at which the beam is focused to a sharp spot of minimum size) is moved farther away from the second anode. Increasing  $E_2$  also gives increased acceleration of electrons. We can therefore say that increasing the voltage  $E_2$  on the first anode will move the focus spot outward, and at the same time give a brighter spot. If the point of focus is originally between the second anode and the fluorescent screen (so that electrons are diverging again as they reach the screen), increasing the first anode voltage will move the point of focus closer to the screen, thereby reducing spot size. When the point of focus is exactly at the screen, the spot size will be a minimum, and all changes in anode voltages will increase the spot size. Decreasing the first anode voltage  $E_2$  will reduce the spot brilliancy, and bring the point of focus closer to the second anode. With those picture tubes that are designed for electrostatic focusing, it is customary to vary the first anode voltage until a sharply-focused image is obtained on the screen.

Normally, the second anode voltage is not readily adjustable, although in certain type high-voltage power supplies an adjustment can be made. A definite voltage, however, is always recommended for this anode, and focusing is accomplished by adjusting the voltage that is applied to the first

anode. Any change in the voltage on the second anode will require readjustment of the focus control ( $R_3$  in Fig. 11) to produce the proper equipotential lines between the first and the second anodes so that the beam will focus to a sharp point on the screen.

## MAGNETIC FOCUSING

The fact that an electron in motion in a vacuum is the equivalent of a current, and is producing magnetic lines of force makes it possible to employ a magnetic field for focusing a divergent stream of electrons to a point. To understand exactly how this magnetic field can be utilized for electron-beam focusing, we must first consider a few fundamental principles of the behavior of electrons in magnetic fields.

A typical t.c.r. tube employing magnetic focusing is shown in Fig. 12. At the left end of the tube is a conventional electrostatic lens made up of a heated cathode, a negatively biased control grid, and low- and high-voltage anodes that serve as the first lens to focus the emitted electrons to cross-over point X, and to accelerate the electrons. From this point the electrons spread out into a cone, and are focused to a spot of the desired size on the screen by the magnetic field that is produced by the focusing coil that surrounds the neck of the tube. The magnetic lines of force produced by this coil are essentially parallel to

the principal axis of the tube, and are distributed uniformly through the neck of the tube.

In Fig. 12, the path taken by an electron leaving point X at the angle  $\theta$  with the principal axis is shown as a long sweeping curve, first away from the principal axis and then toward it. Actually, however, the electrons are twisted around the principal axis in a spiral manner at the same time that they are moving away from or toward the axis.

In order to prove that electron e, as it leaves cross-over point X, will take the path shown in Fig. 12, we must consider its velocity as having two components. Velocity component  $e_L$  provides motion longitudinally along the axis, while velocity component  $e_R$  provides motion radially outward from the principal axis. You will shortly see that motion along the axis is not affected by the magnetic field, whereas radial motion through the magnetic field forces electrons to bend back to the principal axis.

Electron e is thus moving longitudinally along the axis toward the screen at the same time that it is moving radially away from and back to the principal axis. If the radial motion back to the axis can be completed by the time the electron has reached the screen, the desired focusing is secured.

Let's suppose that a straight wire is placed in a uniform magnetic field

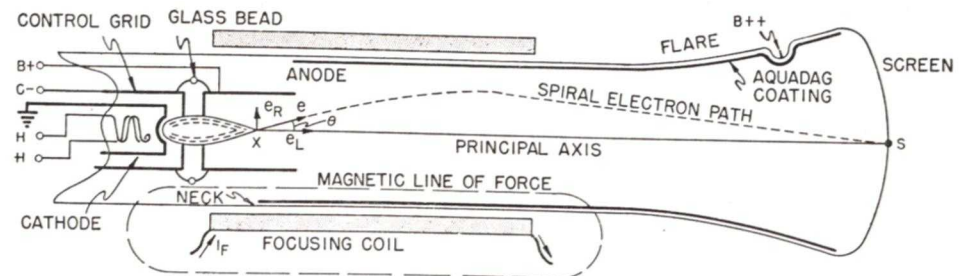
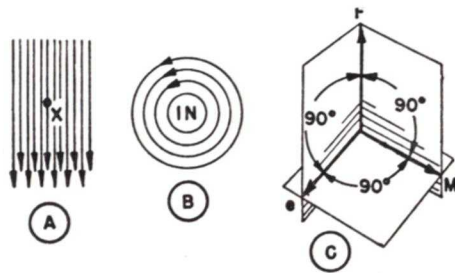


FIG. 12. Elements of a typical electromagnetic picture tube.



that is made up of straight parallel magnetic lines of force, with the wire parallel to these lines of force. When a current is sent through this wire, the current will set up a magnetic field of its own surrounding the wire. These circular magnetic lines of force will be at right angles to the existing straight lines of force at all points, and consequently the interaction between the two fields will be exactly the same at all points around the wire. The result is that the original magnetic field has no effect whatsoever upon the flow of electrons through the wire.

We can replace this wire with a stream of electrons flowing parallel to the magnetic lines of force, because it is electrons in motion that produce magnetic fields; we thus see that when magnetic focusing is employed, electrons traveling along the principal axis are unaffected by the magnetic field.



**FIG. 13.** How the interaction between a fixed magnetic field and the magnetic field of an electron forces the electron path to change direction.

When a wire carrying current is placed at right angles to a magnetic field, we know that there will be interaction of the magnetic fields and a resultant force that tends to move the wire (this is the principle of an electric motor). Electrons traveling at right angles to the focusing magnetic field in a picture tube are acted upon by a resultant force in much the same manner.

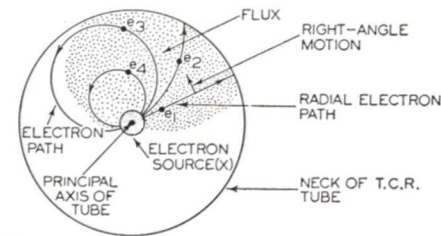
Imagine that the magnetic lines of force shown in Fig. 13A are parallel to the plane of this page, and the electrons are moving into the field (into the paper) at point X, along a path or beam that is at right angles to the page. Associated with these moving electrons will be circular magnetic lines of force having the directions shown in Fig. 13B. When these circular magnetic lines of force exist in the magnetic field of Fig. 13A, there will be a crowding of flux at the left of point X, and a thinning out of flux at the right of point X. This unbalance causes electrons to move to the right, thereby rebalancing the field.

The complete picture of this action is shown in the three-dimensional diagram in Fig. 13C. The initial direction of electron movement (e) and the direction of the magnetic flux (F) are at right angles ( $90^\circ$ ) to each other. As a result of the interaction between the magnetic lines of force, the electrons will be moved to the right (arrow M indicates this motion), at right angles to both the initial electron flow and the original magnetic field. From this fundamental analysis, we can see that an electron traveling perpendicular to a magnetic field is forced to move in a direction at right angles to both its original path and the original magnetic field.

Returning to Fig. 12, we can now see that it is the reaction between the radial electron velocity component  $e_r$  and the focusing magnetic field that causes electron e to be redirected back toward the principal axis of the tube. It will be more convenient to look at a cross-sectional diagram through cross-over point X of the picture tube (Fig. 14) while studying this action.

Let's assume that electrons are moving radially away from cross-over point X, which is our electron source.

If there were no magnetic field in the vicinity, these electrons would move radially out to the neck of the tube, as indicated by path  $e_1$ . With a focusing magnetic field here, at right angles to the electron path, these electrons are given a side push at right



**FIG. 14.** How the strength of the focusing magnetic field affects electron paths in an electromagnetic tube.

angles to their original path, with the amount of this push depending upon the flux density. For a low flux density, the electrons would therefore take path  $e_2$ , and for increasing flux densities they would take paths  $e_3$  and  $e_4$  respectively. In a system of magnetic focusing the magnetic field density is increased simply by increasing the value of direct current through the focusing coil.

Note that paths  $e_3$  and  $e_4$  in Fig. 14 are both complete circles that bring the electrons back to the principal axis. For a given initial electron velocity, increasing the magnetic field density shortens this circular path back to the principal axis. By adjusting the field strength so that it takes electrons just as long to travel this circular path back to the axis as it does for them to travel longitudinally along the axis to the screen, we can make electrons hit the screen right at the principal axis even though they

leave the cross-over at an angle. Varying the focusing coil current changes the magnetic field strength; therefore, in a tube employing electromagnetic focusing, the focusing coil current is varied in order to focus the electron beam.

It is not essential that the focusing coil enclose the entire distance from the cross-over point to the screen. A short coil located near the cross-over point will give electrons the essential twist back to the principal axis, so that they will focus to the desired spot size at the screen.

There is a definite relationship between the velocity of the electrons at the cross-over point and the magnetic field strength required for correct focusing. The greater the electron velocity, the greater must be the flux density in order to secure the desired focusing. Any change in the electrode voltages changes the electron velocities, making it necessary to readjust the focusing coil current in order to maintain the desired sharply focused spot on the screen.

In tubes employing magnetic focusing, the control grid is so designed that it essentially controls only the number of electrons in the beam. The first anode, aside from its action in focusing electrons to the cross-over point, determines the velocity of the electrons at the cross-over point. With this arrangement, there is a minimum of defocusing when the electron beam is modulated with a television signal. Further velocity is imparted to the beam by the second anode which is not designed to form an additional lens with the first anode.



# Deflecting the Electron Beam

Having passed the focusing structure, which may be either a bi-potential lens or an electromagnetic focusing coil, the electron beam travels to the screen in the form of a beam more or less along the principal axis of the tube. This electron beam must be swept horizontally across the screen 15,750 times per second, and must be swept vertically up and down the screen 60 times each second.

There are two methods for accomplishing this sweeping of the electron beam across the screen: 1, electrostatic deflection, in which the beam passes between charged parallel metal plates that attract or repel the electrons to produce the desired bending of the beam; 2, electromagnetic deflection, in which an electromagnetic deflecting yoke produces a magnetic field that interacts with the magnetic field of the electron beam to produce the desired bending.

## ELECTROSTATIC DEFLECTION

When using two parallel charged metal plates to deflect an electron beam, the plates are fed from a push-pull amplifier with a saw-tooth a.c. sweep voltage that makes one plate negative while the other is positive, and vice versa, alternately. Thus the beam will be attracted toward the positive plate and repelled by the negative plate. Since this is a saw-tooth voltage of the a.c. variety, the plates will regularly reverse polarity, and the beam will be swept back and forth across the face of the tube as shown in Fig. 15A, in this case tracing a straight horizontal line. With other plates placed at right angles to those shown in Fig. 15A, as is illustrated at B, a straight vertical line will be traced on the face of the tube. When swept both horizontally and vertically

at the same time, the rapidly occurring horizontal lines are gradually moved down the face of the tube by a single vertical sweep, the vertical sweep then returns the beam to the top of the tube, and the process is repeated, thus scanning the entire screen. This pattern of light produced by the scanning is called the raster.

In modern television work the deflecting plates are maintained at approximately the same d.c. potential as the second anode, being connected to it through decoupling resistors. The sweep signals are then fed through coupling condensers to the deflecting plates.

Electrons enter the region between the parallel plates in Fig. 15A with a definite velocity, corresponding to that given by the potential of the second anode. When plate X is positive with respect to plate Y, it will attract the electrons in the beam and conse-

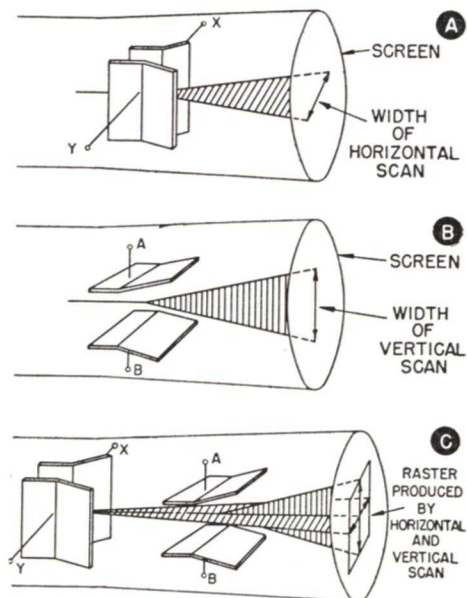


FIG. 15. How the electron beam is swept in an electrostatic tube.

quently pull the beam toward it. On the other hand, when plate Y is positive with respect to plate X, electrons will be repelled from plate X and bent toward plate Y.

The amount of bending will depend upon the voltage difference between the two plates, upon the distance between the plates, and upon the length of time the electrons are between the plates. The greater the voltage difference, the greater will be the bending or deflection. The closer to each other the plates are, the greater will be the deflection. The longer the electrons take to travel between the plates, the greater will be the deflection.

The length of time it takes the electrons to pass through the plates de-

move the spot on the screen a unit distance (the lower the deflection voltage, the greater is the sensitivity), or the distance that one volt will move the spot on the screen (the greater the distance, the greater is the sensitivity). Remember, however, that the second anode voltage that governs the electron velocity must be specified whenever a sensitivity rating is mentioned. This is necessary because increasing the velocity (by increasing the second anode potential) will reduce the deflection sensitivity, and make it necessary to apply higher deflecting voltages to obtain the desired sweep.

**Curved Deflection Plates.** As has already been pointed out, the deflection sensitivity is dependent upon the

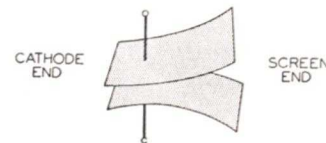


FIG. 16. Flared deflection plates of this sort are often used in electrostatic tubes.

pend upon the electron velocity (the second anode voltage), and upon the length of the plates along the principal axis. The higher the velocity, the less time the electrons are between the plates. Looking at this condition in a slightly different way, we can think of a high-velocity electron beam as being stiff, and hence more difficult to bend. The bending action of an electron beam should be considered in terms of the spot deflection on the screen rather than in terms of the bending angle. Of course, for a given bending angle, the spot movement on the screen will depend upon the distance between the deflecting plates and screen, increasing as this distance is increased.

The deflection sensitivity of an electrostatic deflection system can be expressed either in terms of the deflecting plate voltage that is required to

lengths of the deflecting plates and upon their separation. For a given electron speed, there is an optimum length and optimum separation, but deflection sensitivity can be increased by keeping the beam close to the plates without actually hitting the plates. Curved plates that flare outward in the manner shown in Fig. 16 meet this requirement. You will find that plates of this type are used extensively in picture tubes because they permit a closer spacing of the gun end of the plates, and still do not intercept the beam when it is bent a maximum amount.

## TYPICAL ELECTROSTATIC PICTURE-TUBE CIRCUIT

Let us briefly review what we have learned about electrostatic picture



tubes, and see how they are actually connected in practical TV circuits.

A cross-sectional diagram of an electrostatic-type picture tube, including the electron gun and one set of deflecting plates, is shown in Fig. 17.

Electrons, emitted by the cathode, are accelerated by the first and second anodes. The voltage between the grid and the cathode controls the number of electrons that are able to pass the grid, and this in turn controls the intensity of the spot produced on the screen of the tube.

The grid is at a fixed d.c. potential with respect to ground, but the voltage between the cathode and the grid can be varied by means of potentiometer  $R_1$  that functions as the intensity or brilliancy control. The video signal is applied to the control grid through coupling condenser  $C$ , and is developed across resistor  $R$ . Thus, this signal is effectively in series with the bias voltage.

As you know, the focus of the electron beam is controlled by varying the voltage difference between the first and the second anodes. Thus  $R_4$  serves as the focus control. Resistor  $R_3$  is

connected in series with the first anode to limit the anode current to safe values by causing the anode voltage to drop as the current increases.

The high B voltage (accelerating voltage) is applied to the second anode through protective resistor  $R_5$ . The deflecting plates must have a d.c. voltage almost as high as that applied to the second anode to avoid defocusing of the beam. Therefore one deflecting plate is connected between  $R_7$  and  $R_8$ , and the other deflecting plate is connected to potentiometer  $R_9$ . The sweep voltage is applied through condensers  $C_1$  and  $C_2$ , with resistors  $R_{10}$  and  $R_{11}$  acting as coupling resistors.

If the center arm of  $R_9$  is varied until the voltage applied to the upper deflecting plate is equal to the voltage applied to the lower plate (that is, at the same potential as the junction of resistors  $R_7$  and  $R_8$ ), then the electron beam will have the center position shown at A if the tube is perfect. (The beam is being deflected to either side of this position by the a.c. sweep voltage applied through  $C_1$  and  $C_2$ .)

If we move the center arm from this position (position 2 on  $R_9$ ) so that the

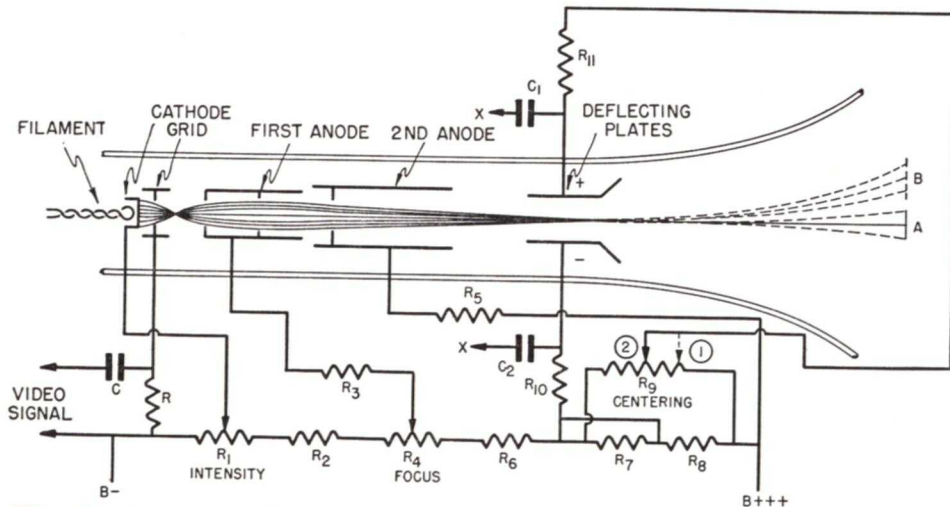


FIG. 17. Cross-sectional view of a typical electrostatic tube, showing voltage division arrangement for one pair of deflection plates.

upper plate is more positive than the lower plate, then the electron beam will be moved upward to position B; that is, as we move the center arm from position 2 to position 1, the beam moves from position A to position B. The beam is still moved to either side of the center position by the saw-tooth sweep-deflecting voltage applied through  $C_1$  and  $C_2$ . Similarly, by moving the  $R_9$  slider the other way, the beam is moved nearer the lower deflection plate. Therefore,  $R_9$  acts as a centering control; irregularities in the tube may prevent the beam tracing from being centered on the tube face, so  $R_9$  can be adjusted as required to center the raster.

The other resistors in the voltage divider, consisting of  $R_2$  and  $R_6$ , serve simply to divide the voltages in the proper proportion between the various electrodes of the picture tube.

We have not shown the other set of deflecting plates here, so in Fig. 18A, a more complete and more typical voltage divider circuit is shown. The high B voltage is supplied to the upper end of the voltage-divider circuit, and the lower end is connected to ground at the point where  $B-$  from the high voltage supply is connected. Voltage is applied to the second anode through resistor  $R_1$  which acts to limit second-anode current to a safe value.

Resistors  $R_2$  and  $R_3$  correspond to  $R_7$  and  $R_8$  in Fig. 17. A lead is taken to one of the vertical deflecting plates through  $R_9$ , while another lead is connected to one of the horizontal deflecting plates through  $R_6$ .

Potentiometers  $R_4$  and  $R_7$  are connected in parallel with  $R_2$  and  $R_3$ ;  $R_4$  is connected through  $R_5$  to the other horizontal deflecting plate. By varying the position of the center arm on  $R_4$ , we can vary the d.c. potential between the two horizontal deflecting plates. Therefore,  $R_4$  acts as the

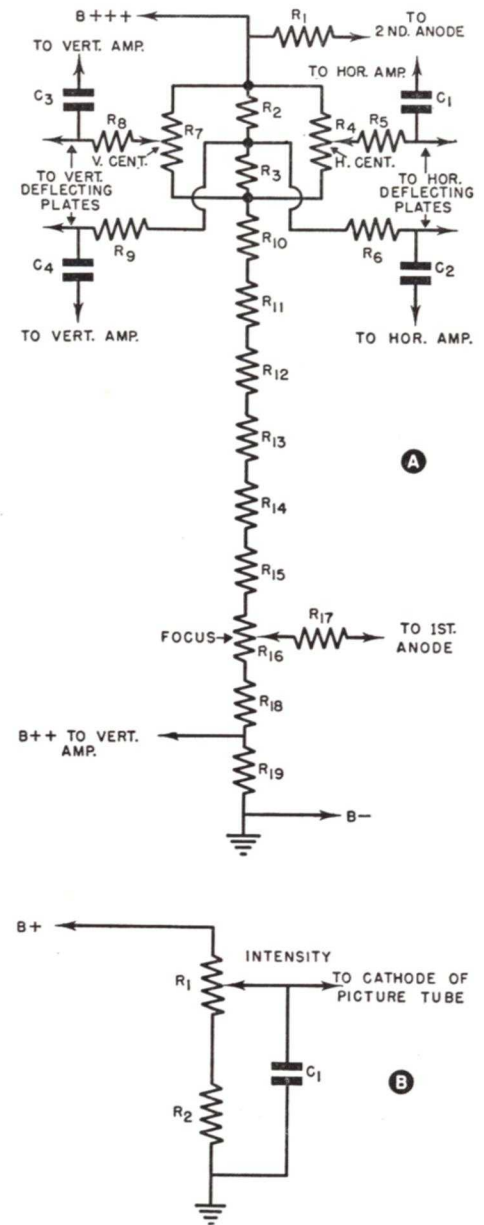


FIG. 18. Typical complete voltage division arrangement used with electrostatic picture tubes.

horizontal centering or positioning control. Resistor  $R_7$  serves a similar function for the vertical plates and is thus the vertical centering control.

The sweep voltage for the vertical



plates is applied through condensers  $C_3$  and  $C_4$ , while the sweep voltage for the horizontal plates is applied through  $C_1$  and  $C_2$ . Since the horizontal-sweep frequency is much higher than the vertical-sweep frequency, smaller condensers may be used at  $C_1$  and  $C_2$  than at  $C_3$  and  $C_4$ .

Note that we have six resistors instead of one between the lower end of  $R_3$  and the upper end of focus control  $R_{16}$ . These correspond to resistor  $R_6$  in Fig. 17. The heat dissipation in a high-voltage divider circuit is comparatively high so a single standard-size resistor, even of a comparatively high wattage rating, is not satisfactory. Rather, a series of resistors are used, with the total resistance of the individual resistors adding up to the correct value for proper voltage division.

Thus the wattage dissipation is divided among the various resistors, and lower-wattage, and hence physically smaller resistors, may be used. If some of the resistors in this group should change in value, the voltage division would also change, and it may be impossible to focus the electron beam. There is less chance of such a change occurring if the wattage rating of the individual resistors is not exceeded.

In this particular voltage divider, provision is not made for controlling the intensity of the electron beam. Rather, a separate d.c. voltage is applied to the cathode of the picture tube as shown in Fig. 18B. By varying the position of resistor  $R_1$ , the potential between the cathode and the grid may be varied with a resultant change in brilliancy. A by-pass condenser,  $C_1$ , is connected between the center arm of the intensity control, shown in Fig. 18B, and ground. This serves to keep the cathode at ground potential as far as video signals are concerned.

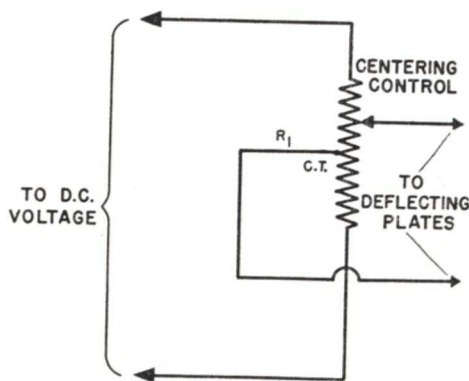


FIG. 19. Tapped centering control often used with electrostatic tubes.

Instead of using resistors such as  $R_2$  and  $R_3$  for applying a fixed d.c. voltage to one of a pair of deflecting plates, a tap may be provided on the centering control as shown in Fig. 19. This may be a center tap, but in some cases it will be found that the tap is off center. This is because some electrostatic tubes, due to manufacturing tolerances, may not require exactly the same voltage applied to the horizontal deflecting plates as is applied to the vertical deflecting plates for proper centering. Thus, the horizontal centering control may have the tap off center, whereas the vertical centering control may have the tap exactly in the center.

**Service Hints.** When replacing the centering controls in a TV set, it is important that an exact duplicate replacement be obtained if a tapped control is used. This insures that the tap will be in the right position for the particular pair of deflecting plates to be controlled.

A change in value of resistors  $R_2$  or  $R_3$  may make it impossible to correctly center the raster. More often this is due to leakage in one of the coupling condensers that feeds the deflecting plates. Leakage in one of the condensers will change the d.c. voltage

applied to the plate in question, and may even throw the raster entirely off the screen, either in a vertical or in a horizontal direction.

## ELECTROMAGNETIC DEFLECTION

You already know that when an electron stream passes through a magnetic field at right angles to the lines of force, the stream is bent at right angles to both the lines of force and the original path. Fig. 20 illustrates how this principle is employed to give electromagnetic deflection in a picture tube. Electrons  $e$ , traveling along the principal axis of the tube in a stream, enter a uniform magnetic field having

bending action will be uniform at all points in the field, and the electron stream will follow a circular path having a radius  $R$ . Once electrons emerge from the field at point 2, they travel in a straight line again. The path shown in Fig. 20 would take the electron stream to the outer edge of the fluorescent screen.

When an electron stream travels through a uniform magnetic field, the velocity of the electrons is not altered by the magnetic field. Increasing the flux density in the magnetic field shortens the length of radius  $R$ , thereby increasing the amount of deflection on the screen. Increasing the length of the magnetic field along the path of

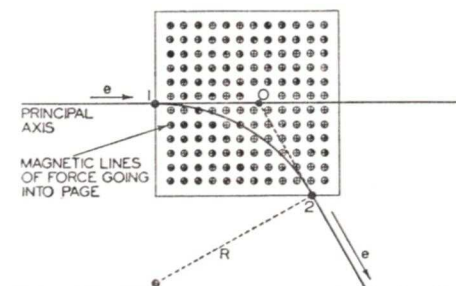


FIG. 20. How electromagnetic deflection works.

lines of force flowing into the paper. By applying the left-hand rule to determine the direction of the magnetic flux created by this electron flow, we find that there is a crowding of flux above the path, and a thinning out or canceling of flux below the path. The electron stream is thus bent downward in the plane of the paper, at right angles to both the original path and the magnetic lines of force. Reversal of the magnetic lines of force will cause the beam to be bent upward. Thus, we can get magnetic deflection as well as magnetic focusing just by using the proper coils for each purpose.

As long as the density of the magnetic field in Fig. 20 is constant, the

electron travel does not affect the value of  $R$ , but does increase the amount of deflection since the electrons are under the influence of the magnetic field for a longer period of time. The higher the velocity of the electrons in the stream, the greater must be the flux density in the field in order to secure a given amount of deflection, for a stiff (high-velocity) electron beam is not bent as readily as a low-velocity beam.

In a practical tube, a magnetic field for beam deflection is produced by an electromagnet that surrounds the neck of the tube. Once the poles of this electromagnet are identified, we know that the electron beam will be de-



flected at right angles to the line between the pole faces. Thus, the pair of magnetic poles that serves for vertical deflection of an electron beam will be mounted horizontally, and the poles that give horizontal deflection will be mounted vertically.

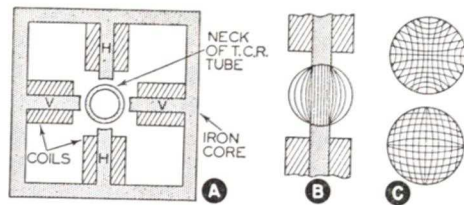


FIG. 21. Design and characteristics of a simple electromagnetic deflecting yoke.

A simple electromagnetic deflecting yoke that provides both vertical and horizontal deflection is shown in Fig. 21A. Note that the vertical deflecting poles V are arranged horizontally, and the horizontal deflecting poles H are arranged vertically. The yoke is constructed from laminated sheet steel, with the coils wound on bobbins, or forms that slip over the poles. Opposite coils are connected so that they have opposite polarity.

Although the simple electromagnetic deflecting yoke in Fig. 21A will give a spot deflection that is essentially proportional to the deflecting circuit current, it will also produce defocusing and pattern distortion. This is because of the fact that the magnetic field between opposite poles is not uniform, but rather has curved lines of force as shown in Fig. 21B. It can be shown by means of a very complex analysis that when electrons travel through a non-uniform magnetic field, the circular beam is flattened out to an egg-shaped spot instead of a round spot on the screen.

When the fields for both horizontal and vertical deflection are non-uniform in density and are curved, pat-

tern distortion of the type shown in Fig. 21C occurs when an image made up of perfectly vertical and horizontal cross lines is being reproduced. We need not consider these defects in detail, since they can be avoided by using deflecting yokes that give uniform, straight-line magnetic fields.

In the improved type of electromagnetic deflecting yoke that is used with modern picture tubes, rectangular coils are wound in such a way that they fit inside one another as shown in Fig. 22. The windings for each coil are connected in series, then bent into the half-cylinder shown in Fig. 22B. Two such systems of coils are placed around the neck of the picture tube, and are connected together in series in such a way as to produce poles of opposite polarity. A pair of coil systems like this produces the desired uniform straight magnetic field. One pair of coils is placed directly over the neck of the tube and made to serve for horizontal deflection, and the other pair is placed over the first pair and made to serve for verti-

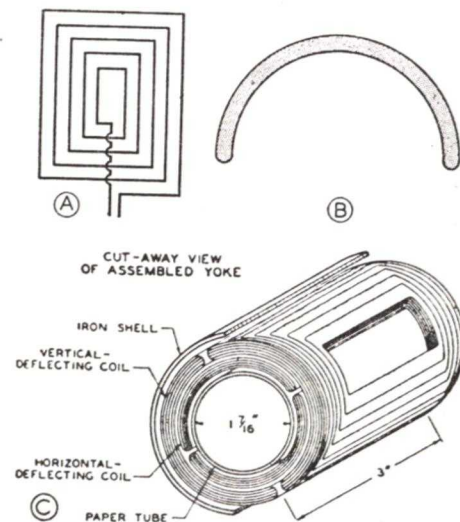


FIG. 22. Construction of a modern deflecting yoke.

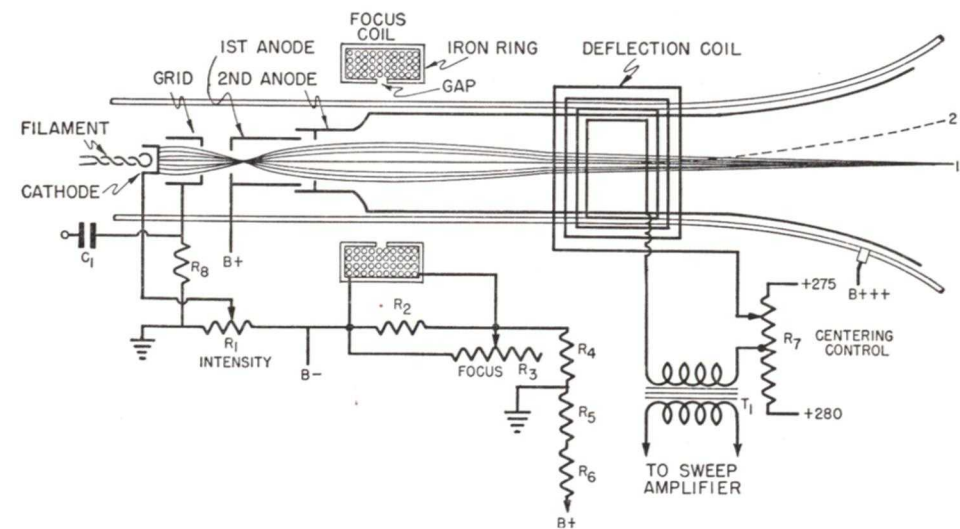


FIG. 23. Cross-sectional view of an electromagnetic tube, showing where the various operating voltages are applied.

cal deflection as shown in Fig. 22C. The entire coil assembly is encased in a soft-iron shell in order to reduce the reluctance of the magnetic circuit, and to prevent the magnetic fields of the coils from affecting the focusing field of the picture tube.

In an electrostatic deflection system, the sweep voltage that is applied to the deflecting plates must have a true saw-tooth characteristic. In an electromagnetic deflecting system, the current through the deflecting coils must have this same saw-tooth characteristic.

### ELECTROMAGNETIC TUBE CIRCUIT

Let us now briefly review some of the things that we have learned about electromagnetic-type tubes, and see how they function in actual receivers.

In electromagnetic tubes the intensity of the electron beam is controlled in the same way that it is in electrostatic tubes, that is, the d.c. voltage applied between the control grid and

the cathode of the tube is varied by means of a potentiometer such as R<sub>1</sub> shown in Fig. 23. The signal is applied through C<sub>1</sub> so that it appears across R<sub>8</sub>.

The current through the focus coil that is placed around the neck of the picture tube is varied in order to change the focusing of the electron beam. As the resistance of R<sub>3</sub> is increased, for example, more current can flow through the focusing coil, and a stronger magnetic field will be produced, changing the focus point of the beam.

A cross-sectional view of the construction of the focus coil is illustrated in Fig. 23. The coil is wound of copper wire and a soft-iron ring is placed around it. A gap is provided in the iron ring, and the magnetic field spreads out from this gap. This provides a concentrated magnetic field that will not extend beyond the section of the tube of the neck in which the focusing action is desired. No matter at what angle the electrons enter the field, the magnetic field provides enough deflection so that they will



all be focused at the same point on the screen. The path followed by any one electron will be a cork-screw shape because of the resultant action of the two forces—the force acting to accelerate the beam (high voltage on the second anode), and the force acting to focus the beam.

**Positioning the Beam.** To position the electron beam, d.c. is passed through the deflection coil in series with the a.c. obtained from the sweep amplifiers. It is quite easy to provide a variable direct current. A variable resistor is placed in the voltage divider of the low-voltage power supply. In Fig. 23, a tapped potentiometer  $R_7$  is used. Thus, as the center arm is moved past the tap, the di-

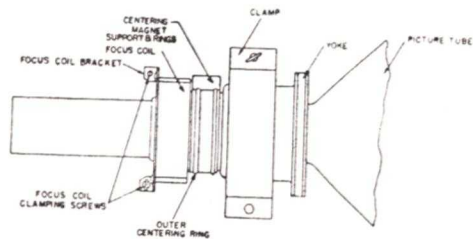


FIG. 24. How a permanent centering magnet is installed.

rection of the d.c. flow through the coil will be reversed, reversing also the movement of the electron beam. Tapped centering controls are not used in all sets, however. In many instances, centering is accomplished by moving the focus coil. Once the correct position of the focus coil has been obtained for proper centering of the picture, the current through the coil may be readjusted to give correct focus. The focusing adjustment will not change the centering of the picture.

Instead of centering the focus coil or allowing d.c. to flow through the deflection coil, centering is sometimes accomplished by means of permanent magnets mounted on the neck of the

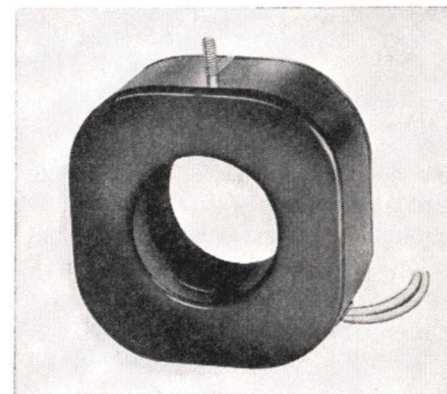
picture tube between the focus and deflection coils. Such an arrangement is illustrated in Fig. 24. The centering ring and the support assembly are shown here between the focus coil and the deflection yoke. The centering assembly consists of a large ring that can be moved forward or backward along the ring-support assembly. To center the electron beam, move the large ring toward the focus coil. The whole centering assembly is rotated until the beam moves to the proper position. Then the large ring is moved forward until the beam is centered. The present trend is, however, toward centering (without special controls or additional magnets) by adjusting the position of the focusing coil.

A typical focus coil is shown in Fig. 25A. This focus coil is an electromagnetic coil, that is, the magnetic field depends directly upon the current flowing through the winding. The bolt extending from the top of the focus coil passes through the mounting assembly, and may be tightly fastened to the assembly with a wing nut after the focus coil has been positioned. This holds the focus coil in place so that it will not be jarred out of position.

Considerable current through the coil is usually required—100 ma. or more. This current, however, is easily obtained from the low-voltage supply of the receiver. When this is done,

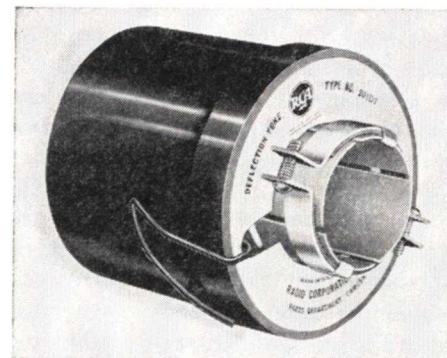
a large percentage of the direct current required from the B supply of the receiver can be passed through the focus coil with only a slight voltage drop. It would, of course, be possible to use a permanent magnet for the focus coil, or to use a permanent magnet to furnish most of the field and a small auxiliary electromagnet for fine focusing.

The focusing field must be produced by well-filtered d.c. in order to avoid blurring of the spot; a.c. ripple through the focus coil would produce a changing electromagnetic field, and as a result the beam would go in and out of focus. For a typical 10-inch



Courtesy RCA

FIG. 25A. Typical focus coil.



Courtesy RCA

FIG. 25B. Typical deflection yoke.

picture tube about 450 ampere-turns are required for the focusing coil to obtain sharp focusing of the beam. For a projection tube with a very stiff beam, about 1000 ampere-turns are required for focusing.

A typical deflection yoke containing the horizontal and vertical deflection coils is shown in Fig. 25B. This also slips over the neck of the tube in front of the focus coil as we illustrated in Fig. 23.

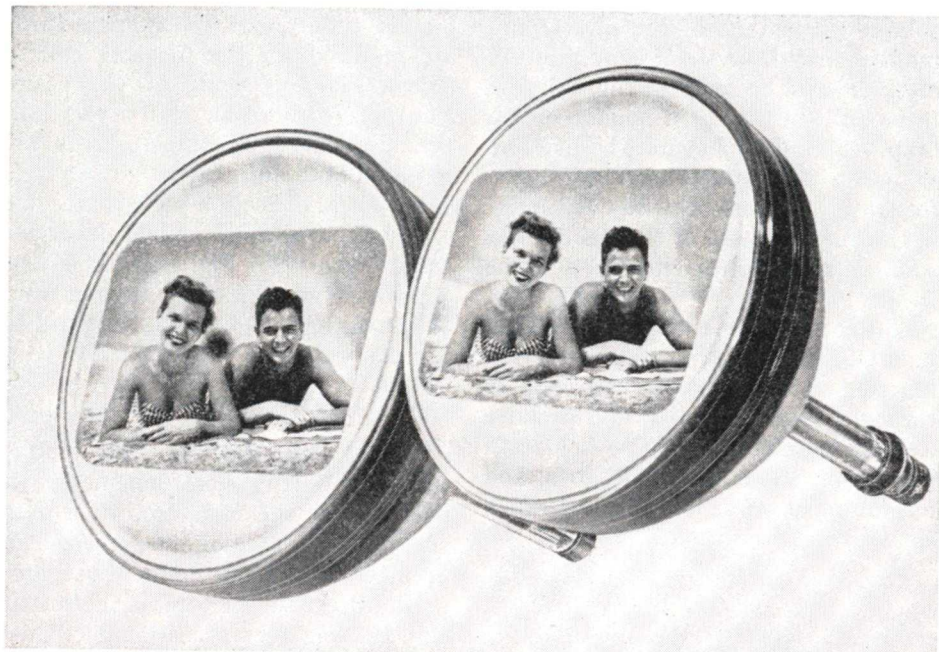
## THE ION SPOT

One of the defects of early picture tubes employing electromagnetic deflection was the formation of a dark spot in the center of the screen. This occurred after a few hours of use, and, as shown in the picture at the left in Fig. 26, was very objectionable. Once this dark spot appeared on the screen nothing could be done about it except to replace the tube.

This dark spot is caused by a beam of negative ions that bombards the fluorescent coating at the center of the screen, causing that portion of the screen to disintegrate, and rendering it incapable of producing very much light.

These negative ions in the electron stream have a much greater mass than the electrons, because they are much heavier. The ion spot can be avoided by using electrostatic-deflection tubes because the electrostatic field deflects these heavy ions and the lighter electrons equally well, so there is no concentration of ions at the center of the screen and no ion spot is formed. However, an electromagnetic field has little effect on the heavy ions, deflecting the electrons only. Therefore, when electromagnetic deflection is used, the heavy ions will strike the center of the screen, and in a short time will cause a dark spot to appear in the center of the screen.





Courtesy Sylvania Electric Products, Inc.

FIG. 26. Notice ion spot in center of the face of the tube at left.

### ION TRAPS

There are a number of methods for preventing these heavy ions from causing a dark spot on the screen. One method is to use an ion trap. This ion trap actually traps the ions in the electron gun, and prevents them from reaching the screen. There are many variations of this trap used by different tube manufacturers, but all operate on the same principle—that an electrostatic field will deflect both ions and electrons equally well, but an electromagnetic field will deflect only electrons.

One popular ion trap arrangement consists of a special construction of the electron gun and a magnetic ring assembly placed around the neck of the tube. The special construction of the electron gun is shown in Fig. 27A. Note that the adjacent ends of the first and second anodes are cut at an angle rather than straight across as in the conventional manner previously

described. Also there is a small aperture at the end of the second anode through which the electrons must pass in order to reach the screen of the picture tube. In general, the first anode will operate at approximately 250 volts while the second anode may have around 8500 volts applied to it. Therefore a strong electrostatic field exists in the air gap between these anodes. Because the gap between the anodes is slanting, the electrostatic field set up in the gap will not follow the normal axis of the tube, but will be slanting like the cut. The ions and the electrons entering this slanting electrostatic field will be deflected away from the principal axis of the tube, and will not get through the small aperture at the end of the second anode, being trapped in the second anode. In order to separate the ions from the electron stream we make use of the fact that a magnetic field will deflect the electrons, but has little or

no effect on the heavier ions. By placing a magnetic ring on the outside of the tube neck, approximately over the gap between the two anodes, and magnetizing the ring in such a way that magnetic flux cuts across the neck of the tube, the effect of the slanting electrostatic field on the electrons can be neutralized.

By proper adjustment of the magnetic ring the electrons can be made to return to a straight line along the principal axis of the tube, passing through the opening in the end of the second anode so that they can strike the fluorescent screen. The heavier ions, however, will remain trapped in the second anode, since the magnetic field has practically no effect on their direction of travel, and they are not deflected back to the principal axis of the tube. This action is illustrated in Fig. 27B. Another but smaller magnetic ring usually follows the first one to compensate for the fact that the first magnet does not exactly line up the stream with the mask hole. However, in some picture tubes only one magnetic ring will be used.

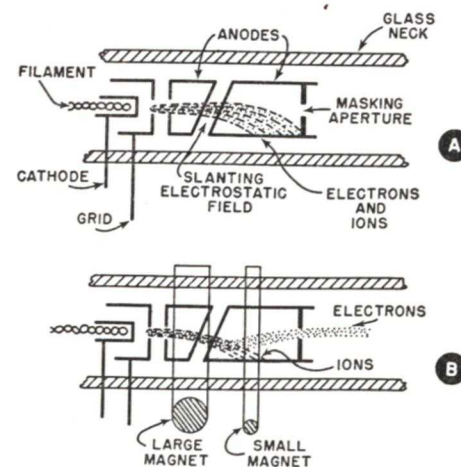


FIG. 27. How a two-magnet ion trap works.

### ION-TRAP ADJUSTMENT

The proper adjustment of the ion-trap magnet on the neck of the picture tube is of major importance in installing and servicing a TV set.

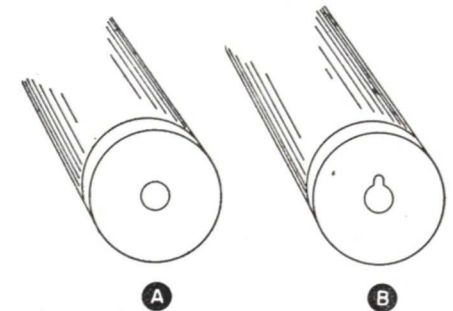


FIG. 28. If the ion trap is not properly adjusted, the aperture at the end of the second anode may be burned.

When the ion trap is completely out of adjustment, the electron beam cannot escape from the second anode, so there is no raster (no screen illumination) at all. If this condition of electron bombardment of the second anode continues for long, a hole may be burned in this element.

When the ion trap is in partial adjustment, there will be a raster, but it will be dim, and may have a "shadow" in one corner or on one side. This occurs because, when the magnet is not in the correct position, the electron beam bombards the edge of the hole in the second anode baffle, instead of going through the aperture. The reduced number of electrons reduces the raster brilliancy. Even worse, the heat thus produced will vaporize the metal of the disc, producing a non-circular hole as shown in Fig. 28B, and releasing gases that have a harmful effect on the operation of the tube. Some of this vaporized material may be deposited on the screen, causing permanently darkened areas.

To avoid damage to the picture



tube, the ion-trap magnet should be adjusted immediately when the tube is installed in the set, and should be checked when the set is moved to a new location as the magnet may have been jarred out of position.

The ion trap is adjusted until the brightest raster is obtained. With the tube operating, and with the brightness control adjusted for low intensity,

the magnet should be moved a short distance forward and backward, and at the same time rotated until the combination of these movements produces this condition of brightest raster. By keeping the brilliancy control at a low setting, the beam current is low enough so that the electron beam is not likely to damage the anode aperture before the magnet is adjusted.

## Fluorescent Screens and Tube Envelopes

Now that you have seen how the electron beam is produced, focused, and deflected, let's learn more about the screen that produces light when struck by this beam.

### FLUORESCENT SCREENS

The special chemical material that is deposited on the inner face of a picture tube (in the position shown in Fig. 29) will produce light when bombarded with a stream of electrons. The explanation usually offered for this phenomenon is that the energy of electron impact disturbs the electrons in the atomic structure of the chemical material, thereby making this material absorb energy. In returning to their normal state, the electrons in this material give off light. Any material that behaves in this manner is known as a phosphor. The production of light by a phosphor while being excited by an electron stream is called fluorescence.

The preparation of phosphor material for picture tubes is a highly specialized branch of chemistry. The most commonly used materials are willemite and zinc sulfide. Willemite is a chemical made up chiefly of zinc,

silicon and oxygen, and gives a green to yellow fluorescence when bombarded with electrons. Zinc sulfide phosphors are available under various trade names, and normally give a blue fluorescence. When used with small portions of other materials known as activators, the fluorescent action is increased and the color of the light is changed. By properly combining the

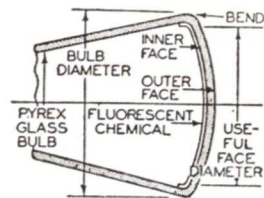


FIG. 29. The fluorescent screen material is deposited on the inner face of a picture tube.

different materials, it is now possible to secure an almost white fluorescence.

**Decay Time.** Once a fluorescent material is bombarded by an electron stream, it will continue to glow even after the electron stream has moved away or has stopped. It is possible to make phosphor materials that will glow as long as one minute after ex-

citation, but these materials would hardly be suitable for picture tubes. In television it is desirable to use materials that glow for very short periods after the excitation has been removed, so that an image remains almost until the next one takes its place, but the

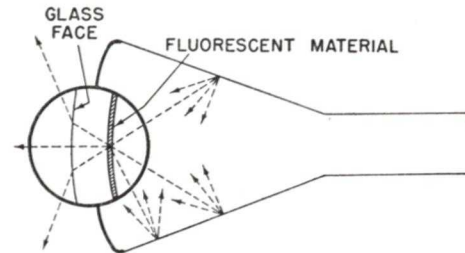


FIG. 30. Light is emitted in all directions from an element of the fluorescent screen of a conventional picture tube.

image should not remain long enough to interfere with a following one.

The glowing of a screen after removal of excitation is referred to as the persistence of the screen, and the time it takes to reduce the glow a certain amount (say to 1/10 of its original brilliance) is known as the decay time. By selecting a decay time that will give a reduction in brilliancy to a negligible value in 3 milliseconds or less, one image will be almost completely dark by the time the following image is produced, and there will be no overlapping of images. The persistence characteristic of a fluorescent screen is highly desirable in that it aids the persistence of vision of the human eye, thereby reducing flicker and helping to maintain screen brilliancy.

### DAYLIGHT TUBES

Considerable work has been done to improve the amount of light obtained from picture tubes. A cross-sectional area of an ordinary picture tube is shown in Fig. 30. In this figure the region in the circle is greatly mag-

nified to show one element of the phosphor that is fluorescing. Light is emitted in all directions from the spot, so at least 50% of the light generated in the screen is emitted toward the electron gun in the neck of the tube. Another 20 to 25% is lost by reflection from the glass on the inside of the tube face. Thus only 25 to 30% of the total light generated passes through the glass face in the form of useful light output.

Fig. 31 shows a tube whose screen is covered with a layer of aluminum deposited behind the phosphor crystals. The light that ordinarily would go back toward the electron gun is reflected forward in the direction of viewing. These tubes with an aluminum backing are frequently referred to as Daylight tubes because they can be viewed in full daylight.

The metallic backing on the screen must be thin enough not to slow down the electron beam, and it should be optically flat so that it will reflect the light that is given off by the phosphor, thus increasing the efficiency of the

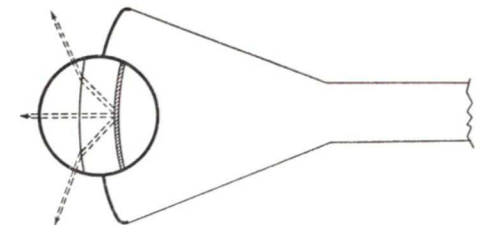


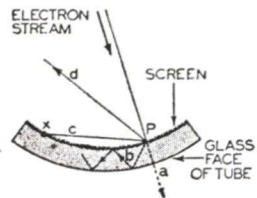
FIG. 31. Most of the light emitted by an element of the fluorescent screen is directed forward if the screen has an aluminum backing.

tube. Also, the metallic backing should provide a conductive surface over which the electrons can move, preventing the screen from assuming a negative charge, so that maximum energy is available from the electrons.

In construction, the aluminum is usually vaporized onto a flat inter-



mediate surface of organic material deposited on the phosphor. The organic coating is then evaporated, leaving the new surface supported on the tips of the phosphor crystals. In addition to producing far more light output, the aluminum backing prevents the formation of an ion spot



**FIG. 32.** Light emitted from an element of an unbacked fluorescent screen may take any of these paths.

burn on the screen because the large ions cannot penetrate the aluminum to strike the screen. Hence, a special gun with an ion trap is not required with tubes of this type. These tubes are widely used for direct viewing and practically all projection tubes employ this aluminum backing, since all the light possible is required in projection.

As shown in Fig. 30, some of the light reflected back into a tube without the aluminum backing will strike the side of the bulb, and is then reflected back through the screen. This may cause an area that is normally dark to be illuminated. As a result the contrast will be poor. To have good contrast the black areas must be black and the white areas must be white with the proper shadings in between. Thus the aluminum backing will, to some extent, improve the contrast.

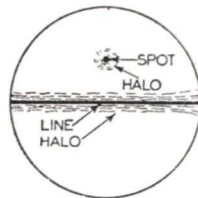
### HALATION

As stated previously, only a portion of the light produced by the electrons bombarding the screen is visible from the outside. The point at which the beam strikes the fluorescent material

becomes a source of visible light, and the produced light rays spread in all directions. Light rays at a large angle to the direct path shown as A in Fig. 32 are reflected back and forth between the inner and outer surfaces of the tube face as indicated by path B.

Some rays from this point source go directly to some other point on the screen such as along path C to point X, causing excessive brightness (particularly when point X represents a dark spot). This latter effect is increased by the curvature of the glass front plate. When relatively flat faces are employed, this trouble is not apparent and as stated before does not occur when aluminum backing is used.

Sidewise dispersion of the light as shown by line B in Fig. 32 causes more difficulty and results in halation. This is illustrated in Fig. 33. Along any one line the effect of halation will cause shadowy lines to border the desired bright line. For this same reason there will be a halo around the spot if the beam were stationary. Focusing adjustments are always made for the sharpest possible line with minimum halo. A technician must be able to

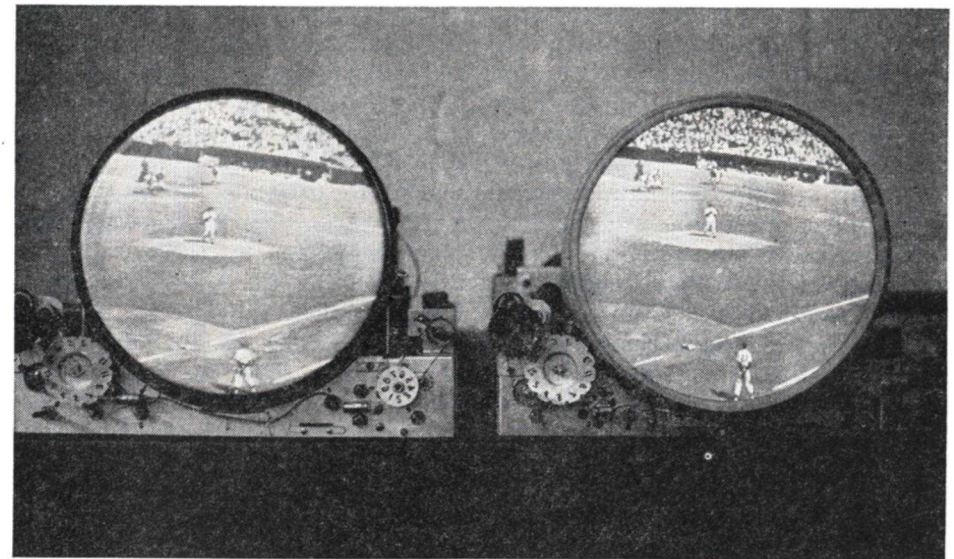


**FIG. 33.** Effects of halation.

recognize halation as an inherent defect in some picture tubes, and should not waste valuable time in attempting to correct the trouble.

### SPECIAL SCREENS AND FILTER GLASS

Halation can be minimized by using an opaque binder with the crystals. The binder confines the light emission



*Courtesy Rauland Corp.*

**FIG. 34.** Improvement in contrast produced by the use of a special glass for the picture tube face is illustrated at the right.

of each crystal to the viewing side of the crystal. This action prevents the scattering of light, and as a result increases the contrast of the picture.

The reflection of light from the air surface of the glass face plate back to the screen, to the surface and back to the screen again is minimized in some tubes by the use of special optical filter glass. (One filter face of this type is called Teleglas; the improvement in contrast is shown in Fig. 34.)

Ordinarily, any light falling on the tube face would change the blacks in the picture to a lighter shade, thereby reducing the over-all range of contrast. By using tubes with a filter glass face plate it is possible to have more illumination in the room where programs are being viewed without the attendant reduction in contrast.

At first, thin filters, sometimes of colored material and sometimes of polaroid, were used in front of the tubes in an effort to preserve contrast in an illuminated room. This cut down on external glare, but did not take

care of the reflections inside the tube face plate that produce halation. It was found that by making the entire face plate a filter, both external and internal reflections could be reduced to a minimum. Thus, both the halation and the external glare are reduced by using optical filter face plates.

Tubes using filter face plates are known as grey tubes, and sometimes as black tubes since the tube when not illuminated has a face considerably darker than that of the ordinary picture tube.

### FACE SHAPES

For viewing purposes, a flat face is desirable for a picture tube, but it is difficult to maintain sharpness of focus on a completely flat screen with a tube having a diameter of more than 10 inches. Referring to Fig. 35, we see that point O is the apparent source of the electron beam after it has been acted upon by the deflecting system. The focusing system in a picture tube is designed to bring the beam to a spot of a definite area at a definite distance



from the focusing electrode structure. Thus, with proper adjustments the spot will be focused at point S in the center of the screen in Fig. 35. The spot will also be focused properly anywhere along the arc 2, for all points along this arc are the same distance from the focusing system as is point S.

If the face of the picture tube is made with a curvature corresponding to arc 2, the spot will be in focus on the screen at all times. Hence, a certain amount of curvature will give better over-all focusing than will a flat face.

On the other hand, if a screen has a radius that is too short (too much curvature), as indicated by arc 3 in

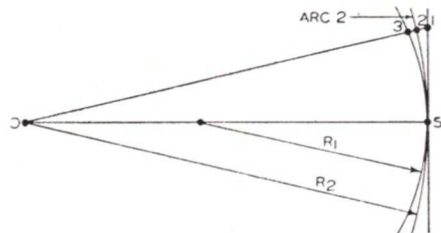


FIG. 35. Effect of screen curvature upon the sharpness of focus.

Fig. 35, the image will be noticeably out of focus near the edges. Hence, such a radically curved face gives poorer picture quality and also is undesirable to watch as the image is curved. In general, therefore, the face plates found in use will either be flat, or will have a slight curvature—just enough to provide better focus and give reasonable safety.

The safety factor is particularly important in the larger picture tubes. A picture tube has an almost perfect vacuum inside, and consequently the normal atmospheric pressure of about 15 pounds per square inch is pressing against the glass envelope at all points, tending to collapse it. A 15-inch diameter picture tube has a face area of

about 177 square inches. Multiplying 177 by 15 gives a pressure of about 2655 pounds on the face of the 15-inch tube.

A flat surface bends far more easily than does a curved surface. If a flat screen were used on a tube of this size, a slight jar or blow might be sufficient to cause collapse of the face. Under this condition the glass flies inward (an implosion) and then outward again, with sufficient force, in the case of the larger tubes, to cause serious personal injury. The use of a high-strength glass that is carefully annealed so that there are no strains, and the construction of the glass envelope in such a way that there are

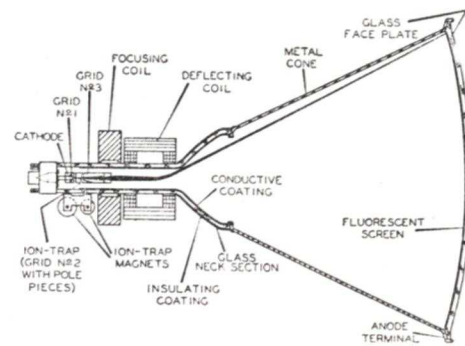
curves rather than flat surfaces at all points minimize the danger of collapse.

### METAL TUBES

The trend in TV receivers has constantly been toward larger pictures and less expensive receivers. The price of picture tubes, however, has made big-picture receivers expensive, since there is a limit to the saving that can be made in component parts and in receiver assembly procedures.

A 16-inch metal tube has been developed that has made drastic price cuts possible for large-picture receivers. This tube provides a picture size intermediate between the popular ten-inch picture tube and the large-

screen projection television systems. This tube is illustrated in Fig. 36. The envelope consists of a metal cone. To the large end of the cone is fused a slightly curved glass face plate; to the smaller end is fused the glass neck section containing the electron gun. The metal cone is made of a chromium-iron alloy chosen because of its



Courtesy RCA

FIG. 36. Cross-sectional view of a 16-inch metal tube.

excellent sealing quality. The shape of the cone was chosen because of its strength and its adaptability to mass production. Unique features of the tube are the large area of glass-to-metal seal between the face plate and the metal cone, and the stress system that permits the use of a relatively thin face plate of uniform curvature.

In order to fit into a wide range of uses, the tube was designed to operate either with a lower-cost power supply, such as is used in present 10-inch receivers, or at much higher voltages.

One of the features of this tube is its light weight. Heretofore, large glass tubes have been extremely heavy, but the 16-inch tube weighs no more than the glass 10-inch tube.

The metal shell serves as the anode, being electrically connected to the anode gun through a conductive coating deposited on the inside of the glass neck section. The metal cone, therefore, is at a high potential and is often

covered by a plastic insulating sleeve. The connection is made to the anode at the portion of the metal envelope marked "anode terminal" in Fig. 36. The flared glass section provides electrical insulation between the deflecting coils that operate at ground potential, and the exposed metal cone surface that operates at a high potential. Of course, one should avoid contact with the metal shell while the receiver is operating because the high voltage is dangerous.

Many of the dangers of implosion are removed by the use of the metal tube, since most of the flying glass comes from a fracture of a tube near the face plate. Breakage of the face plate in the metal tube usually will not send glass flying in all directions.

Metal tubes have also been made in other sizes such as the 8-inch tube and the 19-inch tube. All-glass tubes, however, will continue to be manufactured for a long time, and their price will drop as glass manufacturers find more efficient methods of production.

### SAFETY RULES

As the old saying goes, "Familiarity breeds contempt," and many TV technicians handle picture tubes without the caution that they deserve. To be on the safe side, respect the picture tube, since under some conditions they may be extremely dangerous. Never drop a tube, even from an elevation of a fraction of an inch. Do not slide a tube over any hard surface, because it may scratch at the bend around the face and so weaken the tube that at some future time a slight jar may cause an implosion. A tube should always be placed in its carton or on a rack when not in use. Never subject a tube to sudden changes in temperature; when a tube has been operating for some time, allow it to cool before taking it outdoors.



In tubes that have an outer conductive coating, remember never to touch this coating and the anode connector simultaneously; if you do you may receive a shock because of the charge between the inner and outer conductors. This shock in itself is not particularly dangerous, but could startle you sufficiently to make you drop the tube with a resulting implosion. To avoid such a shock, the anode connector should be discharged to the outer coating before handling the tube, even though it has been out of use for some time.

Although it is a rare thing for a tube to implode, picture-tube manufacturers always emphasize the following: "Shatter-proof goggles and heavy leather gloves should be worn when handling picture tubes. Persons not protected in this manner should be kept at a distance." Observe these picture-tube safety rules at all times.

Practically all large television receivers have a safety glass window over the viewing face of the picture

tube. This window prevents accidental damage to the tube by objects falling on it, and protects the viewers from flying glass if an implosion occurs for any reason. Never remove this protective glass window from the customer's receiver, even though it does slightly reduce the brilliancy of the viewed picture.

From time to time it is necessary to replace defective picture tubes, and this brings up the problem of disposing of the old tube. Use discretion in the breaking up or disposal of picture tubes. Even when put out for the rubbish collector be sure that they are broken to avoid their coming into the possession of children, or for that matter, curious adults. A quick easy method of disposing is to seal the tube in its shipping carton, and then drive a heavy tool such as a wrecking bar through the side or bulb end of the case. Sealed shipping cartons are strong enough to withstand the implosion of the tube.

## Lesson Questions

Be sure to number your Answer Sheet 51RH-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. Why is the inside of the glass envelope of a picture tube coated with powdered graphite which is electrically connected to the second anode voltage supply?
2. What is the purpose of varying the first anode voltage in an electrostatic tube?
3. Why is a variable d.c. voltage applied between the horizontal deflection plates and between the vertical deflection plates in an electrostatic tube?
4. Give two reasons why several series resistors rather than a single resistor are used in the divider networks of some high-voltage supplies.
5. In the deflection system used in an electromagnetic tube, will the horizontally mounted magnetic poles produce: 1, horizontal deflection; or 2, vertical deflection?
6. How can you tell when the ion trap on an electromagnetic tube is properly adjusted?
7. Why is an ion trap unnecessary with aluminum-backed tubes?
8. What is accomplished by making the face plate of a picture tube also serve as an optical filter?
9. Would you expect best over-all focus in a picture tube with a flat face, or in one with a reasonable amount of curvature?
10. Why is it dangerous to touch the shell of a metal picture tube while the receiver is in operation?

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





## EACH DAY COUNTS

Each day of our life offers its own reward for work well done, its own chance for happiness. These rewards may seem small, and these chances may seem petty in comparison with the big things we see ahead. As a result, many of us pass by these daily rewards and daily opportunities, never recognizing that the final goal, the shining prize in the distance, is just a sum of all these little rewards we must win as we go along.

*J.E. Smith*