



# DISPLAY-STORAGE TUBES

## Direct-View Types

Information shown on these pages is to be used in conjunction with RCA display-storage tube data.

RCA display-storage tubes of the direct-view type are used in applications that require a bright, non-flickering display of stored information containing half-tones for relatively long periods of time. They provide continuous displays having high contrast under conditions of high ambient light for many seconds after writing has ceased and integrate repetitive signals so that information can be distinguished from random noise. Typical applications using display-storage tubes include the following:

### RADAR—Ground, Airborne, and Marine

- Fire control
- Search
- Weather
- Ground Mapping
- Proximity Warning
- Navigation

### OTHER INFORMATION DISPLAYS

- Electronic Reconnaissance and Countermeasures
- Compressed Bandwidth Video Systems
- Oscillograph Displays of Non-recurrent Transients
- Sonar

The voltage and other values used in this publication do not apply to any particular display-storage tube type. Although these values may be typical, they are intended only to explain the principles of operation of the device. Refer to the data contained in the technical bulletin for a given tube type for specific ratings, operating values, and performance and characteristic values.

### PRINCIPLES OF OPERATION

A schematic arrangement of a typical display-storage tube is shown in Fig. 1. The viewing electron gun produces a low-velocity, unfocused electron beam that continuously floods the target electrodes. The target electrodes consist of a phosphor screen (usually aluminized) on the inside surface of the faceplate, a backplate mesh covered with a thin layer of insulating material which serves as the storage grid, and a collector grid.

The writing gun (or guns) produces a well-defined high-velocity beam that is deflected, focused, and intensity modulated in the same manner as the beam of a cathode-ray tube.

The writing beam establishes a potential distribution on the storage grid which controls the viewing-beam current reaching the phosphor

screen in the same manner as the grid voltage of a triode receiving tube controls its plate current, i.e., when the storage grid is established at negative voltages with respect to the viewing-gun cathode it can limit or cut off the viewing-beam current.

The tube may also contain a selective erasing gun which produces a low-velocity, focused beam that permits selective erasure of some areas of stored information on the storage grid without disturbing other areas.

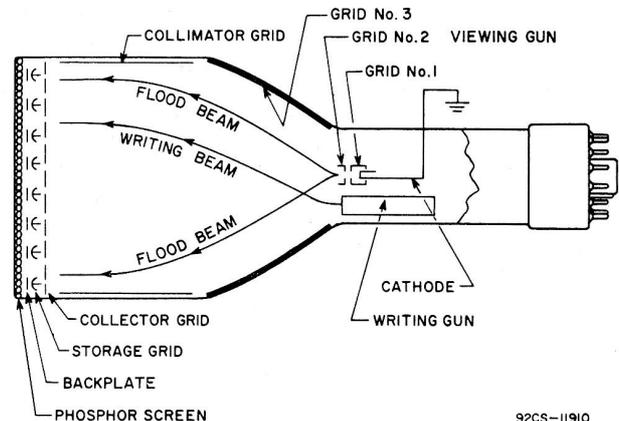


Fig. 1 - Schematic Arrangement of a Display-Storage Tube.

The operation of the display-storage tube may be described by separating it functionally into viewing, writing, and erasing operations.

### The Viewing Operation

In addition to the viewing gun and the target elements, the viewing section contains additional electrodes for the collimation of the viewing beam.

The cathode, grid No. 1, and grid No. 2 of the viewing gun produce a high-density, low-velocity stream of electrons that is typically collimated (made parallel) and controlled in size by adjustment of grid-No. 1, grid-No. 3, and collimator-grid voltages. This collimated stream of electrons continuously floods the collector grid and the storage grid. Collimation is required so that the electrons, after passing through the collector grid, will approach all points on the storage grid in paths normal (perpendicular) to its surface. This normal approach of electrons having uniform velocity makes possible the uniform control of the electrons at every point on the storage grid.



Grid No.3 may be a conductive coating on the bulb-wall interior as shown in Fig.1. This figure also shows the location of the collimator grid which is often a metal cylinder that is mechanically supported by the target electrodes.

The collector grid is a fine metal mesh. It collects secondary electrons emitted from the storage grid during writing, and viewing-beam electrons turned back from the storage grid when the storage grid's potential is sufficiently negative. Also, because the collector grid is the most positive element thus far seen by the electron beams, it repels positive ions (produced by collision of electrons with residual gas molecules) and prevents ions in the region between the guns and the collector grid from landing on the storage grid and thus altering a stored charge pattern.

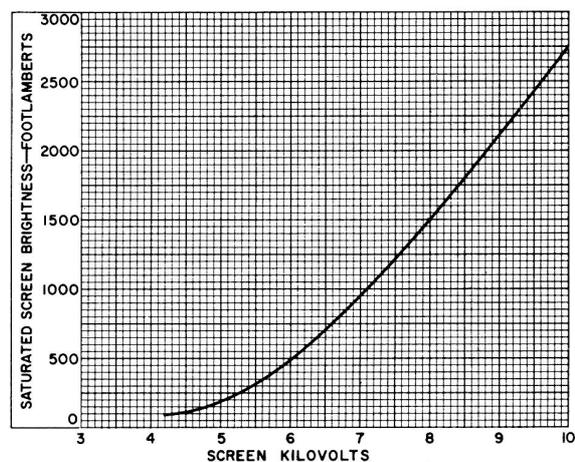
The storage grid consists of a very thin layer of material, having appropriate insulating and secondary-emission characteristics, that is deposited on the backplate, which is a fine metallic mesh. The deposit is on the gun side of the mesh, and leaves the size of the mesh openings essentially unchanged. In effect, the storage grid consists of a multiplicity of independent storage elements, each a capacitor. The thin layer of material of the storage grid serves as the dielectric, and its two surfaces serve as plates. One surface is in electrical contact with the backplate and the other surface faces the electron beams. The potential resulting from the charge stored in these individual capacitors determines the amount of viewing-beam current which reaches the corresponding areas of the phosphor screen, and therefore, controls the brightness of the display.

The backplate is ordinarily operated at a low positive potential (typically +2 volts) with respect to the viewing-gun cathode which is at ground potential. Assume the storage grid has the same potential as the backplate when the viewing section is initially placed in operation. The storage grid has this potential because the elemental capacitors are assumed to be discharged, i.e., there is no previously established charge pattern. Viewing-beam electrons passing through the collector grid are decelerated as they approach the storage grid, and because this grid is assumed initially to be +2 volts, it follows that they will land on its surface. Because of their low velocity, these electrons produce a secondary-emission ratio of less than unity and a net negative charge is deposited on the storage grid. As the negative charge builds upon the elemental capacitors, the potential of the storage grid drops. This process continues until the storage grid reaches an equilibrium value at viewing-gun cathode potential.

Under these conditions, a majority of the viewing-beam electrons passing through the collector grid are funneled through the storage-grid

mesh openings to the phosphor screen and cause it to fluoresce over its entire area. In this condition, the brightness of the screen is designated as "saturated brightness".

Light output from the screen at saturated brightness varies with the voltage applied to the screen. As shown in Fig.2, the light output rises rapidly at screen voltages above a threshold of about 5000 volts for a display-storage tube having an aluminized screen. A display of high brightness is possible because each spot on the phosphor screen is continuously excited by the high-current viewing beam rather than intermittently excited as in conventional cathode-ray tubes. A high-current flooding-type viewing



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Fig.2 - Typical Brightness Characteristic of a Display-Storage Tube Having an Aluminized Screen.

beam can be used because the display function (viewing) is separated from the information input function (writing) and consequently, external focusing, deflection, and modulation of the viewing beam are not required.

Assume that the entire storage grid has been uniformly charged to viewing-gun cathode (ground) potential and that the backplate is at +2 volts. The display is now at saturated brightness. The viewing beam may be cut off from the phosphor screen by making the storage grid sufficiently negative with respect to the viewing-gun cathode. This may be accomplished by shifting the backplate from its normal potential of +2 volts to a more positive potential, for example, +8 volts. Because of the capacitive coupling between the backplate and the storage grid, the storage grid rises an equal amount positive from its initial ground potential of zero volts to a potential of +6 volts. Viewing-beam electrons are now able to land on the storage grid and charge it in a negative direction. Charging continues until the storage-grid potential is reestablished at zero volts,



while the backplate remains at +8 volts. Now, if the backplate potential is returned to its initial value of +2 volts, the storage-grid potential drops correspondingly to -6 volts, a voltage sufficient to assure cutoff. Electrons in the viewing beam are now turned back as they approach the storage grid and return to the collector. The phosphor screen is dark.

At values of storage-grid potential between those which produce viewing-beam cutoff and those which produce saturated brightness, the amount of viewing-beam current which penetrates the storage-grid openings, and hence the amount of light emitted by the screen, is a function of storage-grid potential. This effect is shown in Fig. 3 for a typical display storage tube. For backplate voltages more positive than those assumed in Fig. 3, this storage-grid characteristic tends to shift to the left. For phosphor-screen or collector-grid voltages less positive than those assumed in Fig. 3, the characteristic tends to shift to the right and to exhibit more slope.

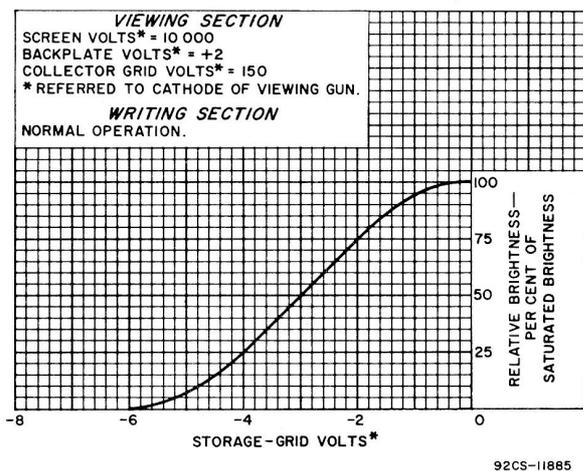


Fig. 3 - Typical Storage-Grid Characteristic of a Display-Storage Tube.

### The Writing Operation

The writing gun of the display-storage tube is similar to that of a cathode-ray tube. Its beam may be focused, deflected, and modulated in the same manner as the beam in a cathode-ray tube. It is used to write information on the storage grid, and contributes little to the total light output from the tube.

The cathode of the writing gun is generally operated at a high negative potential (typically -2000 volts) with respect to the viewing-gun cathode.

The writing-beam electrons land on the storage grid with such a velocity that its secondary-electron emission ratio is greater than unity. Thus, more electrons leave the storage grid than

arrive, and elements of the storage grid assume a more positive charge wherever the writing beam strikes. Because the secondary electrons are attracted to the collector, the writing beam tends to charge the storage grid to the potential of the collector. However, the maximum potential to which an element of the storage grid rises is limited in normal operation by viewing-beam landing to a potential just slightly more positive than that of the viewing-gun cathode.

By controlling the intensity of the writing-beam current, it is possible to control the amount of positive charge deposited on any storage element. Consequently, a storage element can be established in a stable condition at any potential intermediate between the storage-grid cutoff voltage and approximately zero voltage. These potentials, in turn, control the transmission of the viewing-beam current to the screen, as shown in Fig. 3, and produce a half-tone display.

Because the useful range of storage-grid potentials is entirely negative with respect to the viewing-gun cathode, the process of viewing does not in itself cause any deterioration of the stored information. Viewing duration is ultimately limited by the landing of positive ions produced in the region of the target on the storage grid, or by a controlled erasure rate when *dynamic erasure* is employed.

The great multiplicity of elements of the storage grid makes possible the storage and display of half-tone patterns of high resolution. At a display brightness of 50 per cent of saturated brightness, a typical resolution of 50 lines per inch is measured by the "shrinking raster" method. Display-storage tubes designed for high resolution show as much as 110 lines per inch.

### The Erasing Operation

**Static Erasure.** The negative charging of the storage grid when bombarded by the low-velocity viewing beam provides a mechanism by which an undesired charge pattern on the storage grid can be erased. A multiplicity of potentials is established on the storage grid by the modulated beam of the writing gun. Now, increasing the backplate voltage from +2 volts to +8 volts raises the potential of the individual elements of the storage grid to a potential between +6 volts—for an element which has been written to saturation—to zero volts for another element which was unwritten. The screen is now nearly uniformly illuminated at a level equal to, or slightly greater than, the saturated brightness. The low-velocity viewing beam lands on all areas which are at any positive potential, and brings them all to equilibrium at zero volts. Returning the backplate voltage to its original value of +2 volts drops the potential of the entire storage grid to a uniform -6 volts, which is the erased or cutoff condition. This technique is known as *static erasure*.



Using this technique, information written at any time remains at the written brightness level. The display at any moment comprises an integrated sum of all information written since the last erasure but does not permit the distinction of the time at which the information was written. During the erasing cycle the display conveys no information. After erasure, no information will be displayed until a new pattern is written.

The duration of a display may be extended to two minutes or more if half-tones are not involved in the display and if the signals to be written are above a minimum threshold value. The increased duration is achieved by use of an erasing voltage having an amplitude several volts higher than that required for complete erasure which produces an erased condition called "blacker than black". Such a voltage charges the unwritten storage elements more negative than the cutoff voltage and consequently increases the time necessary for ion landing to cause a visible build-up of background brightness. If true half-tone displays are required the amplitude of the erasing voltage should be adjusted to that value which brings the storage grid to just cutoff potential.

**Dynamic Erasure.** In many applications it is desired that writing be followed by a gradual decay of stored information. A gradual decay permits discrimination of the time at which the information was written. This performance is obtained by applying a continuous series of rectangular positive pulses to the backplate at a rate well above the flicker frequency of the human eye. Because the rate of the erasing pulses is above the flicker frequency of the eye, stored information will appear to an observer to be continuously displayed. A satisfactory pulse-repetition frequency is 200 cps. The technique of erasing by applying a series of pulses to the backplate is known as *dynamic erasure*.

The rate of decay of stored information depends on the width of the pulse and its repetition frequency. In contrast to the saturation brightness condition which occurs during static erasure, dynamic erasure gives the appearance of a low level of background brightness resulting from the erasing pulses. The rate of decay of stored information and the apparent background brightness caused by the pulses is proportional to the product of their width and repetition rate.

Brightness-decay characteristics for a typical display-storage tube dynamically erased are shown in Fig. 4. Under the assumed erasing conditions shown in Fig. 4, the display can be erased by a single 6-volt rectangular pulse of approximately 24 milliseconds duration, or by a series of 6-volt pulses having a total duration of 24 milliseconds. Erasing pulses whose amplitudes are smaller than the magnitude of the viewing-beam cutoff voltage do not permit complete erasure. On the other hand, erasing pulses whose amplitude is greater

than the magnitude of the viewing-beam cutoff voltage eventually drive the storage grid beyond cutoff, i.e., to a value "blacker than black". While this may appear to give faster erasure, it will result in the loss of small signals. Therefore, the erasing-pulse amplitude should not be used to adjust the erasing speed.

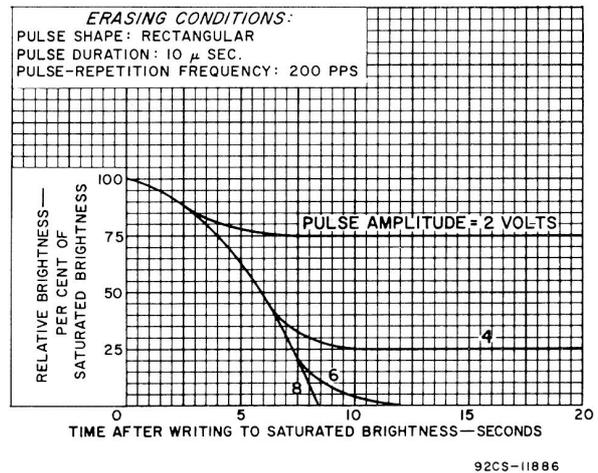


Fig. 4—Typical Erasing Characteristics of a Display-Storage Tube.

In some applications the saturated brightness condition of static erasure or the low level of background brightness during dynamic erasure may be objectionable. These conditions can be eliminated by reducing the applied screen voltage during that portion of the erasure cycle when the backplate is raised to a value more positive than its normal operating voltage.

#### OPERATING CONSIDERATIONS

The precautions which must be observed to obtain reliable service from display-storage tubes are considerably more numerous than those to be observed for the more familiar oscillograph-type cathode-ray tube. If these precautions are observed, these devices may be operated with a high degree of confidence in obtaining reliable and trouble-free service throughout the warranty period and beyond.

This section contains information which, when used along with the maximum ratings established for the individual tube type will prevent the occurrence of electrical situations which may result in permanent storage-tube damage. *Only items likely to result in permanently damaged tubes are listed below. Items affecting only the quality of tube performance have been purposely omitted.* It is highly recommended that safeguards to protect against the situations described below be designed into the equipment to prevent inadvertent display-storage tube damage.

**Maximum Ratings.** Failure to stay within the absolute-maximum ratings of the tube as shown



in the technical bulletins will result in impaired tube life or immediate tube destruction. For this reason, it is advisable to design voltage controls in such a manner that it is impossible to apply to the tube a voltage exceeding its maximum rating. Often, excessive voltages result from open and short circuits in power-supply circuits, or from an open electrode-terminal connection. In the latter case, the corresponding tube electrode can float to uncontrolled potentials.

**Screen-Circuit Impedance.** An adequately rated one-megohm (minimum) resistor must be in series with the screen-terminal lead. Capacitance to ground (or elsewhere) from the section of the lead between the resistor and the screen terminal must be very low. For this reason, this section of the lead must be unshielded, must be no more than about one foot long, and must have no capacitors connected to it. The resistor should be rated at 2 watts and an end-to-end voltage of 7500 volts.

Failure to include this resistor almost invariably results in tube damage. Damage usually consists of an open internal screen connection caused by excessive screen current. When attempts are made to operate such tubes, no light is observed coming from the phosphor screen. Mechanical damage to the phosphor screen can often be observed in non-operating tubes.

**Collector-Circuit Impedance.** A 10,000 ohm (minimum) resistor must be in series with the lead to the collector terminal. Capacitance to ground (or elsewhere) from the section of the lead between the resistor and the collector terminal must be very low. For this reason, this section of the line must be unshielded, must be no more than about 3 feet long, and must have no capacitors connected to it. The resistor, to be protected in the event of a collector short circuit, should be rated for service at 10 watts and 500 volts.

Failure to include this resistor occasionally results in permanent damage to the storage surface due to excessive collector current. This damage is local in extent and appears in the display as small permanent bright spots. However, not all bright spots are caused by omission of this resistor.

**Excessive Writing-Beam Current Density.** The writing-beam current density of any area of the storage grid should be no more than is necessary to write that area to saturated brightness during one scan of the writing beam. Excessive writing-beam current density can permanently damage the storage surface.

Such damage ordinarily is local in extent and appears as permanent light or dark areas or spots in the display, coincident with areas

struck by the excessive writing beam. In severe cases, mechanical damage to the phosphor screen can be observed on the face of the non-operating tube.

Under ordinary operating conditions, sufficient latitude exists in the maximum ratings so that a small degree of excessive writing-beam current density does not cause damage, unless prolonged for several hours. Nevertheless, it is strongly recommended that writing-beam current never be greater than that required for a given application.

During the operation of display-storage tubes, certain situations may arise that can quickly cause excessive writing-beam current density and consequent damage. These situations and safeguards against them are described below.

**Failure of Scanning.** Failure of scanning while the writing beam is turned on results in excessive writing-beam current density which often results in localized permanent storage-grid damage. Provision should be made to cut off the writing-beam current automatically in case of a scanning failure. The writing-beam current can be cut off by an electronic switch which applies -200 volts bias to grid No. 1 of the writing gun. This switch should be actuated by a portion of the scanning voltages applied to both sets of deflecting electrodes.

**Loss of Bias.** Loss of writing-gun control-grid bias, or loss of blanking, which causes the writing-gun control grid to be at or near zero bias, will result in excessive writing-beam current which may result in localized permanent damage to the storage grid.

**Turning on Equipment.** In some cases, the order in which voltages are applied to display-storage tubes when equipments are turned on can give rise to a situation of "no bias" or "no scanning". If writing-gun high voltage is applied before writing-gun bias, a zero-bias condition will exist. If writing-gun high voltage is applied before the writing-gun deflection voltages, a "no scanning" condition will exist. In these cases, damage as described above can occur. It is obvious that an extremely serious condition exists when the writing-gun high voltage is applied before either bias or deflection voltages.

In some equipments, the application of bias to the writing-gun control grid is delayed because of high impedance in the control-grid-to-bias-supply return circuit. One way to avoid this condition is to use a time-delay relay, operating from the writing-gun high-voltage switch, to connect the writing-gun control grid to a low-impedance point of the bias supply at a bias voltage sufficiently great to cut off the writing-gun beam until after the high voltage is applied.



To avoid a condition of runaway charging and possible tube damage, it is necessary that the viewing beam be operating before the writing beam is turned on. Allow the viewing-gun heater to reach operating temperature, and allow the viewing-gun beam current to reach normal operating value before turning on the writing-gun beam current. Furthermore, always keep the viewing-gun beam on till the writing beam is turned off.

**Runaway Charging.** A condition of runaway charging of the storage grid may result if the writing beam is allowed to land on the storage grid with the viewing beam turned off, if the writing beam is incident on an area of the storage grid not covered by the viewing beam, or even though the viewing beam is turned on if the current density in the writing beam exceeds that in the viewing beam. Such a runaway condition can occur because of the non-equilibrium writing process involved.

Because the electrons in the writing beam land with an energy such that the secondary-emission ratio of the storage-grid surface is greater than unity, this surface charges positively toward collector potential. Normally, the landing on the storage grid of the viewing-beam electrons keeps any portion of the storage-grid surface from charging above viewing-gun cathode potential. When this limiting action of the viewing beam is not present, the storage-grid surface may charge under the action of the writing beam to a value such that sparking occurs through the insulating layer between the storage-grid surface and the backplate. This sparking is observed as random bright flashes on the screen. In the event of sparking, permanent damage (loss of the ability to store a signal in localized areas) to the storage grid may result. Such damage can sometimes be avoided if the writing process is quickly stopped.

**Reduced Viewing-Beam Diameter.** In many display-storage tubes, the application of certain ranges of voltage to the viewing-gun grids will cause the viewing beam to be focused into a small spot. In this condition, the viewing beam is quite intense and can change the secondary-emission properties of the storage grid in the bombarded area. The voltage ranges assigned to the various viewing-gun grids in the technical bulletins under Maximum Ratings are chosen so that the viewing-beam current cannot be focused into a small spot.

In summary, the following precautions must be followed to protect the display-storage tube from inadvertent damage—

1. Do not exceed maximum ratings.
2. Be sure to include the screen resistor.
3. Be sure to include the collector resistor.

4. Do not apply excessive writing-beam current density.
5. Protect against scanning failure.
6. Protect against loss of bias.
7. Apply voltages to tube in correct order.
8. Never write unless viewing beam is on.
9. Stay within recommended viewing-grid voltage ranges.

#### GENERAL CONSIDERATIONS

**Handling.** The display-storage tube should preferably be transported or handled with the face up. Care should be taken to prevent knocking or bumping the bulb terminals. Such rough treatment may cause either immediate or delayed cracking of the metal-glass seals.

**Support.** Display-storage tubes which are not provided with an integral magnetic shield may be mounted by using a padded clamp around the neck of the tube and by sponge-rubber supports around the tube, except near the bulb caps. The tube should not be supported by the base or socket. Support for display-storage tubes having an integral magnetic shield is generally effected by using padded clamps around the neck and large diameter of the tube unless otherwise specified in the technical bulletins.

Supporting systems for "ruggedized" display-storage tubes should take into consideration mounting arrangements that will take full advantage of the environmental ratings of the tube.

**Shielding.** Magnetic shielding, if not integral in the display-storage tube, should always be provided to prevent external fields from interfering with the required accurate control of the low-velocity viewing beam. A cylindrical shield of properly annealed high-permeability material about 1/16-inch thick is usually satisfactory. The integral shielding provided in some display-storage tubes is satisfactory for most applications.

**Degaussing.** Display-storage tubes supplied both with or without integral magnetic shields should be degaussed before being placed in operation. A degaussing coil suitable for use with 5-inch display-storage tubes may be made by winding 900 turns of No. 17 enameled wire on a 7-inch diameter form 2 inches long. After connecting the coil to a suitable supply line (220 vac, 60 cps), slowly (taking at least 30 seconds) pass the display-storage tube through the coil and then slowly withdraw it completely from the ac magnetic field. Repeat this procedure at least two times. The tube should be removed at least five feet distant from the coil before disconnecting the coil from the supply line.

**Deflection Considerations for Electrostatic Types.** As with conventional oscillograph tubes, balanced electrostatic-deflection circuits should be employed. Each pair of the deflecting electrodes should be operated at an average potential about the same as that of grid No. 4 of the writing gun.



**Video-Drive Considerations.** In most applications the information to be stored and displayed by the tube should be applied as a video signal to the control grid (grid No.1) or cathode of the writing gun. The writing-gun control grid should never be more positive than necessary to write the display to saturated brightness for a given scanning speed and drive condition. In determining the writing-drive requirements, it should be remembered that writing is essentially a charge-depositing process. The instantaneous writing-beam current needed for saturated writing varies directly with the speed at which the writing beam is deflected across the storage grid and varies inversely with the number of times a given storage element is written upon in one complete scan period.

*The high voltages at which display-storage tubes operate may be very dangerous.* Great care should be taken in the design of apparatus to prevent the operator from coming in contact with the high voltages. Safety precautions include the enclosing of high-potential terminals and the use of interlocking switches to break the primary circuit of the power supply when access to the equipment is desired.

In the use of high-voltage tubes, it should always be remembered that high voltages may appear at normally low-potential points in the circuit as a result of capacitor breakdown or incorrect circuit connections. Therefore, before any part

of the circuit is touched, the power-supply switch should be turned off, and both terminals of any capacitors grounded.

**The Use of Safety Glasses.** It is recommended that shatter-proof protective glasses be worn when handling display-storage tubes having a diameter greater than 5 inches to help protect operators against tube implosion should the tube be accidentally struck.

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