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tech tips

Restoring CRTs With The CR70 "BEAMBUILDER"®

The cathode ray tube (CRT) is the only electronic component in widespread use today that is guaranteed to fail. This is because the CRT depends on a hot cathode to produce an electron beam. Shorts, cathode buildup, or loss of emitting material are problems that eventually plague most CRTs. The CR70 "BEAM BUILDER" is designed to extend the useful life of CRTs that develop these common failures.

This Tech Tip explains the use of the CR70 for restoring monochrome (B&W) and tri-color (color) CRTs which are commonly used in television receivers, monitors, oscilloscopes and data display terminals. Other Sencore TECH TIPS cover the operation of CRTs and testing CRTs with the CR70, plus applications of the CR70 in specialized applications including camera pickup tubes and projection CRTs.

Symptoms Of Bad CRT

A bad CRT produces several common symptoms which are easily observed on the picture screen. However, the same symptoms that are produced by a bad CRT may also be the result of a problem that is external to the CRT. Here are some examples.

Dark or dim picture: This could result from a CRT with weak emission, a shorted gun element, or an open cathode (K). Other possibilities include wrong bias, insufficient second anode voltage, low or missing filament voltage, or a problem in the video circuits.

Dark blacks and over driven whites: A weak CRT gun (or all 3 guns in a color CRT) could result in non-linear light output from the tube (called bad "gamma"). The same symptoms are also caused by problems in the video amps, or wrong bias voltages to the tube.

Bad color tracking or gray scale: A tri-color CRT that has a weak gun will produce a picture that cannot be color balanced. Instead of pure whites and shades of gray, the picture may look reddish, greenish, etc. Misadjusted background or bias controls, or a defective chroma demodulator also produces these symptoms.

Intense color: Another symptom possibly caused by a defective CRT is a bright colored raster that cannot be adjusted. This may result from a short inside the CRT, or an open control grid. An external defect such as a shorted driver may also cause the symptom.

Test The CRT First

As the above examples show, never assume that the CRT is at fault based only on the fact that it produces a bad picture. Before you restore a CRT with the CR70, always test it first with the CR70 test functions. This will save you from wasting time restoring the CRT when in fact something external to it is at fault. Additionally, restoration is a subtractive process. It does not add new material to the cathode, but rather removes the buildup to expose new emitting material. Removing the buildup also removes a small amount of good emitting material. Therefore, unneeded restoration will shorten the life of a CRT that does not need it.

The most important reason for testing a CRT before you restore it, however, is that the test results will guide you in how to most effectively restore the CRT. Customer reports and research by Sencore Application Engineers indicates that 9 out of 10 weak CRTs can be successfully restored to "like new" operation. In most cases, restoration effectively doubles the useful life of the CRT.

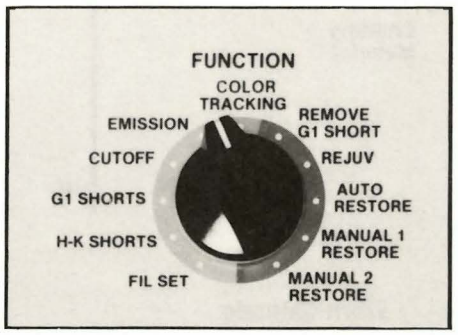

Fig. 1: The first six positions of the CR70 "Function" switch provide dynamic tests of the CRT gun. Use the results of these tests to determine the most effective restoration procedure to use.

What The Tests Mean

The CR70 provides several dynamic tests to positively determine the condition of the electron guns in a CRT. If the CRT tests GOOD on EACH test (including the COLOR TRACKING test for color CRTs), it does not have a gun related failure. However, a BAD indication for any test indicates that one of the CR70 restoration functions should be performed. Perform the CR70 tests in order as they appear around the Function switch. Here is a brief overview of what each test failure means about the condition of the CRT.

H-K shorts "BAD": The H-K position tests for shorts between the heater (H) and cathode (K). H-K shorts are one of the few gun element shorts which can usually not be successfully removed with a CRT restorer. This is because the delicate heater is often burned open by any attempt to remove the short.

A "bad" test reading, however, does not necessarily mean that the CRT should be discarded. Some CRTs employ a directly heated cathode and normally tests as having an H-K short. In

other situations an H-K short may not cause a problem. Symptoms of an H-K short are a bright white or colored raster with no control of brightness, or visible retrace lines. Often, H-K shorts can be isolated with an external brightener or filament transformer.

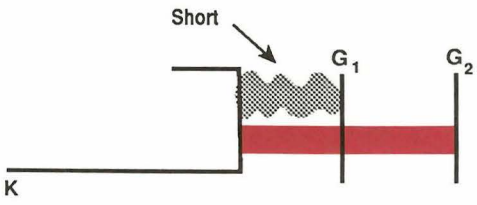

Fig. 2 : In a CRT that has a G_1 short, all of the electrons developed by the cathode rush toward the phosphor screen, out of control.

G1 shorts "BAD": A "bad" G1 Shorts test indicates that a short (which is usually a piece of stray contamination that has broken loose from the cathode) exists between the Cathode and G1, or between G1 and G2. Symptoms of a G1 short are visible retrace lines, or a bright white or colored raster with no control of brightness. Most G1 shorts can be removed with the REMOVE G1 SHORTS function. Occasionally, a G1 short will read way at the bottom, left of the "Bad" scale. This indicates a more severe short that could be caused by the elements actually making physical contact. Shorts caused by warped elements cannot be removed.

CUTOFF Won't Set Into "Cutoff Set" box: The meter indication on a tube that fails the CUTOFF test will either: 1) not adjust up to the cutoff box, or 2) it will be very difficult to adjust down into the box and will continually drift up above the box. Each result indicates a different problem with the tube.

In the first case (needle stays below box) the cathode is worn. This is the most common CUTOFF failure. Usually the cathode is worn in the center but will emit from the edges. This produces a symptom of a picture with deep blacks and bright "silvery" whites, or a gray scale that changes hue with brightness changes. A worn cathode is usually restored with one of the RESTORE functions.

The second CUTOFF failure (needle won't adjust down into box) indicates an open G1, or that air has leaked into the tube due to a leaky seal. The symptom of an open G1 is a very bright white or colored raster. Air that has leaked into the tube results in a blank raster, since the cathode is totally encrusted. Additionally, the needle will peg and a blue haze will surround the gun as the CUTOFF control is increased because the air ionizes. Neither an open G1 or an air contaminated tube can be restored with lasting results.

EMISSION "BAD": A tube that tests in the "Bad" meter region in the EMISSION test produces an overall dull picture that lacks brightness. This is one of the most common CRT failures. The cause is nearly always buildup on the cathode which can be removed with the CR70 RESTORE functions. However, if the tube has been extensively restored before, low emission may be the result of a loss of emitting material on the cathode.

EMISSION zero: A CRT that produces no indication on the emission test (and will not adjust into the Cutoff Box) has a completely encrusted cathode, an open cathode, or a cathode that has been stripped of its emitting material. The raster symptom is a black picture, (monochrome CRT) or a color picture that is lacking one primary color. An encrusted cathode can be cleared with the REJUV function and then further restored with the CR70 RESTORE functions.

EMISSION LIFE "BAD": A dropoff in emission when the LIFE test button is depressed usually is an indication that the cathode is becoming covered with contamination, although a loss of emitting material may also be the cause. Tubes that pass the other tests but fail the LIFE test will likely have symptoms that go unnoticed under normal operating conditions. The most common symptom is a picture that quickly gets darker as the filament voltage (line voltage) is reduced slightly. A tube that tests bad in the LIFE test can be restored to proper emission using the RESTORE functions.

COLOR TRACKING "BAD" (color CRTs only): All three guns of a color CRT may test good in the EMISSION test, yet the tube may fail to produce an acceptable picture. The reason is that the output from all three guns must balance to produce white. If one, or two of the guns have appreciably less emission than the strongest gun, the symptom will be a gray scale that has a color hue and can not be balanced. Since each gun has good emission, be careful to not over restore the CRT. Proper color tracking is restored by using one application (3 full cycles) of AUTO RESTORE on the gun or guns that test bad.

Deciding Which Restoration To Use

Different CRT gun failures require different levels and types of restoration, as determined by the CR70 test results. The CR70 provides five different levels of restoration and shorts removal to match the CRT gun failure. An explaination of how these levels work is given in the last section of this TECH TIP. Use the following table as a guide to match the test result to the type of CR70 restoration to use on the CRT.

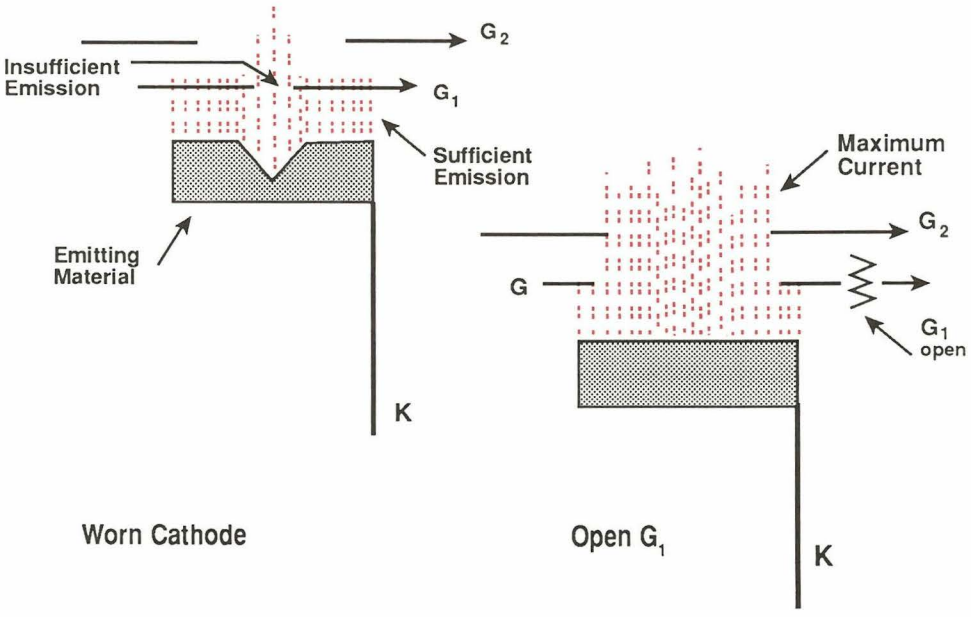

Fig. 3: Bad cutoff is caused by either a worn cathode or open G_1. A CRT that has a worn cathode (left) will produce insufficient beam current for gray picture elements, but since the edges of the cathode are good, sufficient emission is available when G_1 opens up for bright picture elements. An open G_1 (right) results in no beam control, much like an H-K short.

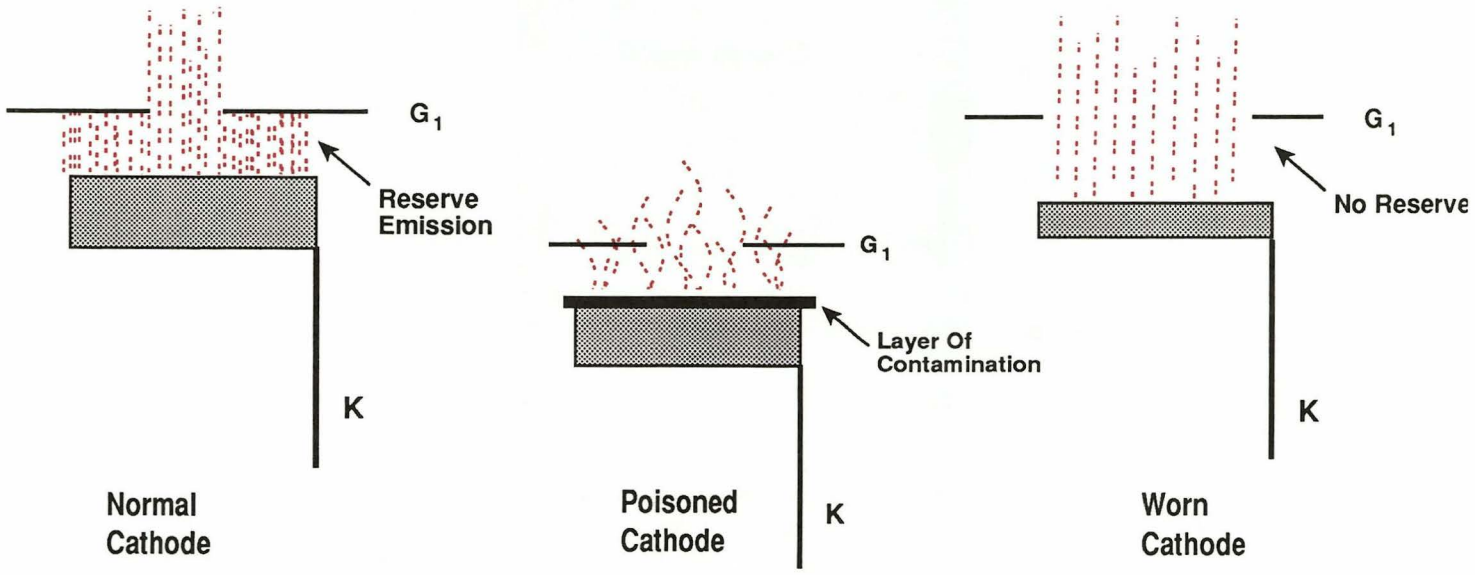

Fig. 4: A good cathode produces more than enough electrons than needed for adequate beam current (left) but when the cathode becomes encrusted (center), no beam current can flow. Emission that drops off when the LIFE test button is depressed is caused by a weak cathode that has no reserve electrons (right).

Using The CR70 Restore Functions

Table 1 lists the restoration process you should use based upon the tube's test results. For most tubes, you will start with the lowest level, auto restore. The following guidelines give more specific instructions for each CR70 Restore function.

Test Results				Restoration Procedure
Cutoff	Emission	Life	Tracking	
good	bad			Auto Cycle, then MAN 1 if still weak.
bad	good			Auto Cycle once.
bad	bad			Auto Cycle. REJUV if less than 20 mA restore current.
good	good	bad		Auto Cycle once.
good	good	good	bad	Auto Cycle lowest gun(s).

TABLE 1: Use the CR70 test results to determine which restoration procedure to use.

NOTE: *Restoration will not damage the CRT if it is used properly. But remember, restoration is a subtractive process. Over-restoring a tube that is marginal (by using repeated Auto Restore on a tube having bad cutoff and good emission, or by using higher levels of restoration than shown in this table) may degrade the tubes performance or further damage it. Never "clean" a gun that tests good. The CR70 tests are dynamic, and if tube tests good on ALL tests it will provide acceptable performance.*

REMOVE G1 SHORT

1. Set the CR70 "Setup" switches to the gun that tested with a G1 short.

2. Set the FUNCTION switch to "Remove G1 Shorts" & wait 30 seconds for the heater to cool.

3. Press and hold the red "REJUV OR RESTORE" button for 1 second to allow the CR70 to discharge through the short.

4. Retest the gun for shorts and repeat the above steps if necessary.

REJUVENATION

1. Set the CR70 "Setup" switches to the gun to be rejuvenated.

2. Set the FUNCTION switch to "REJUV".

3. Press and hold the red "REJUV OR RESTORE" button for 2 seconds to allow the CR70 to discharge through the buildup.

4. Retest the gun for G1 shorts, Cutoff and Emission and proceed with Auto Restoration if necessary.

AUTO RESTORE

1. Set the CR70 "Setup" switches to the gun to be restored.

2. Set the FUNCTION switch to "AUTO RESTORE".

3. Allow the filaments 30 seconds to warm up before proceeding.

4. Press and hold the red "REJUV OR RESTORE" button while the CR70 automatically cycles through 3 cycles of on/off restore current (approximately 4 seconds on, 2 seconds off each cycle) as indicated by the meter.

5. Retest the gun for G1 shorts, Cutoff and Emission.

MANUAL 1 & MANUAL 2 RESTORE

1. Set the CR70 "Setup" switches to the gun to be restored.

2. Set the FUNCTION switch to "MANUAL 1" or "MANUAL 2 RESTORE".

3. Allow the filaments 30 seconds to warm up before proceeding.

4. Press and hold the red "REJUV OR RESTORE" button while monitoring the restoration current on the bottom "Restoring Current" scale of the meter. Observe the following:
   a. Continue to hold the "REJUV OR RESTORE" button as long as the restoring current holds steady or increases, but
   b. NEVER apply restoring current longer than 15 seconds continuous.

5. Retest the gun for G1 shorts, Cutoff and Emission.

How Restoration Works

The CR70 provides 5 levels of progressive restoration. These include Remove G1 shorts, Auto Restore, Manual 1 Restore, Manual 2 Restore, and Rejuv. The G1 shorts function is used solely to remove shorts, while the other functions are designed to remove cathode contamination. All 5 levels are provided for optimum results without over restoration. Following is a brief summary of how each function works.

REMOVE G1 short: This function removes flakes of contamination that become lodged between G1 and cathode, or between G1 and G2. When the CR70 is set to this function, the cathode and G2 are connected together inside the unit. The filament voltage is removed, and a capacitor which has been charged to 450 VDC is applied between G1 and K/G2. The capacitor discharges through the short, effectively vaporizing it. This capacitive discharge technique is very effective in removing shorts, and will not damage the CRT, since when the short is gone, the current stops.

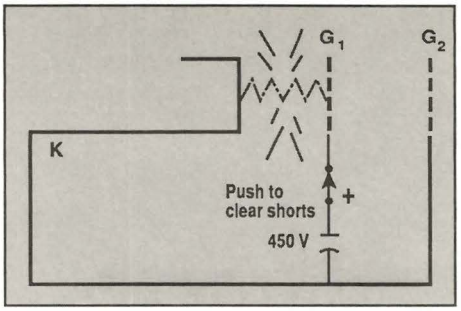

Fig. 5: G_1 shorts vaporize as a 450 volt capacitor discharges through the shorting particle.

RESTORATION: The CR70 provides 3 levels of restoration; Auto, Manual 1, and Manual 2. Each of these functions are similar in their operation and effect on the cathode. Restoration "boils" off the cathode contamination and allows fresh emitting material to be exposed on the cathode's surface. The three restoration levels differ in the intensity of the restoring current.

Auto restoration is the least intense and is therefore always used first. The restore current is limited to 100 mA, and is cycled on and off 3 times to heat the cathode to the point where restoration can occur, while keeping it from overheating. Auto restore is sufficient to effectively restore most cathode-related problems.

Manual 1 is the next higher level for use on tubes which are not adequately restored by Auto Restore. Restore current is again limited to 100 mA, but the current is allowed to flow longer (as long as the REJUV OR RESTORE button is held in) to further heat the cathode's surface.

The highest level of restoration is provided by Manual 2. This is a "last resort" level and is used when several attempts of lower restoration fail to return the tube to acceptable performance. Like Manual 1, the restoring current flows as long as the REJUV OR RESTORE button is held down, but the current is limited to a much higher level of 150 mA. This superheats the cathode to remove the contamination, but it can very quickly strip the cathode of all its emitting material.

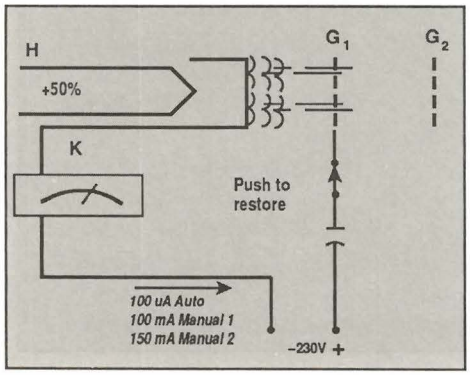

Fig. 6: Restoration increases the filament voltage and passes a 100 or 150 milliamp current through the cathode to remove cathode poisoning.

In all three Restoration functions the filament voltage is increased, and a positive voltage is applied to G1. The positive voltage on G1 pulls a much larger than normal amount of electrons from the cathode and brings fresh emitting material to the surface. (Normal beam current is approximately 300 uA, compared to as much as 150 mA of restore current).

Note that the restore current is the result of electrons that are emitted from the cathode. As the cathode begins to restore, the restoring current indicated on the CR70 meter will increase. If the cathode is totally encrusted, or stripped of emitting material, no current will flow when the restore button is depressed.

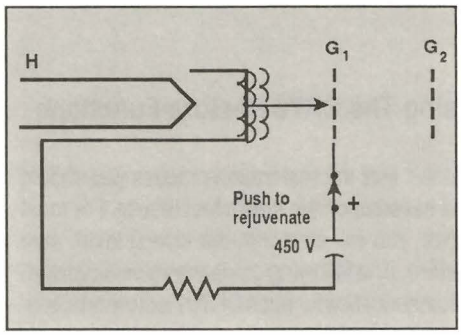

Fig. 7: The CR70 places a protective resistor in series with a 450 volt capacitor to limit cathode current during rejuvenation.

REJUV: The rejuvenate function is used when the CRT cathode is so totally encrusted that no restore current can be drawn by the other Restore functions. In the REJUV function, a charged capacitor is connected between the cathode and G1, similar to the REMOVE G1 SHORTS function. However, in REJUV the filament voltage is left on. This means that the electrons under the cathode "crust" are active and want to be liberated. When the sudden positive voltage from the capacitor is applied to G1, they break free, essentially cracking the layer of contamination. Once the layer of contamination has been cracked, Auto Restore can be used successfully.