

July 1, 1958

## WL-7228 FIVE INCH DIRECT VIEW STORAGE TUBE

The WL-7228 is a five-inch storage tube with selective erasure, developed by Westinghouse, for applications which require a bright display free of scintillations. The WL-7228 can be used in fire control radar, weather radar, transient studies, data transmission, half-tone storage, and visual displays requiring steady, narrow bandwidth transmission capable of being carried by telephone lines.

Performance characteristics of the tube include brightnesses of up to 2000 foot-lamberts with 10,000 volts applied to the phosphor, good resolution of half-tone displays. The writing speed of from  $10^4$  to  $10^5$  cm/sec is capable of freezing high frequency transients and, consequently, it provides sufficient time to adequately examine and record them.

The tube contains electrostatically focused and deflected writing guns and a flood gun. The writing guns can be used either for writing or selective erasure. In writing the beam lands at such a velocity that the secondary emission ratio is greater than unity and the storage grid is charged positively. If the velocity of the beam is further increased, the secondary emission ratio goes below unity and the storage grid is charged negatively, thereby erasing the written charge pattern. The writing and erasing operations are described in detail in the "Principles of Operation."

The viewing or reading is accomplished by a wide-angle beam of electrons which floods the electrodes controlling the storage and brightness of the display.

The WL-7228 is designed to be operated unpressurized in airborne applications. The pin connections have been grouped to separate high potential gradients over long external paths to eliminate electrical leakage at high altitudes. The grouping of the pin connections also incorporates improved deflection characteristics by eliminating long inductive leads from the base to the deflecting electrodes. The deflection leads are brought out radially through the neck to minimize lead length and cross coupling.

## PRINCIPLES OF OPERATION

## The Viewing Operation

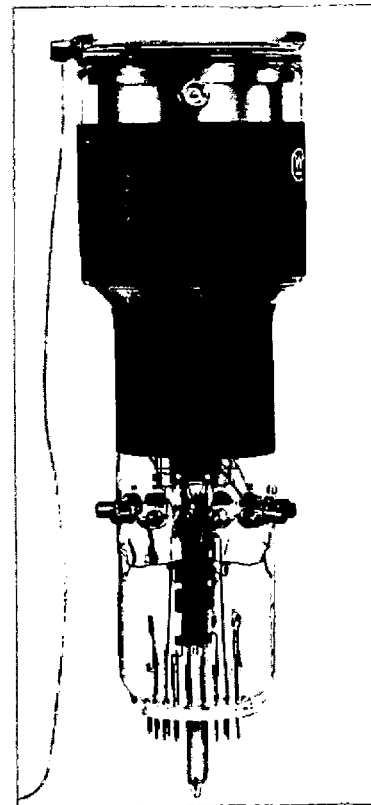
The flood gun, in conjunction with its grids - the control grid no. 1, the accelerating grid no. 2, the collimating grids no. 3 and no. 4, a storage grid capacitively coupled to a backing electrode, a collector grid, and a highly-efficient phosphor screen - comprise the viewing section.

The flood gun provides a low-energy, high-density, highly-divergent beam which continuously floods the electrodes of the viewing section. Grids no. 2, no. 3, and no. 4 act as the collimating elements of the viewing section. These grids consist in general of conductive coatings on the bulb wall. The collimation is necessary in order that the low-velocity electrons will approach the storage grid in paths normal to the plane of the storage

grid. This requirement causes all of the electrons of the viewing beam to arrive at the storage grid with equal energy components in the direction normal to the storage grid, thus causing any potential pattern existing on the storage grid to affect all of the electrons equally.

Electrically connected to the grid no. 4 is the collector mesh. This mesh not only serves to collect the secondary electrons from the storage grid and to uniformly accelerate the flood electron, but it also repels any positive ions produced by collisions of electrons with residual gas in the region between the collector and the flood gun cathode. This action prevents the ions from landing on the storage grid with resultant neutralization of the written charge pattern and destruction of the signal.

The storage grid consists of a fine metal mesh, one side of which is covered by a thin layer of insulating material. The insulator acts as a large number of individual storage elements capacitively coupled to the mesh. The charge established on the insulator by the writing beam modulates the viewing beam



Approx. one-fifth  
actual size

Special Devices Section

WESTINGHOUSE ELECTRIC CORPORATION, ELECTRONIC TUBE DIVISION, ELMIRA, NEW YORK

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Page 2

In much the same way as modulation is provided by the control grid of a triode. The more positively charged regions of the storage mesh allow higher currents to reach the phosphor, corresponding to a highlight signal. The less positively charged elements allow proportionately smaller amounts of current to reach the phosphor, corresponding to half-tones. Thus, the WL-7228 is able to display visual output complete with half-tones.

### The Writing Operation

The writing gun is similar to that used in electrostatically focused and deflected oscillograph tubes. This gun is capable of a high-density beam with very high resolution. The writing gun is generally operated between 1000-2000 volts. At this potential the electrons from the writing beam have sufficient energy to cause a secondary emission ratio greater than unity. Thus, since more electrons are leaving the storage grid than are arriving, a net positive charge results. The control grid of the writing gun regulates the amount of current falling on the storage grid at any particular instant. Therefore, the amount of positive charge developed on a particular element of the storage grid is proportional to the magnitude of the writing beam at the instant at which it is discharging that element. If it were not for the viewing electrons, the storage grid would charge to a potential near that of the collector. However, when the storage grid becomes more positive than the flood gun cathode, the landing of the viewing beam will limit any further charging. It is possible, then, to establish on the storage grid a charge corresponding to any potential intermediate between the storage

grid cutoff voltage and the viewing gun cathode surface potential.

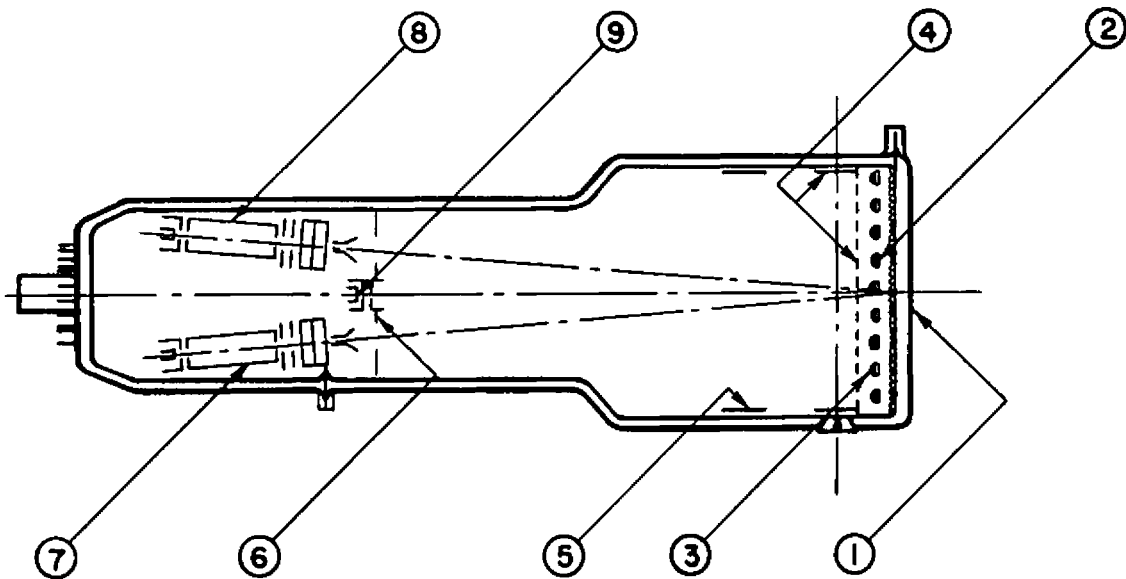
The potential of any particular element regulates the amount of viewing beam current reaching the phosphor. The visual output brightness of any element on the phosphor is proportional to the density and velocity of the electrons landing on the element. Because the potential is constant, the brightness is therefore directly proportional to the density of the viewing current which is in turn regulated by the potential on the storage grid.

### Erasing Operation - Flood Gun Erasure

The stored pattern is erased by applying positive pulses to the backing electrode. Since the storage grid is capacitively coupled to the backing electrode, its potential tends to follow that of the backing electrode. Therefore, the positive pulses applied to the backing electrode cause the storage grid to shift in the positive direction and allow the flood electrons to land until the storage grid is charged to cathode potential. Then, with the pulse removed, the storage grid potential falls to a value which is at or beyond cutoff. The magnitude and duration of the pulse applied to the backing electrode determines the amount which the storage grid becomes negative with respect to the flood gun cathode with the pulse removed.

### Erasing Operation - Selective Erasure

It is often advantageous to erase a specific part of the stored signal without erasing other parts. As the total electron-



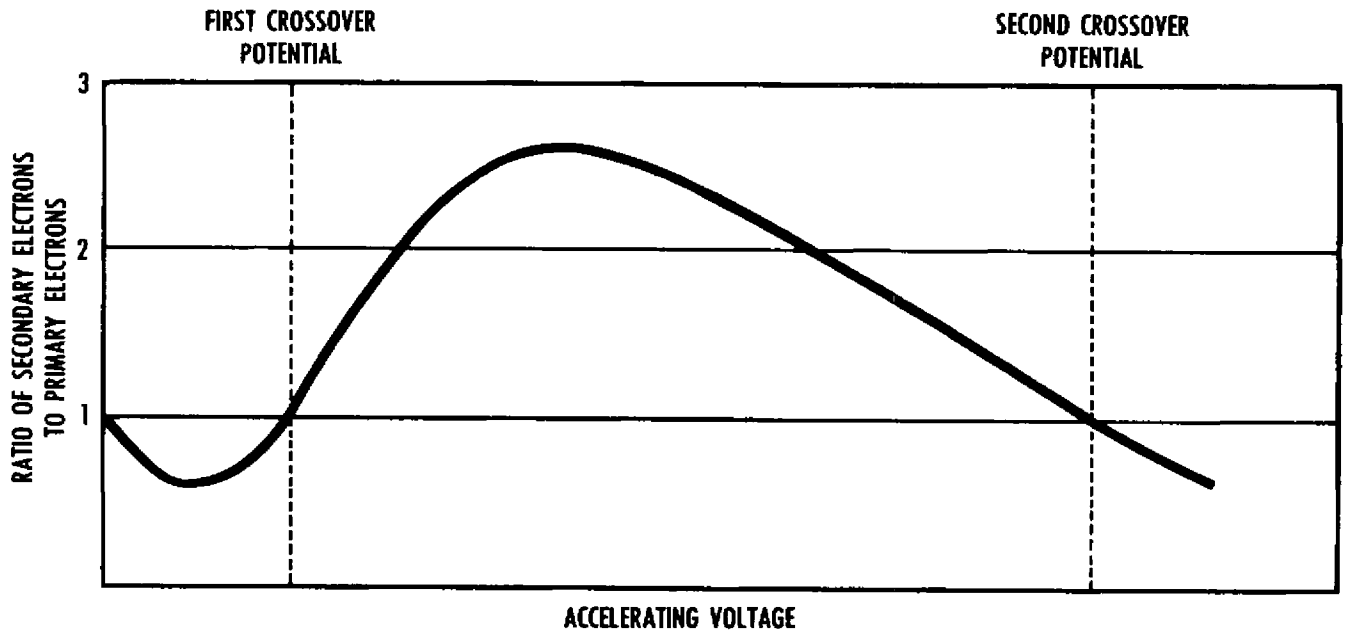
CE-A1384

- 1 - VIEWING SCREEN
- 2 - BACKING ELECTRODE
- 3 - STORAGE GRID
- 4 - COLLECTOR GRID - GRID NO. 4
- 5 - GRID NO. 3

- 6 - GRID NO. 2
- 7 - WRITING GUN
- 8 - ERASE GUN
- 9 - FLOOD GUN

Figure No. 1

SECONDARY EMISSION CHARACTERISTIC



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$$\text{SECONDARY EMISSION RATIO } \delta_c = \frac{\text{CURRENT AT COLLECTOR}}{\text{PRIMARY BEAM CURRENT}}$$

The secondary emission curve shows the various modes of operation in a direct view storage tube. When the electrons land between the first crossover and the second crossover, the secondary emission ratio is greater than unity and the insulator is charged positively, producing a written signal. If the primary energy is increased above the second crossover, the insulator is

charged negatively, erasing the written pattern.

The viewing is accomplished with electron potentials from zero volts to some slight negative voltage. Therefore, the viewing electrons do not land and do not affect the stored signal.

Figure No. 2

volt energy of the beam increases from zero volts, the secondary emission ratio first decreases then increases to a maximum value, substantially greater than unity. This maximum usually occurs between 500 and 1000 volts for the WL-7228. In the interest of better resolution, operation of the writing gun at 1500 volts is recommended. As the voltage of the electron beam increases further, the secondary emission ratio goes below unity, and it becomes possible to use the beam for selective erasure. With the WL-7228, selective erasure of reasonable speed usually occurs at a voltage of the order of 3000 volts. This high velocity erase mode has many advantages. The erase beam has high resolution resulting in much greater selectivity. The erase beam is also capable of much greater density. The greater beam density not only results in a faster erasing speed, but also results in substantially less interaction between guns used simultaneously in the write or erase modes.

the effect of the collimating optics of the flood gun on the erase beam. Since the erase beam is of the same order of velocity as the flood beam in this system, the collimating optics of the flood gun converge not only the flood beam, but also the erase beam. The erase beam tends to be deflected toward the center of the tube by the collimating lenses. Consequently, a low velocity erase beam is very difficult to control and has serious non-uniformities in deflection linearity.

Since the WL-7228 utilizes a selective erase system with a high velocity beam, it is essentially free from distortions of the type described above. Therefore, the WL-7228 is a completely flexible direct view storage tube. The WL-7228 may be employed as a direct view storage tube with two separately focused and deflected writing guns. Simply by raising the potential of one of the writing guns, the tube becomes a direct view storage tube with very high selectivity and speed of erasure.

A serious drawback of a low velocity erase system is

### Write Through

It is often desirable to display non-stored information simultaneously with stored information. This mode of operation or WRITE THROUGH is practical only if the non-stored information does not seriously disturb the charge pattern established on the storage grid. In order not to deteriorate the charge pattern, a secondary emission ratio of unity is necessary. The secondary emission curve in Figure No. 2, indicates that unity secondary emission occurs at three primary electron beam energy levels. Two of these — the zero energy potential and the first crossover

potential — occur at energy levels too low for a well defined beam necessary for detailed information. The third unity secondary emission energy level occurs at the second crossover potential which is at sufficiently high beam energy (approx. 2500 to 3000 electron volts in the WL-7228) to be suitable for displaying detailed information without seriously affecting the stored signal. By adjusting either the erase gun or the write gun to the second crossover potential, WRITE THROUGH — simultaneous display of stored and non-stored information — is possible for limited periods with minimum impairment of the stored signal.

### GENERAL

|                                                       | <i>Writing Section</i>                  | <i>Selective Erase Section</i> | <i>Viewing Section</i> |         |
|-------------------------------------------------------|-----------------------------------------|--------------------------------|------------------------|---------|
| <b>Heater for Unipotential Cathode:</b>               |                                         |                                |                        |         |
| Voltage (ac or dc) . . . . .                          | 6.3 ± 5%                                | 6.3 ± 5%                       | 6.3 ± 5%               | Volts   |
| Current . . . . .                                     | 0.6                                     | 0.6                            | 0.6                    | Ampere  |
| <b>Cathode Heating Time (min):</b>                    |                                         |                                |                        |         |
| Before other electrode voltages are applied . . . . . | --                                      | --                             | 30                     | Seconds |
| Focusing . . . . .                                    | Electrostatic                           | Electrostatic                  | None                   |         |
| Deflection . . . . .                                  | Electrostatic                           | Electrostatic                  | None                   |         |
| Phosphor . . . . .                                    | High Visual Efficiency Type, Aluminized |                                |                        |         |
| Fluorescence . . . . .                                | Yellow                                  |                                |                        |         |
| Phosphorescence . . . . .                             | Yellow-Green                            |                                |                        |         |
| Min. Useful Display Diameter . . . . .                | 4"                                      |                                |                        |         |
| Max. Overall Length . . . . .                         | 16-1/2"                                 |                                |                        |         |
| Seated Length . . . . .                               | 15"                                     |                                |                        |         |
| Greatest Bulb Diameter . . . . .                      | 5 ± 1/16"                               |                                |                        |         |
| Base . . . . .                                        | Small Button Thirtyfour (JETEC E35-28)  |                                |                        |         |
| Bulb Terminals (Four) . . . . .                       | Recessed Small Ball Cap (JETEC J1-22)   |                                |                        |         |

### MAXIMUM RATINGS Absolute Values

|                                                   | <i>Writing Section</i> | <i>Selective Erase Section</i> | <i>Viewing Section</i> |       |
|---------------------------------------------------|------------------------|--------------------------------|------------------------|-------|
| Screen Voltage . . . . .                          | --                     | --                             | 11000 max.             | Volts |
| Backing Electrode Voltage . . . . .               | --                     | --                             | 35 max.                | Volts |
| <b>Equivalent Voltages</b>                        |                        |                                |                        |       |
| Grid No. 4 Voltage . . . . .                      | 3000 max. § 150 max. ♪ | 3500 max. ▲ 150 max. ♪         | 300 max.               | Volts |
| Grid No. 3 Voltage . . . . .                      | 1000 max. §            | 1250 max. ▲                    | 300 max.               | Volts |
| Grid No. 2 Voltage . . . . .                      | 3000 max. §            | -3500 max. ▲                   | 150 max.               | Volts |
| Cathode Voltage . . . . .                         | -3000 max. ♪           |                                |                        | Volts |
| <b>Grid No. 1 Voltage:</b>                        |                        |                                |                        |       |
| Negative Bias Value . . . . .                     | 200 max. §             | 200 max.                       | 200 max.               | Volts |
| Positive Bias Value . . . . .                     | 0 max. §               | 0 max.                         | 0 max.                 | Volts |
| Positive Peak Value . . . . .                     | 0 max.                 | 0 max.                         | 0 max.                 | Volts |
| <b>Peak Deflection Voltage:</b>                   |                        |                                |                        |       |
| Between G4 and any Deflection Electrode . . . . . | 500 max.               | 600 max.                       | --                     | Volts |
| <b>Heater-Cathode Voltage:</b>                    |                        |                                |                        |       |
| Negative Heater Voltage . . . . .                 | 125 max. §             | 125 max.                       | 125 max.               | Volts |
| Positive Heater Voltage . . . . .                 | 125 max. §             | 125 max.                       | 125 max.               | Volts |

TYPICAL OPERATING VALUES

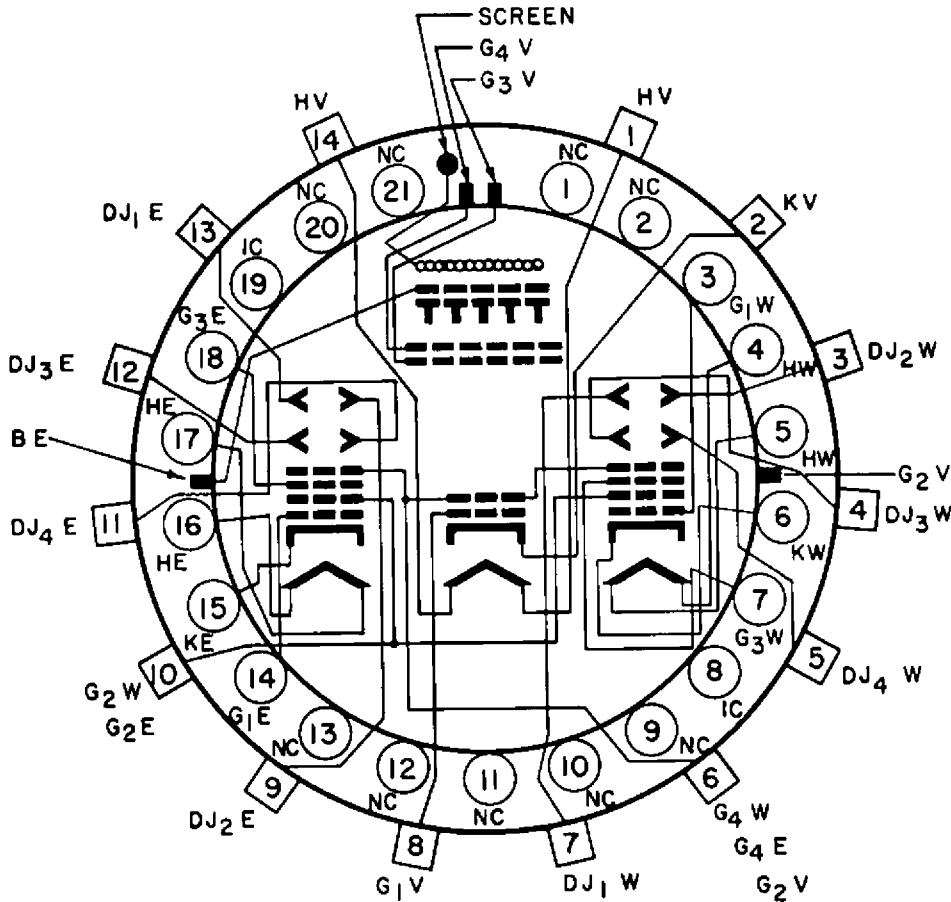
|                                          | <i>Viewing Section</i> † |            |            |            |
|------------------------------------------|--------------------------|------------|------------|------------|
| Screen Voltage . . . . .                 | 10000                    | 10000      | 5000       | Volts      |
| Backing Electrode . . . . .              | 5 to 20                  | 5 to 20    | 5 to 20    | Volts      |
| Grid No. 4 Volts . . . . .               | 200 to 250               | 150 to 200 | 150 to 200 | Volts      |
| Grid No. 3 Volts . . . . .               | 50 to 150                | 25 to 125  | 25 to 125  | Volts      |
| Grid No. 2 Volts □ . . . . .             | 70 to 105                | 50 to 80   | 50 to 80   | Volts      |
| Grid No. 1 Volts . . . . .               | 0 to -70                 | 0 to -50   | 0 to -50   | Volts      |
| Max. Screen Current . . . . .            | 700                      | 400        | 400        | uamps      |
| Max. Grid No. 2 Current . . . . .        | 3                        | 2          | 2          | Ma.        |
| Max. Grid No. 3 Current . . . . .        | 2                        | 1.5        | 1.5        | Ma.        |
| Max. Grid No. 4 Current . . . . .        | 3                        | 2          | 2          | Ma.        |
| Max. Backing Electrode Current . . . . . | 2                        | 1.5        | 1.5        | Ma.        |
| Max. Cathode Current . . . . .           | 5                        | 3.5        | 3.5        | Ma.        |
| Resolution • . . . . .                   | 250                      | 250        | 250        | lines/dia. |
| Number of Half-Tones * . . . . .         | 4-5                      | 4-5        | 4-5        |            |
| Viewing Duration • . . . . .             | 20                       | 40         | 40         | Sec.       |
| Brightness † . . . . .                   | 2800                     | 1500       | 300        | ft-l.      |
| Erasing Speed † . . . . .                | 10000                    | 10000      | 10000      | cm/sec.    |

|                                  | <i>Writing Section</i>      | <i>Selective Erase Section</i> |  |         |
|----------------------------------|-----------------------------|--------------------------------|--|---------|
| Ranges for Electrode Supplies: § |                             |                                |  |         |
| Grid No. 4 Voltage . . . . .     | 500 to 3000 §               | 500 to 3500 ▲                  |  | Volts   |
| Grid No. 3 Voltage . . . . .     | 12 to 30% of $E_{c2}$       | 12 to 30% of $E_{c2}$          |  | Volts   |
| Grid No. 2 Voltage . . . . .     | 500 to 3000                 | 500 to 3500                    |  | Volts   |
| Deflection Factors:              |                             |                                |  |         |
| $D_{j1} + D_{j2}$ . . . . .      | 28-38 Vdc/in/KV of $E_{c4}$ | 28-38 Vdc/in/KV of $E_{c4}$    |  |         |
| $D_{j3} + D_{j4}$ . . . . .      | 28-38 Vdc/in/KV of $E_{c4}$ | 28-38 Vdc/in/KV of $E_{c4}$    |  |         |
| Writing Speed ■ . . . . .        | 100000                      |                                |  | cm/sec. |

- RESOLUTION: Number of total lines resolved by shrinking raster method with Grids No. 2 and 4 at 1000 volts with respect to the writing gun cathode.
- \* NUMBER OF HALF-TONES: Observed with video signal from EIA test pattern as signal.
- VIEWING DURATION: Measured as the time required for the background brightness to increase from zero brightness and with screen at indicated voltage.
- † BRIGHTNESS: Measured as the maximum average brightness with the entire storage grid written to maximum brightness and with screen at indicated voltage.
- † ERASING SPEED: Measured as the time to selectively erase from saturated brightness to black level with zero bias on erase gun and grids No. 2 and 4 of the erase gun at 3000 volts with respect to the erase gun cathode.

- § Voltages are shown with respect to the cathode of the writing gun.
- ▲ Voltages are shown with respect to the cathode of the viewing gun.
- ▲ Voltages are shown with respect to the cathode of the erase gun.
- Grid No. 2 of viewing gun connected internally to Grid No. 4 of writing gun. (Grid No. 2 of writing guns usually connected externally to Grid No. 4 of writing guns.)
- WRITING SPEED: Measured as the time required to write from zero to 90% of maximum brightness with zero grid bias on the writing gun and Grids No. 2 and 4 of writing gun at 1000 volts with respect to the writing gun cathode.



BOTTOM VIEW

CE-A1383

**SOCKETS**

- |                                       |                                       |
|---------------------------------------|---------------------------------------|
| 1 - No connection                     | 12 - No connection. Do not use.       |
| 2 - No connection                     | 13 - No connection. Do not use.       |
| 3 - Grid No. 1 of writing gun         | 14 - Grid No. 1 of erase gun          |
| 4 - Heater of writing gun             | 15 - Cathode of erase gun             |
| 5 - Heater of writing gun             | 16 - Heater of erase gun              |
| 6 - Cathode of writing gun            | 17 - Heater of erase gun              |
| 7 - Grid No. 3 of writing gun         | 18 - Grid No. 3 of erase gun          |
| 8 - Internal connections. Do not use. | 19 - Internal connection. Do not use. |
| 9 - No connection. Do not use.        | 20 - No connection.                   |
| 10 - No connection. Do not use.       | 21 - No connection.                   |
| 11 - No connection. Do not use.       | 22 to 35 - No connection.             |

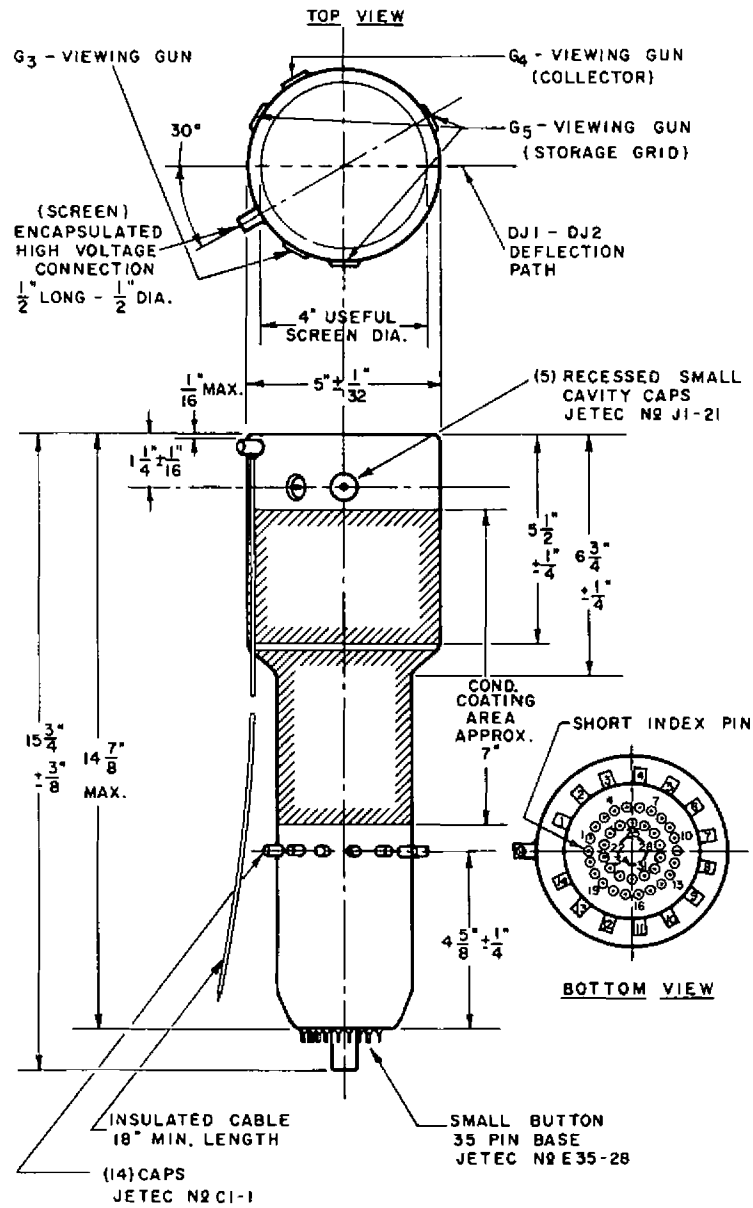
- DJ - Deflecting Electrode  
W - Writing Gun  
V - Viewing Gun  
E - Erasing Gun

**NECK CONNECTIONS**

- |                                                                                         |                                                                |
|-----------------------------------------------------------------------------------------|----------------------------------------------------------------|
| 1 - Heater of viewing gun                                                               | 8 - Grid No. 1 of viewing gun                                  |
| 2 - Cathode of viewing gun                                                              | 9 - DJ <sub>2</sub> of erase gun                               |
| 3 - DJ <sub>2</sub> of writing gun                                                      | 10 - Grid No. 2 of writing gun, and<br>Grid No. 2 of erase gun |
| 4 - DJ <sub>2</sub> of writing gun                                                      | 11 - DJ <sub>2</sub> of erase gun                              |
| 5 - DJ <sub>2</sub> of writing gun                                                      | 12 - DJ <sub>2</sub> of erase gun                              |
| 6 - Grid No. 4 of writing gun, Grid No. 4 of<br>erase gun and Grid No. 2 of viewing gun | 13 - DJ <sub>2</sub> of erase gun                              |
| 7 - DJ <sub>1</sub> of writing gun                                                      | 14 - Heater of viewing gun                                     |

FLEXIBLE LEAD - Screen Connection

RECESSED CAVITY CAPS - See Outline Drawing



CE-B-1382

Center line of bulb will not deviate more than 3° in any direction from perpendicular erected at center of face plate.

The plane through the tube axis and each of the following items may vary from the DJ1 - DJ2 deflection paths by these

angular tolerances (measured about the tube axis): encapsulated connection (screen), 30° ± 5°; index pin of base, ±10°; fifteenth (vacant) position of C1-1 caps on tube neck, ± 10°; DJ3 - DJ4 deflection paths, 90° ± 3°. Index pin of base and fifteenth cap position are on same side of tube as encapsulated connection.

