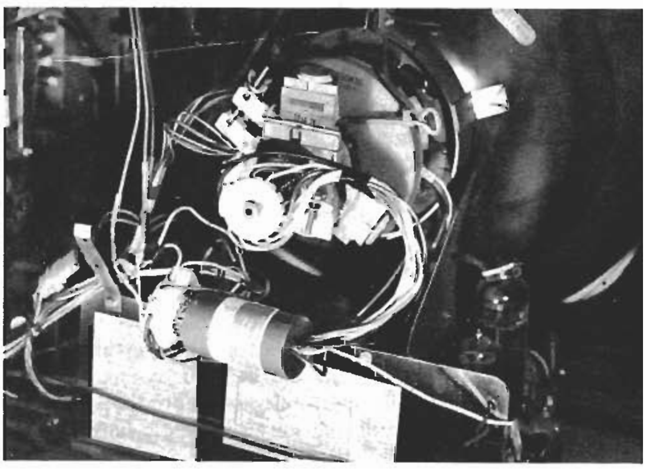
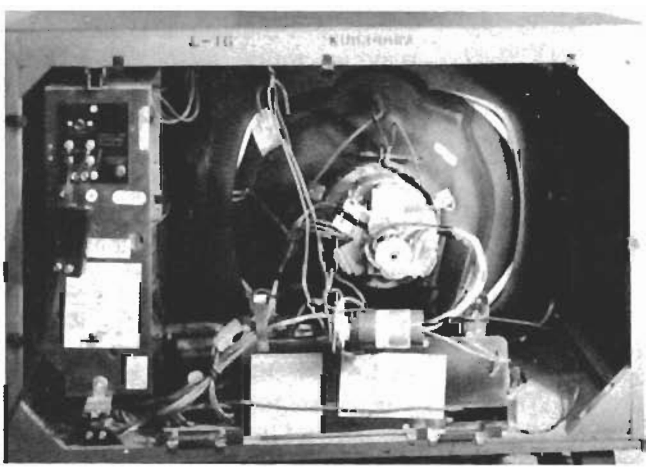
HOW AND WHY

Picture Tube Brightener$ Can Save You Dollar$

Television picture tube brighteners have been around for quite a few years. Here is a fresh look at what they are all about.





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THE USEFUL LIFE OF A TV PICTURE TUBE IS usually determined by the weakening of the electron beam. Yet the phenomenon of electron emission in the beam from the oxide-coated cathode is largely unexplained. However, exhausted cathode emitters do have remarkable recuperative power. When certain restoring devices are used, picture tube life can be extended. This article will attempt to explain the process that makes this regeneration possible.

The picture tube

The TV picture tube is a special kind of vacuum tube in which a narrow beam of electrons behaves like an electronic pencil and draws a visible trace or pattern on a specially prepared screen. In many respects, its operation parallels that of an ordinary receiving or transmitting vacuum tube. In an ordinary vacuum tube as well as in a CRT or picture tube, electrons are created by a heated cathode located at the base of the tube inside the glass envelope. Thermionic emission in a

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vacuum tube occurs when the electrons in the cathode material contain enough thermal energy to overcome the forces at the emitter surface and escape.

In an ordinary vacuum tube, the emission occurs over the entire outside surface of the cathode (emitter). (See Fig. 1.) In the picture tube, the emission comes from only the top surface of the cathode. More precisely, emission occurs only under the area projected by the aperture in the control grid. To fully comprehend why this happens requires some information about the effect of the control grid and the first anode on emission.

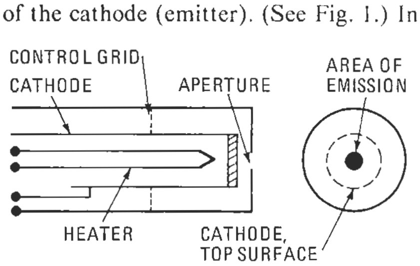

FIG. 1—THE CATHODE STRUCTURE in a TV picture tube. The black dot in the center shows the cathode area that is actually used.

Thermal agitation of the cathode coating material causes the cathode to emit electrons. Since this cathode coating is located in one particular place—on the cathode face opposite the control-grid aperture—principal emission moves in a forward direction from this surface. Because of the shape of the cathode, the emission does not come from a point source. So, while the emission is generally in a forward direction, it takes place randomly. Some electrons leave the cathode in a direction that is parallel to the axis but off to one side, and some leave at various angles to the axis.

Moreover, the velocity of the electrons varies. Some electrons leave the cathode at high speed, but the majority are low-velocity charges. For simplicity, assume that the initial velocity of the emitted electrons is substantially zero and any forward motion they exhibit after leaving the cathode is attributable to acceleration by the voltages applied to the first anode, in opposition to the negative voltage at the control grid.

An electrostatic field (called the first lens) exists between these elements and varies with the control-grid voltage, thus controlling the emission from the cathode. For any fixed voltage applied to the first anode, the control-grid voltage controls the number of electrons that can pass through the aperture.

Figure 2 shows the field distribution for two assumed grid-bias values, 0 (Fig. 2-a) and −30 volts (Fig. 2-b), and a fixed voltage value on the first anode. With a bias of 0 volt, the area adjacent to the cathode (between the cathode and control-grid aperture) has a comparatively high positive potential as a result of the field.

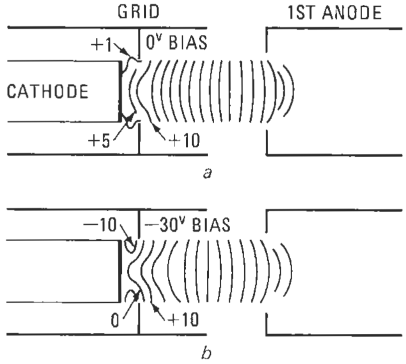

FIG. 2—FIELD DISTRIBUTION FOR two grid-bias values; (a) 0 bias. (b) 30 volts bias.

"Under such conditions of 0 grid voltage, it has been found that the area of the cathode which is emitting corresponds approximately to a projection of the area of the grid aperture; the maximum number of electrons are passing through the grid opening and the beam current density is high.

"When the control grid is made negative by an increase in the bias (−30 volts in the figure), the field distribution in the vicinity of the cathode is altered so that only the center of the emitter surface is behaving as an emitter. The other areas are influenced by the space charge and effectively are not emitting. The result is a reduction in beam density and several other related effects."[1,2]

It should be emphasized that showing the electric field and lines of force schematically is strictly a device to help you visualize certain phenomena. The lines of force having certain physical properties are convenient working tools to explain what happens.

The thermionic emission that comes from under the aperture opening of the picture tube emitter continues until there is a depletion of electrons. Even after emission from the electron gun *appears too low* to provide enough density for a good picture, the cathode emitter material is almost *90% unused*. At this point the useful end-life of the tube has apparently been reached, because the picture is not bright enough for proper viewing.

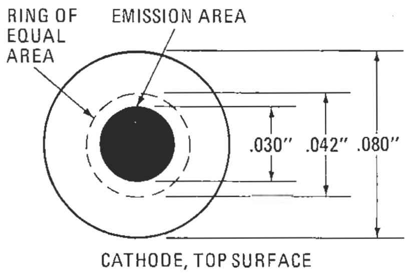

FIG. 3—WHEN BRIGHTENER IS USED, diameter of emitting area is increased slightly as shown.

This apparent contradiction can be better understood by examining the cathode. It is typically a metallic cylinder that is about .080 (5/64) inch in diameter and .340 (11/32) inch long, and is closed at one end (see Fig. 3). The heater is inside this cylinder with its leads through the open end, and it is coated to provide electrical insulation. The outside closed end of the cylinder is coated with an emitter material (i.e., magnesium oxide) that looks pure white when it is new. When the tube is depleted, there is a metallic dot near the middle of the white surface of about .030 inch in diameter. This diameter corresponds to the aperture opening of the control grid.

The cathode is held permanently in place by a metallic ring molded into the ceramic supports of the electron gun. The control grid is an inverted dish or cup that almost completely covers the cathode, and also is held in place by the ceramic supports. There is a space between the grid cup and top of the cathode on the order of .055 inch. Because of this spacing and type of construction, the cathode cylinder is barely visible through the glass neck of the tube, and the top of the cathode is virtually impossible to inspect once the electron gun has been manufactured.

Picture tube manufacturers rarely run a control sample picture tube to normal emission depletion and then inspect the cathode surface. Quality control samples are generally tested only for about 4000 hours, equivalent to two years of normal use, and then they are inspected. (Normal viewing is considered to be six hours a day.) When a picture tube is operated beyond that 4000-hour period to electron beam depletion and apparent end-life, it seems unlikely that the tube engineer would break the tube apart to check the gun parts let alone saw or cut open the metal control grid to inspect the used-up cathode surface. Yet, if he did he would find new emitter material surrounding the tiny metallic dot of depleted surface.

The size of the dot and the new material surrounding it suggests that the picture tube life could be prolonged if the new electrons could be moved to the area under the control-grid aperture. Again, take a look at the dimensions involved. The aperture opening produces a narrow beam and an electrostatic lens that can project an image on the picture tube screen. This opening is about .030 inch in diameter (.015-inch radius). The unused emitter area is about .0043 square inch compared with a .0007-square-inch depleted emitter area, yet the picture tube can no longer produce a picture that is bright enough for normal viewing. Contrast is lacking because there is not enough electron beam density to fully activate the picture-tube-screen phosphor dots. Warm-up time is unusually long since the cathode temperature slowly increases to give the last electrons sufficient energy to escape.

TV tube brighteners

In the late 1940's, a transformer device was designed by the Perma-Power Company to increase the power applied to the heater and raise the temperature of the cathode in the emission-depleted picture tube. (A patent was filed in 1952 and granted in 1956.) This device (called a TV tube brightener) is permanently installed in the TV set, and the increased power it feeds to the older heater is applied whenever the set is on. Thus, the kinetic energy of the electrons in the cathode emitter surface is increased. As a result, the electrons in the ring surrounding the depleted area can migrate to the area under the control-grid aperture opening, and this area of new material is thus used.

It is interesting to observe how small a ring of cathode material of equal area to the depleted area is. This ring has an outside diameter of .042 inch and a radius of a .021 inch. You can easily understand that if only three-thousands of an inch of material surrounding the depleted emitter area emits electrons that migrate under the aperture opening, then this emission includes almost 50% new material.

Early studies of black-and-white picture tubes were made in which cathodes from tubes that had reached end-life were compared with some that had reached a second end-life after using a brightener. The depleted areas in the tubes using brighteners were on the order of 1¼ to 1½ times larger. The increase in viewing time was often more than 50 percent (see Fig. 4).

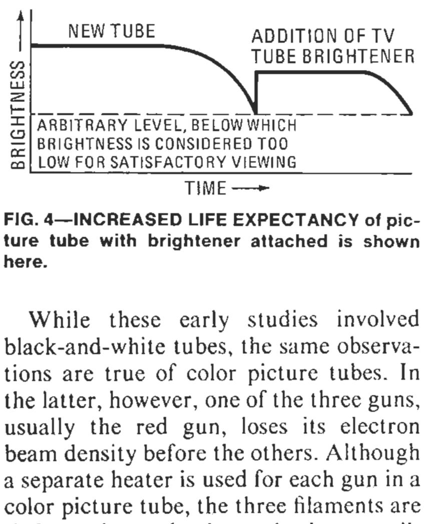

FIG. 4—INCREASED LIFE EXPECTANCY of picture tube with brightener attached is shown here.

While these early studies involved black-and-white tubes, the same observations are true of color picture tubes. In the latter, however, one of the three guns, usually the red gun, loses its electron beam density before the others. Although a separate heater is used for each gun in a color picture tube, the three filaments are tied together and only two leads are available at the picture tube socket. To raise the (heater) power on one gun, the power on all three guns must be raised.

Fortunately, no ill effects result from this procedure. Since the electron gun is a controlled emission device, you use the CRT bias controls on the set to readjust the electrostatic fields in order to keep beam-current densities balanced. This is a function of the electrostatic field distribution. The fact that more electrons are available than are needed does not affect how many are drawn off and used.

In the manufacturing process, picture tubes are processed through exhaust-and-aging cycles. This process includes procedures that decontaminate the tube elements and remove gases. The aging process also initiates emission from the cathode surface, to assure consistent emission from tube to tube. Procedures vary, but elevated temperatures and heater power are always used. The control grid and first anode areas can be heated to 800 °C for 10 to 20 minutes, and twice the normal heater voltage can be applied for these intervals. One and one-half times the normal heater voltage is generally applied for an extended period of time with normal voltage on the first anode.

Since the cathode heaters and other tube elements are designed to withstand this exhaust-and-aging process, it is easy to understand why a TV tube brightener can be used without damaging the picture tube.

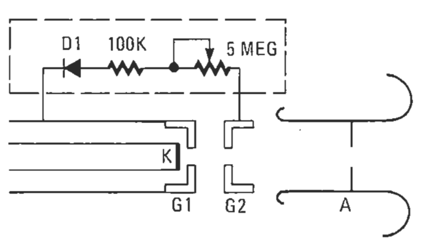

FIG. 5—ADDING RESISTANCE between G1 and G2 reduces the field and tends to open the beam.

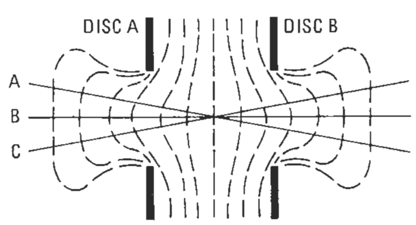

FIG. 6—THE EQUIPOTENTIAL SURFACES between two discs, each having an aperture at its center.

In addition to applying more heater power to regain emission, the electrostatic field can be readjusted as follows: The leads for control grid G1 and first anode G2 are accessible outside the picture tube so that a potentiometer can be installed between them. Since the voltages on the control grid and first anode are essentially fixed with reference to cathode K, applying resistance between the G1 and G2 leads reduces the field and tends to open the beam. The accelerating voltage is constant, resulting in an increase in beam current (see Fig. 5).

However, any condition that alters the distribution of the field also affects the focus. Figure 6 shows the equipotential surfaces between two discs, each having an aperture at its center. The equipotential surfaces bulge through the holes, causing some electrostatic field to leak outside the normal region. If electrons a, b and c are placed to the left of plate A, electrons a and c will converge as they cross the convex equipotential lines that protrude through the opening in plate A. Electrons a and c will tend to cross each other within the field between the two apertures, and then continue along a diverging path as they cross the concave equipotential lines that protrude through the opening in plate B. This procedure is

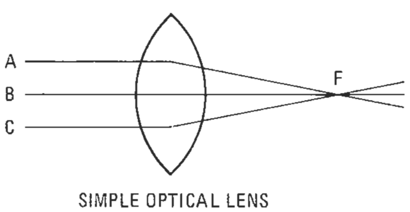

FIG. 7—SIMPLE OPTICAL LENS is similar to electron lens described in the text.

similar to what occurs in an optical lens having three incident rays (see Fig. 7).

Although it is true that any set of curved equipotential lines resemble a simple electron lens because they refract the electron path, the complete electron gun field is more complex (see Fig. 8).

However, it should not be difficult to visualize how the charged cylinders in an electron gun form an electrostatic field that controls the electron beam and focuses it. The dimensions of the crossover point, as determined by the control-grid and first-anode voltages, are also the dimensions of the beam when it is properly focused by the second electron gun lens and strikes the screen.

However, any device that changes the designed field distribution can produce some undesirable effects. It can affect the dimensions of the first crossover point and the angle of divergence at which the electron beam leaves the crossover point and, to a limited extent, it can affect the position of the first crossover point.

Emission slump

One of the least understood and most prevalent picture tube problem is known as emission slump. It is generally accepted that the cathode slowly becomes con-

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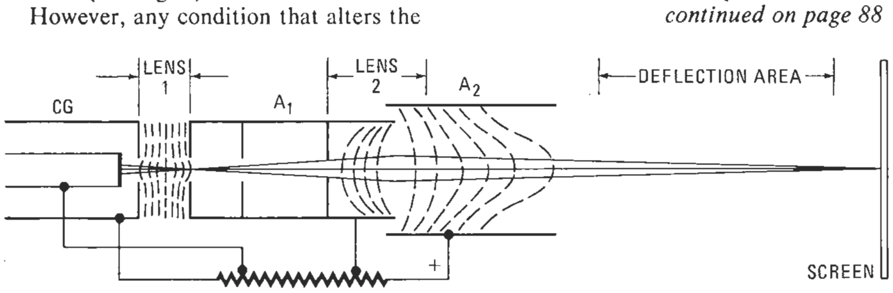

FIG. 8—ELECTROSTATIC FOCUSING SYSTEM as it is used in a TV picture tube.

PICTURE TUBE BRIGHTENERS

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taminated, limiting emission. This contamination is caused by out gassing of tube elements or from slow air leaks. Examining the cathodes of such tubes reveals heavy crystalization in the center of the cathode. When a contaminated tube is turned on, the electron cloud under the grid aperture opening is rapidly depleted and the tube becomes emission-limited. In some cases, after the tube is on for some time, heat builds up around the cathode and raises the temperature of the cathode sufficiently to increase emission.

The effect of low emission is to limit the beam current and diminish picture brightness. If the brightness level is too low for normal viewing, the tube has apparently reached end-life.

Using a brightener on a contaminated tube causes a rapid decontamination of the cathode surface and raises the emission level. A satisfactory beam current is obtained almost instantly.

Restorers

Devices known as restorers or rejuvenators are also designed to improve picture tube emission by removing contamination and restoring the emitter surface under the grid aperture. This technique involves elevating the heater voltage and simultaneously applying a high positive voltage between the grid and cathode, thereby causing an abnormally high cathode current. Unless this technique is carefully controlled, the cathode can be easily damaged. Several early restorers were hazardous and caused a fair number of picture tubes to be destroyed. In the capacitative discharge method, an arc is actually produced that provides intense localized cathode heating. However, the field, can be strong enough to actually remove material from the cathode.

Improved rejuvenators have automatic controls and can apply the required high voltage levels in increasing steps to limit the energy level. However, they generally do so at some sacrifice in the duration of the improvement.

The most recently developed rejuvenators use more effective control circuits so that the duration of the high cathode current is long enough to assure good restoration, but short enough to reduce damage to a minimum. Automatic controls are used to prevent user error.

One of the problems of the rejuvenator is that the cathode current flows from the entire cathode surface during rejuvenation. However, to be successful, the emission restoration must occur in the cathode area directly beneath the grid aperture. Fortunately, this is usually the area of greatest heat because the heater is in the center of the cathode cylinder.

To know if rejuvenation has been successful it is necessary to measure the quality of the beam current after rejuvenation. Unfortunately, the grid current cannot indicate emission quality from the cathode area directly under the grid aperture; only a true beam-current-emission test can do this. This is why you may obtain disappointing results, even with tests indicating success.

In color sets, restoring one gun may mean one or both of the other guns must be rejuvenated. Rejuvenating the low-emission gun of a color picture tube can increase the emission to the original beam-current level, so that it may not track with the other aged guns whose beam currents may have declined from the original level, even though their brightness level is satisfactory.

Unsatisfactory picture tube performance can often be diagnosed visually by a repair technician, and modern test equipment and performance data help substantiate the visual judgment. A tube brightener can always be tried without risk (unlike many restorers), and it can be used in all applications in which a restorer is effective and in many in which it might not be. A brightener will work longer than a restorer; therefore, it can be implemented in all low-brightness-level situations. **R-E**