Himmelbauer

Westinghouse

Display Storage Tubes

- Principles of Operation
- Applications
- Phosphors
- Technical Data

Foreword

As with many electronic developments, the United States military was among the first to recognize the advantages provided by Display Storage Tubes. These devices are sophisticated cathode ray tubes, which provide very high light output and have the ability of signal integration which literally brings information out of random noise.

The Westinghouse Aerospace Division was one of the first manufacturers to be awarded contracts to produce radar systems employing Display Storage Tubes for radar output. The improved performance and flexibility of these systems resulted in thousands being used by the military.

In support of the Aerospace Division's requirements, Display Storage Tubes were developed and produced at the Westinghouse Electronic Tube Division. The initial intercept radars for the F-4 aircraft, APQ-72 and APQ-100 used the WL-7268 family of Display Storage Tubes. The F-4 "Phantom" has since become the front-line fighter, bomber, and reconnaissance aircraft, as evidenced by the many versions of the airplane in current use and production.

Through continuing advances in the "state-of-the art, " Westinghouse developed and patented High Contrast Display Storage Tubes which overcame the common disadvantage of earlier designs, namely low contrast.

The High Contrast Display Storage Tubes have an additional mesh element, called the suppressor, which, with simple external circuitry, makes the contrast ratio very high at any persistance. With the elimination of background brightness, the high contrast tube made it possible to display information at very low light levels, thus providing more halftones than conventional tubes under similar operating conditions. The increased halftone capability of these tubes was the key to acquiring the system performance for the new generation of systems which required both radar and TV displays. Significantly, this increase in performance was obtained while still retaining all of the storage and integration features of conventional Display Storage Tubes.

The success of this development resulted in a substantial increase in demand for High Contrast Tubes. In 1966, a program was initiated to more than double output capacity at the Electronic Tube Division. A multi-million dollar expansion of over 17,000 square feet was added to the manufacturing facility. Included in the expansion was the addition of three ultra-clean rooms and the most modern processing equipment available. All of the critical assembly operations, from mounting and bulb screening through final sealing, are currently performed in the hospital-pure environment of class 100 vertical and horizontal laminar flow clean rooms. This means higher quality and greater reliability of Westinghouse Display Storage Tubes.

Our highly competent staff, utilizing these finest manufacturing facilities in the industry, has made it possible for Westinghouse to achieve and maintain its position as the country's leading Storage Tube supplier.

Present and Future Programs

Intercept Radar
F4 Phantom Aircraft
(Models F4B, F4C, F4D, F4E, F4J, F4K, F4M)

Multimode Radar
A6A + E Intruder Aircraft

Search and Homing Radar
F-111 Aircraft
(Models F-111A, F-111C, F-111E)

Terrain Following Radar
A7 Corsair II

Antisubmarine Sonar
AN/SQS-505 and AN/SQS-26

Reconnaissance System
USD-7

Commercial Weather Radar
RCA-AVQ-10 and AVQ-21 and AVQ-30

Medical Instrumentation

Scan Converter Systems
Air Traffic Control

Introduction

This Westinghouse Display Storage Tube publication is intended to help solve your display storage tube problems by providing up-to-date information on Westinghouse's in-depth ability to fill your system requirements.

For the system design engineer, a full discussion, "Principles of Operation and Applications" is included to aid in understanding the functions and performance "trade-offs" of both conventional types and Westinghouse High Contrast Display Storage Tubes.

Detailed information is also included on contrast enhancement and phosphors. To emphasize the services and capabilities available to you, sections are provided on Westinghouse engineering and manufacturing personnel, along with a picture tour of our facilities.

A comprehensive listing of both electrostatic and magnetic deflection types currently available from Westinghouse is also included for your review.

We trust this information will aid in your design and selection of the display storage tube best suited for your system requirements and that you will consider Westinghouse early in your design to take full advantage of our technical and production capabilities.

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Operation and Application of Display Storage Tubes

D. C. Brooke

A direct view Display Storage Tube (DST) produces a bright display whose persistence can be varied by the viewer during tube operation. Depending on the type DST chosen, persistences ranging from several hundred microseconds to several hours can be obtained. Following is a description of the principal characteristics of the transmission-modulation types of DST currently available from Westinghouse.

OPERATION AND APPLICATION

DST Operation

CATHODE RAY TUBE vs. DISPLAY STORAGE TUBE

The CRT

The conventional cathode ray tube has an electron gun which generates a high energy, small cross-section electron beam which is focused and directed onto a phosphor viewing screen on the inner surface of a faceplate. This electron beam may be scanned to produce a visible pattern on a phosphor by application of transverse electromagnetic or electrostatic fields to the beam near its point of exit from the electron gun. The maximum brightness obtainable and the decay rate of the brightness after the electron beam leaves a given area of the phosphor are determined largely by phosphor type, the energy and current-density of the electron beam, and the beam scanning speed.

The DST

The Display Storage Tube (DST), like the CRT, has a high energy electron gun which produces a small cross-section, high current-density electron beam that is accelerated to a high velocity. As in the CRT, either electrostatic or electromagnetic deflection systems may be employed to direct the focused beam to any point in the display area. Unlike the CRT, in which the beam is focused directly on the viewing screen, however, the DST's writing gun electron beam is focused and directed onto a dielectric-coated grid which is closely adjacent and parallel to the viewing screen.

This grid is a rectilinear metal mesh composed of 250 or more wires per linear inch, and coated on the side that faces the writing beam with a thin layer of dielectric material. The metal mesh is referred to as the *backing electrode*, and the surface of the dielectric material facing the electron gun is called the *storage surface*. The assembly comprising the backing electrode and the dielectric is the *storage grid*.

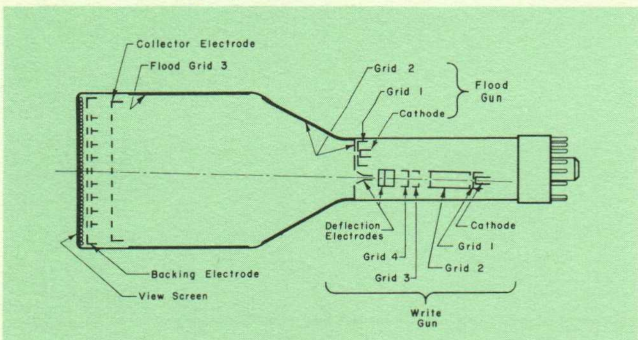

FIGURE 1. Cross-section of DST.

The Writing Gun

The high energy writing beam upon striking the exposed dielectric storage surface liberates secondary electrons from the dielectric material in a quantity determined both by the energy of the impinging beam and the physical properties of the dielectric material. Figure 2 is a curve for a typical dielectric and shows, as a function of primary energy, the ratio of secondary electrons ejected from the dielectric to primary electrons striking it. The primary energy is generally taken as the potential difference between the surface of the primary electron gun cathode and the surface of the dielectric.

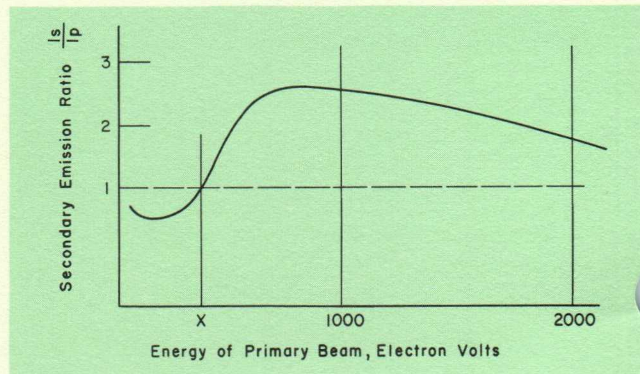

FIGURE 2. Secondary emission ratio, δ as a function of primary energy, for a common dielectric material.

The point marked X on the abscissa represents the primary energy at which the number of secondary electrons ejected into space from the dielectric just equals the number of primary electrons striking the surface. At that energy, referred to as the *first cross-over potential*, the secondary emission ratio is 1. Primary electrons striking the dielectric below first cross-over potential charge the surface in a negative direction. The DST writing gun is normally operated at an energy substantially above the dielectric's first cross-over potential at a level that yields a secondary emission ratio greater than unity.

The Flood or Viewing Gun

In addition to the high-energy writing gun, the DST has a low-energy electron gun which produces a large diameter flood of electrons which is also directed toward the storage grid. Electron lenses, defined both by conductive coatings on the inner wall of the tube envelope and by internal metal cylinders, shape the flood electrons into a large diameter, uniform cross-section cone. The lenses and coatings serve also to collimate the beam, bending the electrons onto paths that are all very nearly parallel to one another to ensure their approach to the storage grid at very nearly right angles. The viewing gun is operated at an energy between zero and first cross-over potential, at the level which yields a less-than-unity secondary emission ratio at the dielectric surface.

A collector grid, also constructed of metal mesh, is mounted close to the dielectric storage surface. Besides serving as a collector electrode for secondary electrons released from the dielectric, this grid acts also as an ion-repeller and flood beam accelerating anode. As an ion-repeller it prevents many of the positive ions which are generated in the major volume of the DST from influencing the charge on the storage dielectric. As a large diameter flood anode and part of the collimating system, it accelerates the flood electrons to collector potential to help assure that all approach the storage grid at a uniform velocity.

Flood electrons that pass through the collector grid mesh openings come under the influence of the storage grid and pass through the storage grid mesh holes where permitted to do so by the amount of charge on the storage dielectric. Those flood electrons allowed to pass through the storage grid are accelerated to a high velocity by the potential difference between storage grid and viewing screen, and strike the viewing screen with sufficient energy to excite the phosphor. See Figure 3. The light output for a given phosphor type will depend on the number of flood electrons and on their energy at impingement.

The viewing screen phosphor is deposited on the inner surface of the DST faceplate. This phosphor is covered on the side that faces the viewing gun by a vapor-deposited, electron-pervious thin film of aluminum to help reduce backscattered brightness losses and to prevent phosphor damage from ion bombardment. Electrons with impinging energies above approximately 2 kv are sufficient to permit penetration of the aluminum film and excitation of the phosphor.

The number of flood electrons that can get through the holes in the storage grid to excite the phosphor is determined by the electric fields in the vicinity of the storage grid holes. These electric fields are, in turn, primarily a function of: (a) the charge on the dielectric surface and (b) the voltage applied to the backing electrode, both with respect to the flood gun cathode potential; (c) the potential difference between backing electrode and collector grid; and (d) the potential difference between backing electrode and viewing screen.

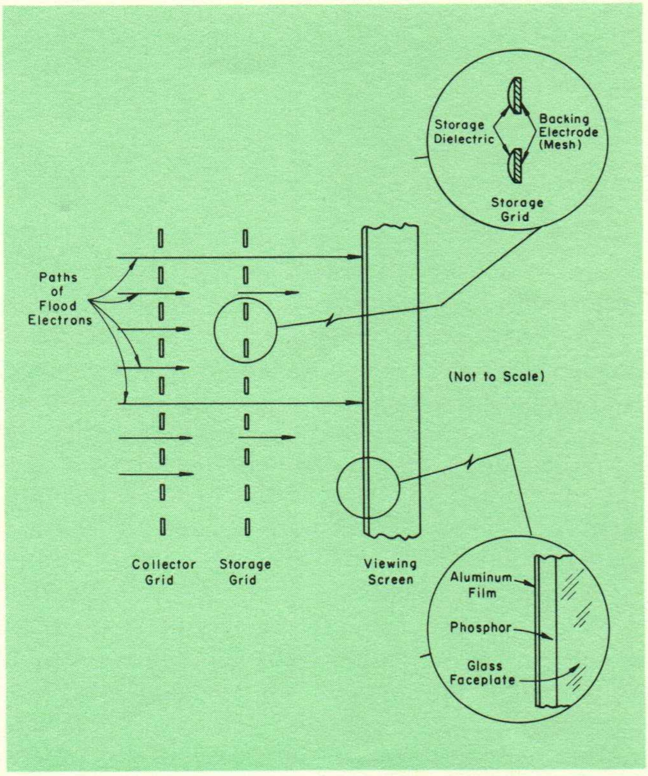

FIGURE 3. Cross-section of DST viewing section

By controlling the charge on the storage dielectric and consequently the magnitude of the surface potential in the vicinity of the storage grid holes, the number of flood electrons exciting the phosphor can be controlled. The entire operating concept of the DST revolves around the control of this dielectric charge.

In subsequent discussion, unless stated otherwise, all flood or viewing gun voltages are with respect to the flood gun cathode which will be assumed to be grounded and at zero potential.

A DST before operation for the first time will generally have no charge on the dielectric, the potential everywhere on the surface equal to the potential of the supporting metal storage grid. Application of rated voltage— say, 2 volts— to the backing electrode of this DST will cause the entire dielectric surface to rise instantaneously also to 2 volts (assume for a moment that no flood electrons are yet arriving at the surface). If flood electrons are now allowed to approach the dielectric surface, a large proportion will pass through the grid

OPERATION AND APPLICATION

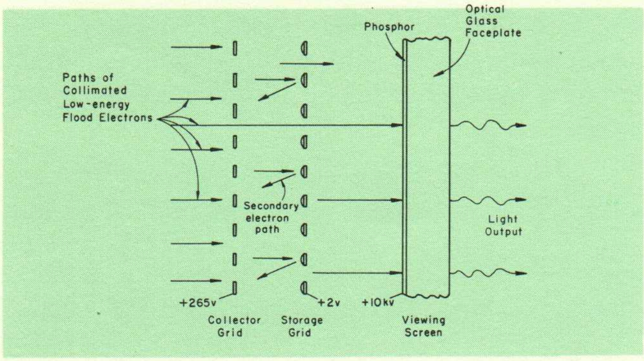

FIGURE 4. Cross-section of DST viewing section, illustrating the condition of storage surface equilibrium (entire dielectric at zero volts).

holes and be accelerated to the viewing screen where they excite the phosphor. See Figure 4. Some, however, will be attracted to the positive storage surface and will land there. Their energy, 2 volts, is well below the first cross-over potential of the dielectric material so the dielectric will take on these primary flood electrons in larger numbers than the secondary electrons it gives up. This will continue until the dielectric attains enough charge (2 volts in this example) to bring the surface down to flood cathode potential. At this point the flood electrons will no longer have sufficient energy to further alter the charge, the potential difference between dielectric surface and flood cathode having reached zero. Any tendency for the surface potential to drift positive will be countered by landing of flood electrons and the surface will be maintained in this *equilibrium potential* condition at zero volts until intentionally changed. The overwhelming majority of approaching flood electrons pass through the storage grid openings under this condition and excite the viewing screen phosphor to *saturation brightness*.

If the surface potential is made negative with respect to equilibrium potential, some of the flood electrons will be repelled back toward the collector grid and the DST light output will be reduced. The more negative the surface, the lower the light output; if made sufficiently negative it cuts off all the flood electrons and the viewing screen is left dark. The negative potential that just achieves this cutoff condition is the storage surface *static cutoff potential*.

Practical applications of the DST deal with selectively controlling the charge at any desired location on the storage dielectric in such a manner as to vary the surface potential between approximately zero (maximum brightness) and the cutoff condition (no light output).

The Writing Operation

It follows that if the potential on the entire dielectric surface can be varied to control overall light output, a variation of potential on a specific location on the surface will produce a corresponding change in phosphor light output opposite only that particular location. The writing gun is the means used to discretely change the charge on the dielectric to achieve this end.

If the entire storage surface is initially charged negative to the static cutoff condition in the manner described later in THE ERASING OPERATION, flood electrons will be unable anywhere to pass through to excite the viewing screen phosphor. See Figure 5. Under this condition the

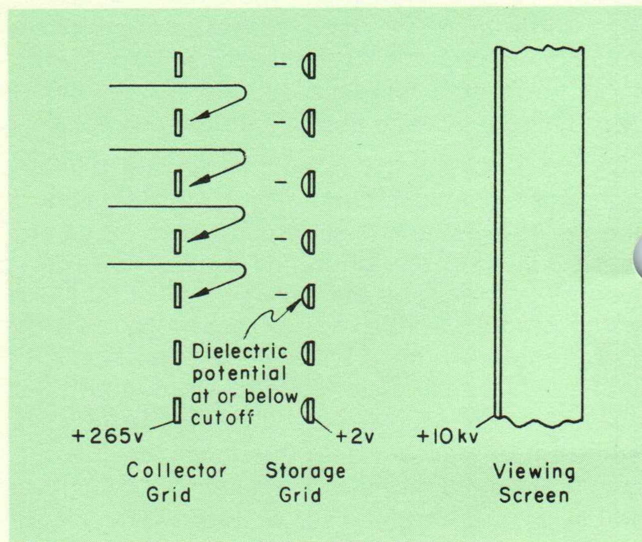

FIGURE 5. Cross-section of DST viewing section illustrating storage surface cutoff (static cutoff).

viewing screen is dark and the storage surface is ready to be written upon. The operating potential of the writing gun cathode is chosen so that electrons emitted from it strike the dielectric surface above the first cross-over potential of the dielectric material. When the writing beam is deflected to a given location on a negatively-charged storage grid, the number of secondary electrons ejected from the dielectric surface exceeds the number of arriving primary electrons and the dielectric discharges at that location in a positive direction. See Figure 6. The amount it discharges toward zero (flood cathode potential) and the rate of charge change are a function of write gun beam current, the time the beam dwells on that location and the secondary emission ratio of the dielectric material under the selected operating conditions.

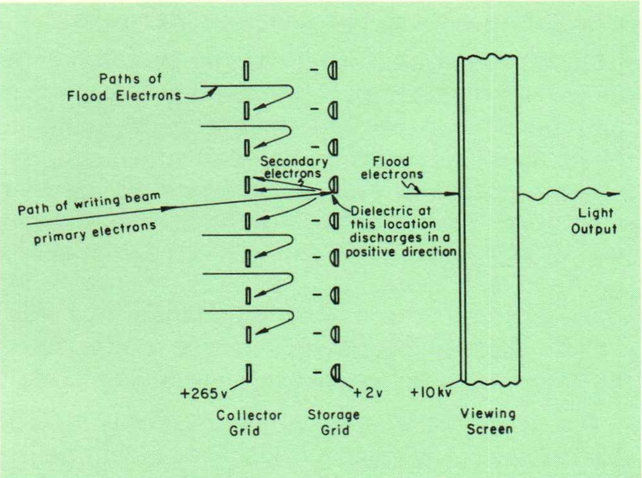

FIGURE 6. Cross-section of DST viewing section illustrating the writing operation.

The Viewing Operation

As the potential at a specific location on the dielectric surface of the storage grid is brought out of static cutoff by the impinging writing beam, flood beam electrons are permitted to pass to the viewing screen through the grid holes at that location. See Figure 7. The viewing screen brightness opposite that location will depend on the potential level to which the writing beam has discharged the storage surface; low brightness corresponding to surface potentials near cutoff, and high brightness corresponding to those near zero.

Figure 8 illustrates the relationship between storage surface potential and output brightness. Observe in Figure 8 that the brightness is not linear with surface potential, the change becoming more gradual at potentials both near zero and static cutoff. Reasonable linearity (between 5 and 15 per cent, depending on tube type) is obtained between those surface potential levels that correspond approximately to 10 and 90 per cent of equilibrium brightness.

Under normal drive conditions, the write beam will be able to discharge the dielectric no higher than approximately zero potential. Any tendency for the surface to become more positive than this results in flood electrons landing, causing it to be maintained in the equilibrium potential condition.

Under abnormal conditions of excessive write gun drive, however, the write beam may be able to force the surface potential sufficiently positive that it exceeds first cross-over potential. Should this occur, the flood electrons would then have enough energy as they land to carry the surface potential further positive and this quickly becomes a runaway condition, the surface potential rising rapidly toward collector potential. Because the dielectric layer is very thin, it may break down electrically if this *runaway charge* condition is allowed to occur. For this reason, and to avoid possible thermal and physical damage to the dielectric, the write gun should not be driven harder under static conditions than is just necessary to obtain a saturation brightness display.

The previous discussion has shown that the write beam can bring a specific area of the static cut-off surface into the condition where flood electrons will be admitted through the storage grid holes. Once the surface has been brought to a desired potential level, it is no longer necessary

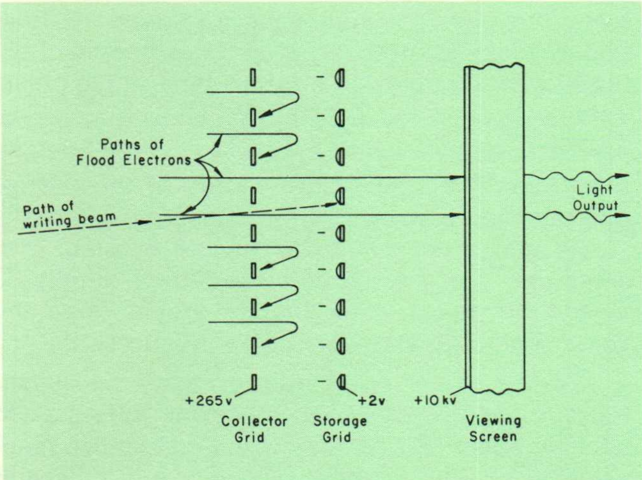

FIGURE 7. Cross-section of DST viewing gun section illustrating viewing process after (or during) writing.

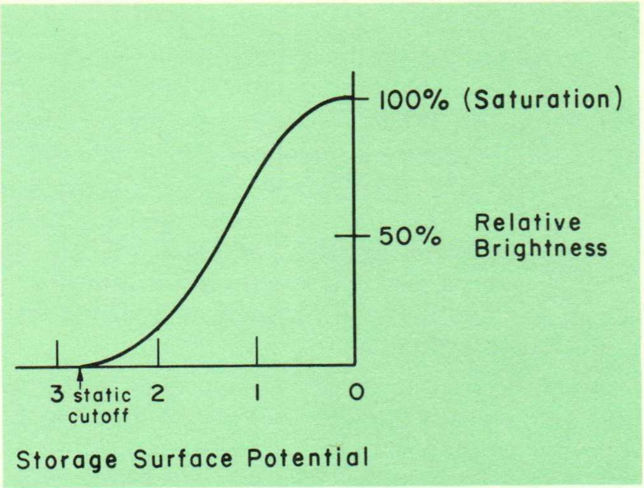

FIGURE 8. Relative brightness as a function of storage surface potential.

for the write beam to remain on that specific location; it may be cut off or moved to a new location as desired. The flood beam, once started, streams through continuously, and excites the phosphor to the brightness that corresponds in Figure 8 to the surface potential selected. The image is stored at that location and would remain for weeks were it not for the presence in the DST of positive gas ions.

Ion Writing

Even though the collector grid prevents most of the positive ions which are generated in the tube volume from reaching the storage surface, a small percentage can get through. These, and additional positive ions which are produced by electron/gas molecule collisions in the space between collector and storage grids, are attracted to the negatively-charged areas on the dielectric surface and recombination takes place, a negatively-charged area on the surface giving up an electron to an ion. There are sufficient ions present that the recombination process goes on continuously, removing electrons from the surface and forcing the entire surface in a positive direction until it is eventually discharged to zero. This is evident in the display as a slow increase in brightness over the display area until the entire area becomes erased to maximum brightness. The time period over which the display can be viewed before this discharge by positive ions is called the *gas viewing duration,* and may be as short as 15 seconds or as long as a half hour, depending on the tube type and the display requirements.

THE ERASING OPERATION

Manual Erase

A charge pattern on the dielectric surface may be removed by the viewer without the need to wait for ion discharge. It can be done manually by raising the backing electrode potential a few volts above its normal rest value to allow flood electrons to land on the dielectric and discharge any stored pattern to flood cathode potential. When the charge everywhere on the dielectric surface is equal to flood cathode potential, the DST is in a fully erased condition.

With the DST in this condition, flood electrons are able to pass through the storage grid and excite the viewing screen to saturation brightness. In order to prepare for new information, a means must now be provided to uniformly, negatively charge the entire dielectric surface by an amount sufficient to just cut off these flood electrons.

Lowering the backing electrode potential to its former rest value causes the dielectric surface to fall below zero by the amount of the change (because of the inherent close capacitive coupling between the dielectric surface and its backing electrode). If the change is great enough, the surface will go to or below static cutoff potential and no flood electrons will be able to reach the viewing screen. Under this condition the fully erased, slightly negatively-charged dielectric is ready for new information to be written.

The usual practice when manually erasing is to make the initial increase in backing electrode potential equal to or slightly greater than the surface static cutoff potential. This assures full erasure of the entire surface when the backing electrode is returned to its normal rest potential.

Erasure performed in this manner removes the stored charge information in a single operation. In practice, a single positive voltage pulse, slightly greater in amplitude than the value of surface cutoff potential, may be applied to the backing electrode each time complete manual erasure is desired after writing. The pulse width need only be long enough to allow the flood electrons to discharge the surface to zero potential. The minimum pulse width that will just permit erasure of all areas to cut off on application and removal of a single pulse is the *single pulse erase time* of the tube. Depending on the type tube chosen, this value will usually be between a half and several hundred milliseconds.

Dynamic Erasure

Many applications require the displayed information to decay away slowly after it has been written, rather than be removed abruptly by a single pulse. This is done in the DST by applying a series of narrow, positive voltage pulses to the backing electrode. The sum of the widths of the narrow pulses must equal or slightly exceed the width of a single pulse that would, in manual erasing, give complete erasure. The pulse train amplitude should be equal to or slightly greater than the value of storage surface static-cutoff potential.

With the use of pulse train erasure, the dielectric surface accepts flood electrons during each positive pulse interval just as in single pulse manual erasure. The width of the individual pulses in the train is made short, however, to ensure that the display cannot erase completely in one pulse; the result is partial charge removal during each pulse interval, a number of pulses being required to discharge the surface fully to flood cathode potential. The narrower the width of the individual pulses with respect to the pulse period, the longer it takes to achieve total erasure.

The rate at which the display decays on a given DST type during dynamic erasure, then, is dependent principally on the erase train duty cycle. The higher the duty cycle— either through increasing the repetition frequency with a constant pulse width, or increasing the pulse width with a constant repetition frequency, or a combination of both— the shorter the display decay time.

Control of erase train duty cycle during DST operation is extensively used in practical applications to permit observer-control of display persistence.

In practical, long-persistence operation, the erase train amplitude must be slightly greater than the value of storage surface static-cutoff potential if complete erasure is to occur. This is due principally to positive ions landing on the dielectric surface and slowly discharging any stored information toward zero during the interval between successive erase pulses. The lower the erase train duty cycle, and hence the longer the persistence, the larger the pulse amplitude must be in order to erase the display to cutoff. Depending on the tube type and the application, this amplitude increase is of the order of 10 to 20 per cent of that required for complete erasure at short persistences.

The appearance of the display during dynamic erasure is a slow decay of stored information against a dimly illuminated background. This dim background over the whole of the display occurs because flood electrons can pass through the storage mesh holes during each short erase pulse interval and excite the viewing screen. If the pulse repetition frequency is sufficiently high, the observer's eye integrates the individual bursts of light occuring during each pulse into a fixed, low background brightness. The brightness of this background is directly proportional to the erase pulse duty cycle: a 1 per cent duty cycle illuminates the entire screen to 1 per cent of equilibrium brightness; a 10 per cent erase duty cycle produces a background illumination equal to 10 per cent of equilibrium.

Dynamic Write-Erase

In dynamic write-erase operation, a positive erase pulse train is applied continuously to the backing electrode and the duty cycle adjusted to give the desired display persistence. In addition, the writing gun or guns are used to continuously update the decaying display information.

In this mode of operation, both writing gun drive and sweep speed must be interfaced with the erase duty cycle to provide the desired display persistence and brightness. Information to permit evaluation of the most suitable DST for a given display application is available from the DST data sheets and from direct communication with the manufacturer.

The display system designer, given control of erase duty cycle as well as the usual control of writing gun drive, has a wide range of persistence available for a variety of end-use display applications.

DST Application

Persistence Vs. Erase Duty Cycle

Display persistence during dynamic write-erase may be varied by adjusting the erase train duty cycle. The duty cycle required to obtain a given persistence may be closely determined from the expression:

$$\text{duty cycle} = \frac{\text{erase time}}{\text{persistence}}$$

where erase time is the single pulse erase time of the DST (obtained from the DST Data Sheet); persistence is the desired decay time of the display from equilibrium brightness to 10 per cent of equilibrium; and duty cycle is the erase pulse width divided by erase train period. This expression is sufficiently accurate for use in practical DST applications for persistences from about 0.2 second to 7 seconds. For longer persistences it is necessary to take into account the effect of ion landing on the storage surface by increasing the erase train amplitude by 10 to 20 per cent.

Figure 9 illustrates the relationship between brightness decay and time for a typical DST whose erase amplitude is adjusted to equal storage surface cutoff.

Note that some 90 per cent of the brightness decay occurs in about the first half of the total time, while the last 10 per cent decays in the remaining half. This non-linear response is usually inconvenient in dynamic displays as it means that approximately half the assigned erase period (per-

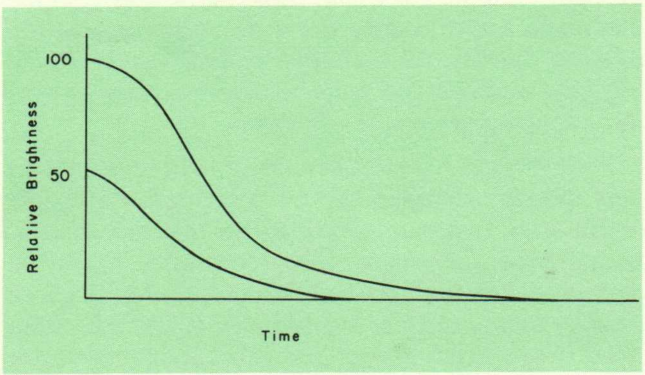

FIGURE 9. Brightness decay with time, dynamic erasure.

sistence) is taken up erasing very low light level information; the display, as just noted, having erased to about 10 per cent in the first half of the time. This is often overcome in practical dynamic displays by operating the DST with the erase pulse amplitude adjusted some 20 per cent beyond the cutoff value, forcing the last 10 per cent of the decaying information beyond cutoff. The useful persistence under this over-erasing condition is approximately half that obtained with the erase train amplitude equal to cutoff and has the advantage that the display decay is more nearly linear with time. This is illustrated in Figure 10.

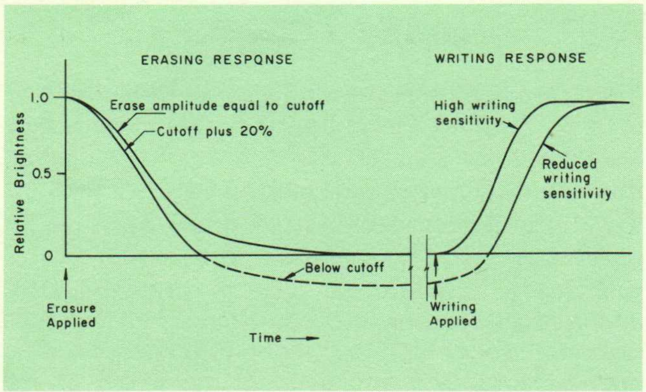

FIGURE 10. Dynamic erasure and writing response as a function of erase train amplitude; erase train duty cycle held constant.

The principal disadvantage of over-erasing in this manner to improve the decay linearity is a reduction in writing sensitivity on infrequently-written display areas. This sensitivity reduction occurs because areas not frequently written upon erase very nearly to the full range of erase amplitude— that is, some 20 per cent into cutoff. Areas frequently written upon, on the other hand, erase only to cutoff. The net result is that the frequently written-upon areas have greater writing sensitivity and respond more readily to subsequent re-writing. It is seen, then, that over-erasing to improve persistence linearity is a compromise between linearity and writing sensitivity.

Erase Pulse Shape

During dynamic erasure with rectangular erase pulses, portions of the display which are written to less than equilibrium brightness decay to cutoff at a different rate than portions written fully to equilibrium. All areas can be made to decay to cutoff more nearly in the same time by using triangular or trapezoidal-shaped erase pulses.

Erase Train Amplitude

The value of erase pulse amplitude required to erase to a given brightness level is dependent, in part, on duty cycle. Long persistence displays using low erase duty cycles require higher erase amplitude to achieve cutoff than do short persistence displays. The difference in amplitude, as mentioned earlier, is of the order of 10 to 20 per cent and should be programmed into the display circuitry if variable or adjustable persistence is required of the display. Failure to provide the additional amplitude for the longer persistence displays will permit the display brightness to slowly build up between successive scans. Failure to reduce this additional amplitude during short persistence operation will lead to a reduction in writing sensitivity while in the short persistence mode.

It may seem desirable in some applications to hold the erase duty cycle constant and permit the operator to vary persistence over a broad range by adjusting only erase pulse amplitude. Although persistence can be varied in this manner, it generally proves unsatisfactory because of the large change in persistence that occurs for small changes in erase amplitude (see Figure 11), and because it compromises writing sensitivity. The compromise occurs because the high erase amplitude that would be necessary to achieve short persistence causes infrequently-written areas to erase well into cutoff and substantially reduces the sensitivity of the dielectric surface in those areas for subsequent writing.

No direct damage is likely to occur to the DST by using this technique, provided the tube's electrical ratings are observed, but it is not a recommended procedure in most dynamic applications because of the amplitude stability requirements to maintain a selected persistence, and the unsatisfactory trade-off between persistence and writing sensitivity.

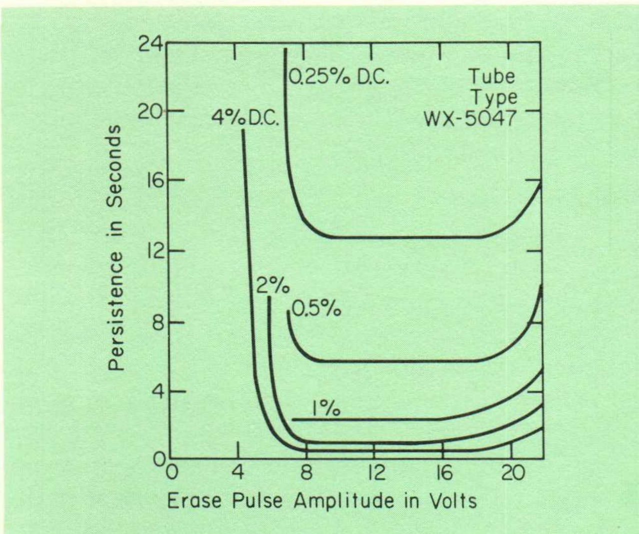

FIGURE 11. **Change in Persistence as a function of Erase Pulse Amplitude. Note the large persistence change that occurs to the left of the knee with small changes in erase amplitude.**

The Overall Transfer Characteristic

In a dynamic display, where writing and erasing inputs are applied continuously, the response of display brightness to a change in write gun control grid voltage may be approximately determined by the output brightness/control grid voltage transfer curves for the tube being used and illustrated in Figure 12. Note that with a given, fixed sweep speed the response of display brightness to a change in write gun grid drive is a function of the erase train duty cycle. A low erase duty cycle, represented by the curve labeled "Erase Duty Cycle #1", permits low values of grid drive to write the display to full brightness; a higher value, such as the one labeled #3, doesn't permit full brightness writing for the same value of grid drive. Under the erase conditions shown in the curves marked #4 and #5, a full saturation brightness display cannot be obtained for any value of grid drive unless writing gun sweep speed is decreased.

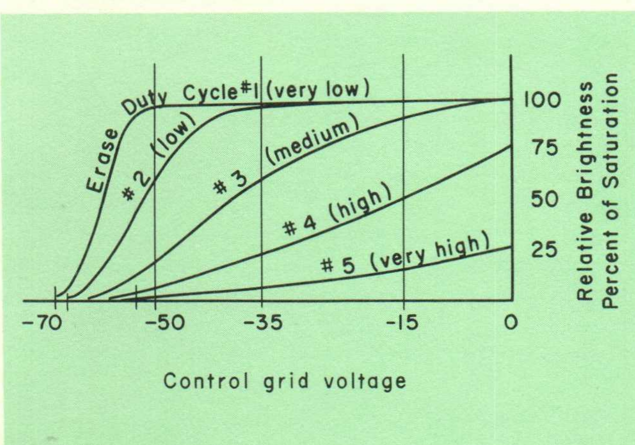

FIGURE 12. **TYPICAL OVERALL TRANSFER CHARACTERISTICS. Display brightness as a function of write gun control grid voltage. Stationary image; with sweep speed held constant; erase amplitude adjusted to 1.0 volt into cutoff at each erase duty cycle.**

Gray Scales

Figure 12 also illustrates the variation in gray scale reproduction that occurs in dynamic write-erase operation with changes in erase duty cycle. Better control of gray scales is obtained at the higher erase rates (Curves 3, 4 & 5), but the dynamic brightness range available at these rates becomes less because of the increase in background brightness (erase background) and the decrease in maximum light output.

Considerable improvement can be obtained in displaying the lower level gray scales if the erase background brightness is eliminated. This is done in practical applications either by employing a DST equipped with an additional grid designed for this purpose. (See High Contrast Display Storage Tube Section, Page 20), or through the use of screen voltage blanking.

Use of the DST in television displays, where good gray scale reproduction is usually desired, requires operation at high erase duty cycles. The high duty cycle offers a two-fold advantage; minimum smear or picture lag on moving images, and operation in the region in Figure 12 (Curves 3 or 4) that favors maximum gray scale reproduction without crushing of the picture highlights.

The term "gray scale" has received a number of different interpretations in the past, both by tube manufacturers and users. Thus, it becomes somewhat difficult to assess the suitability of a particular DST in a specific application unless the manufacturers data sheets support the gray scale specification with qualifying data. Sweep speed, maximum and minimum brightness, writing gun drive, erase conditions, and whether the applied gray scale steps are linearly or logarithmically related to one another are some of the more important parameters that should be examined in any such specification.

Lack of an available, good definition of gray scales in the storage tube industry has probably been the largest factor responsible for the different interpretations. There is a growing tendency toward specifying DST gray scale response in terms of dynamic range and signal-to-disturbance ratio in order to avoid the more common misinterpretations, and there is some liklihood that EIA and MIL Std 1311 will adopt this approach in the near future.

In the interim, the potential storage tube user should as completely as possible specify his gray scale requirements by providing adequate supporting information when querying a DST manufacturer on tube performance.

Equilibrium Brightness vs. Saturation Brightness

As observed in an earlier section, the storage surface of a previously erased, operating DST will slowly rise to equilibrium potential due to the effects of ion generation, provided that during the rise, there are no simultaneous writing or erasing inputs. Under these conditions the display reaches *saturation brightness*, the highest brightness the DST can be expected to produce when operated within its ratings.

During dynamic operation, however, the DST is operated with essentially simultaneous writing and erasing inputs. For any dynamic combination of write beam sweep speed, write gun drive or erase duty cycle, the maximum brightness that can be achieved is termed *equilibrium brightness*. As illustrated in Figure 12, equilibrium brightness may be equal to or less than saturation brightness, depending on the specific value of sweep, drive and erase duty cycle selected.

Brightness Uniformity

The brightness uniformity of the display is controlled primarily by the effectiveness of the viewing section collimation system and the uniformity of writing beam current density with deflection angle. The collimation control(s) should be adjusted to give a flat brightness profile at the display diameter recommended by the data sheet for a given DST type. Slight adjustment of the viewing gun control grid potential during or after collimating usually assists in improving the uniformity.

Writing beam center-to-edge defocusing, and consequent changes in current density as the beam is scanned across the storage grid, leads to variations in brightness uniformity. If dynamic focus correction is not used to reduce this effect, it can in part be compensated for by adjusting the write gun focus control for optimum focus at a point on the storage grid 1/4 to 1/3 along the display screen radius. Final adjustment of write beam focus for best uniformity consistent with the required display resolution should be made on the end-use dynamic display.

Writing Speed

The write gun scanning speed that provides, in a single scan, a specified display brightness at a specified writing gun control grid voltage (drive) is the DST's writing speed. It is often specified at 90 per cent saturation brightness and at the write gun control grid voltage that provides a given display resolution.

The scanning speed is usually described in inches-per-second along the storage grid, wherein a one-inch long linear trace swept in one microsecond moves at a scanning speed of 1×10^6 inches-per-second. A DST sweeping at this speed, if it can write to 90 per cent of equilibrium brightness in a single scan while providing a given resolution, has a writing speed of 1×10^6 inches-per-second.

Writing speed may be called out at other than 90 per cent of equilibrium brightness. The DST manufacturer's data sheet for a given type usually specifies the brightness level or levels at which this parameter is measured.

A convenient and useful description of writing speed is offered by curves of the type illustrated in Figure 13. These curves are based on non-integrating single-scan writing; that is, the response of an unwritten dielectric to a single writing scan. They are very nearly equally applicable if complete erasure of the dielectric to just cutoff is done between successive writing scans or frames. A vertical line extended up from any selected sweep speed on the abscissa describes the brightness response at that sweep speed to the plotted change in write gun control grid voltage. This is useful for describing both the dynamic range and linearity of the DST for non-integrating writing.

Signal Integration

The DST is an integrating device. If a low-level signal from the write gun is written repetitively at the same location on the storage surface, it will, on consecutive hits, integrate to charge levels

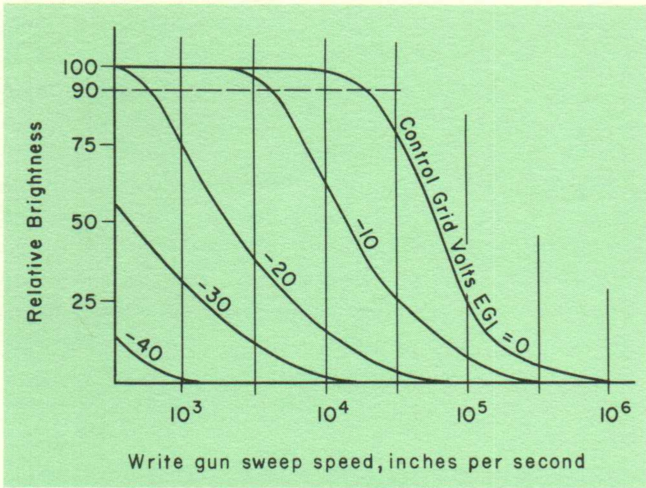

FIGURE 13. Single-scan writing speed, typical performance.

successively closer to equilibrium potential. In the absence of dynamic erasure such a signal will, after several hits, provide a saturation brightness display; in the presence of erasure it will integrate to some intermediate brightness level between saturation and cutoff.

Figure 14 illustrates brightness response as a function of the number of times the input signal repetitively writes on any particular storage surface location. For any fixed signal input conditions, the slope of the curves will be determined by the DST erase characteristics and writing speed. If a specific display system design requires a steep brightness slope (maximum possible brightness for the least number of hits), the display designer should choose a high writing speed, relatively slow erasing DST.

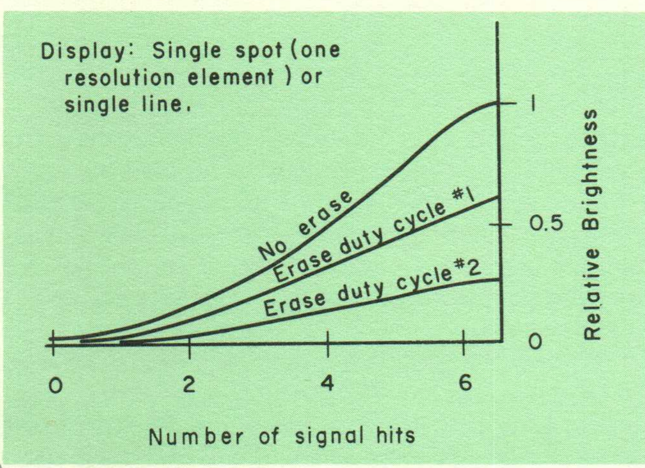

FIGURE 14. Display brightness as a function of the number of times a writing signal is written repetitively on the same location on the storage surface (writing beam current is the same value during each hit).

Resolution

For a fixed sweep system stability, in-use resolution in a given DST design is governed largely by the required display brightness, persistence and sweep speed.

In general, the greater the required brightness the less the resolution where the increased brightness is obtained by, (a) driving the control grid harder for constant erase rate and sweep speed, (b) decreasing the erase rate for constant drive and sweep speed, or (c) decreasing the sweep speed for constant drive and erase rate. Increased resolution at reduced brightness results from (a) a decrease in drive with constant erase rate and sweep speed, (b) an increase in erase rate with constant drive and sweep speed, or (c) an increase in sweep speed with constant drive and erase rate.

Should a given display system requirement specify a high resolution - high brightness display, a DST with short erase time and high writing speed should generally be chosen. Such a choice would be required at high sweep speeds if resolution loss had to be held to a minimum on fine-detail, moving targets (minimum smear).

Focus and Astigmatism Adjustments

Like the CRT, the DST experiences resolution loss as the beam is swept away from the nominal undeflected spot position on the display. This loss is caused largely by spot defocusing due to changing geometry with deflection, and astigmatism—the distortion of the beam cross-section as the beam passes through non-uniform or non-symmetrical electric fields. The magnetically deflected DST, although its center resolution for a given accelerating potential is about the same as that of the electrostatically deflected tube, suffers less center-to-edge resolution loss with deflection.

Best center-to-edge resolution will be obtained with the DST if dynamic correction for defocusing and astigmatism is employed. Focus correction is usually accomplished by applying a voltage to the write gun focus electrode whose amplitude varies in synchronism with the beam deflection waveform. The amplitude and rate of change of the focus correction waveform is a function of the geometry of a given tube type and may be determined from the DST manufacturer's Data Sheets or by direct communication with the DST manufacturer.

Figure 15 illustrates the variation in focus voltage required with horizontal and vertical deflection in a two-writing gun, electrostatically deflected DST of a common family type.

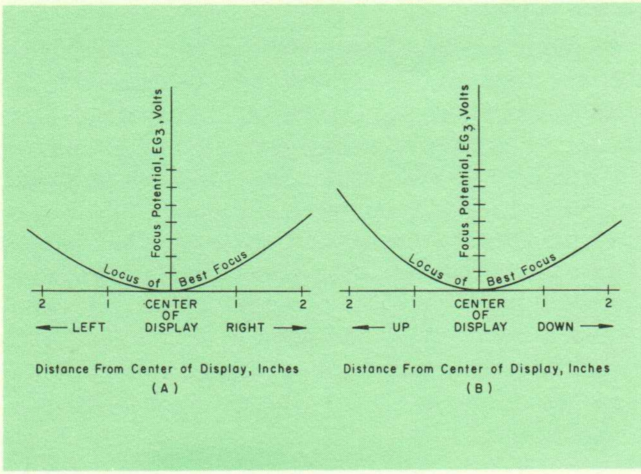

FIGURE 15: Variation of focus voltage to maintain best focus with deflection of beam from display center. A: horizontal deflection; B: vertical deflection.

Dynamic astigmatism correction on electrostatic deflection DST's is accomplished most effectively if the writing guns are especially equipped with separate, internal, astigmatism-control electrodes. If a given type is not so equipped, the mean potential of the deflection plates may be varied dynamically about the potential of the write gun final anode to obtain the least astigmatic spot with deflection. Curves of required correction voltage have the general form shown for focus correction and may be obtained from the DST manufacturer's data sheets or by direct communication with the DST manufacturer.

Extending Viewing Duration

In some applications it may be desirable to increase the gas viewing duration of the DST so that a written and stored display may be viewed for a long period without objectionable background brightness buildup. This is done by operating the flood gun at reduced beam current levels with the result that fewer ion-producing collisions can occur between the electrons in the viewing beam and residual gas molecules.

Reducing the potential of the second anode of the viewing gun (and lowering the collimating system electrode potentials to maintain uniform collimation) is one way of reducing flood beam current and permits effective control of gas viewing duration. Another popular method is periodic interruption of the flood beam current by pulsing either the second anode or the control grid of the flood gun to cutoff at a duty cycle appropriate to the extension in gas viewing duration required. The lower the duty cycle when using this method, the longer the viewing duration. This pulse train should be at some repetition frequency above visual flicker that doesn't produce interference with either the erase train or any applied write gun modulation. Both these methods, because they lower the viewing gun beam current, reduce display brightness and increase the DST's erase time.

Increasing Display Contrast

The residual background brightness occurring in dynamic write/erase displays due to flood electrons landing on the viewing screen during each erase pulse on-time may be reduced or eliminated to improve the contrast of the display. An effective method of doing this is to reduce the viewing screen potential to the point of visual display extinction during the on-time of each erase pulse. On types requiring 10 KV view screen potential, the screen voltage may be dropped to about 2 KV, the stopping potential of the aluminum backing film on the viewing screen. To be effective, the viewing screen negative pulse train must be in synchronism with the erase train and have rise and fall times somewhat less abrupt than those of the erase train.

Another effective method of preventing the flood electrons from reaching the viewing screen during erase pulse on-time is use of a DST with a grid installed for this purpose between view screen and storage mesh. This grid requires a negative pulse train of about 70 to 80 volts to blank the screen during erase. This pulse train must also be in synchronism with the erase train and have rise and fall times less abrupt than the erase pulses. In this type of DST (See High Contrast Display Storage Tube Section, Page 20), the viewing screen potential remains fixed at its normal d.c. operating level unless varied manually for brightness control.

With both of these methods of contrast improvement the erase time of the tube is decreased for a given storage dielectric, permitting display of fast-moving targets with a minimum of smear. Both methods reduce display brightness by an amount proportional to the duty cycle of the negative pulse train.

Improving DST Performance

For best performance and maximum display stability the DST should be operated from regulated power supplies.

Of particular importance is the regulation of the flood gun heaters, the storage grid voltage, and all voltages supplied to the write gun electrodes. The viewing screen, however, should be supplied from a high impedance, poorly regulated source to reduce personnel hazard. This is often done by inserting a one megohm resistor in series with the viewing screen lead back at and within the viewing screen power supply.

On electrostatic deflection types the output impedance of the deflection amplifiers should be kept as low as practicable consistent with good amplifier design. This should be done to prevent electrons which are picked up by the deflection plates from producing a back-bias on the plates with resultant undesirable deflection errors in the displayed information.

On electromagnetic deflection types the deflection coils should be housed in an enclosure that has sufficient magnetic shielding material on the end facing the viewing screen that the deflection fields cannot influence the flood gun electron beam.

When operated at very low beam currents, such as might be done when operating a high writing speed DST at low sweep speeds, the writing gun may show a tendency to exhibit beam current drift. This can be detected after the normal gun warm-up time as a slow change in display brightness with time. It can best be compensated for externally by detecting the change in beam or cathode current, amplifying this change and then applying this correction signal to the control grid in such a polarity as to oppose the change. This is done in high quality CRT displays when the beam current used for a given display is a small proportion of the total current available and where the output brightness for a given drive must be held substantially constant with time.

Many DST's are supplied with a magnetic shield which is bonded to the tube envelope with a resilient potting compound to help protect against damage from shock and vibration. If the shield on the DST chosen for a particular display application isn't normally equipped with mounting feet or ears, it should be mounted to the end-use equipment by bracelet-type padded split-clamps or equivalent. Shock mounts should be used between the clamps and the mounting bed where necessary to limit vibration and shock inputs to the tube to the values specified in the DST data sheet. Clamping to the DST shield should be done only at the points recommended by the DST manufacturer.

An unshielded DST should be mounted within a magnetic shield when installed in the equipment in which it is to be operated. The tube may be held in place in the shield by suitable padding which limits the vibration and shock inputs to the tube to the values specified in the data sheet for that type.

Factory-collimated DST's are available to simplify tube setup in the field and in original equipment. These tubes have voltage-divider networks potted either in the tube base or between magnetic shield and tube envelope which are proportioned to supply the proper voltages to the collimating electrodes. The end-user's equipment, besides providing the other normal tube operating voltages, need supply only one each regulated positive and negative input voltage to the precollimation network to obtain a properly collimated flood display. The precollimation is done at the DST manufacturer's plant prior to tube shipment and helps ensure a properly collimated flood gun display when the tube is installed in the end-user's display system.

Precollimated tubes are recommended whenever the end-use requires DST replacement and setup in a minimum of time or when misadjustment of the tube cannot be tolerated. Where skilled personnel or ample setup time are available, better overall display system performance can usually be obtained with a non-precollimated DST, the experienced installer being able to adjust the display taking into account any system to system variations in voltages supplied to the tube.

Brightness Control

Display brightness for a given writing and erasing rate may be varied by altering the voltage supplied to the viewing screen. This is illustrated in Figure 16.

In the conventional (non-high contrast) DST the viewing screen potential has an effect on the operating characteristics of the storage surface, wherein a reduction in viewing screen potential decreases the dielectric surface cutoff range for a given storage grid erase pulse input. If close control of persistence is desired concurrent with varying the screen potential for brightness control, the erase pulse amplitude should be varied slightly simultaneous with any alteration of applied viewing screen potential. Alternatively, a DST employing an additional grid between the storage grid and view screen could be utilized, this additional grid isolating the storage grid from any effects of changes in viewing screen potential (see High Contrast Display Storage Tube Section, Page 20).

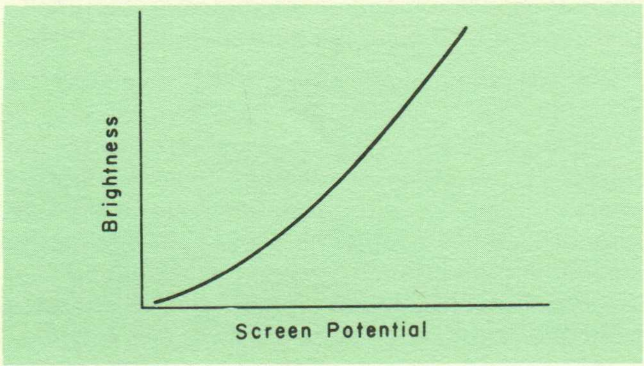

FIGURE 16. Display brightness as a function of Viewing Screen applied potential.

Precautions

Effective control of display brightness can be obtained by adjustment of the DST viewing screen potential. One note of caution, however; display brightness is a function both of viewing screen potential and write gun drive. Maximum rated display brightness can be obtained only with the viewing screen operated at its rated voltage. At reduced viewing screen voltages, no attempt should be made with write gun drive to obtain display brightness higher than that shown to be available in the Brightness/Screen Voltage Curve for the tube in use. To do so may result in damage to the storage dielectric. In the event that an operating DST is observed to be overwriting at a given grid drive and viewing screen voltage, reduction of the viewing screen voltage will *not* protect the storage dielectric from damage even though the display brightness is reduced. Damage to the dielectric can be prevented only by control of electron beam current from the writing gun. It is recommended that the initial setup of any new display or different sweep speed be made with the DST operating at rated viewing screen voltage; once the writing gun control grid is adjusted to a level below overwriting, the viewing screen voltage may then be reduced as required to give a comfortable display brightness.

Magnetic Field Influence

Because the electrons from the flood gun are moving toward the storage grid at a relatively low velocity, they are quite susceptible to undesired deflection from nearby magnetic fields. The magnetic shield with which many DST's are equipped permits a good quality display in the average electronics system, but caution should be observed in mounting the DST close to transformers, blower motors, and meter movements. The strong magnetic fields produced by these devices may not be attenuated sufficiently by the magnetic shield to avoid display distortion. Particular caution should be observed in mounting such field-producing components near the unshielded DST faceplate.

DST's should never be stored near magnetrons. The high flux from the magnetron may magnetize the DST's magnetic shield and the few internal parts which are made of magnetic materials and distort the display.

A magnetized DST can generally be identified by the asymmetrical brightness uniformity it exhibits when operating. Such a tube can usually be degaussed, however, and should present normal display uniformity afterwards. A suitable degaussing coil for seven-inch diameter and smaller DST's would be 800 to 850 turns of AWG 20 Formvar wire, space-wound on a 9-inch mandrel. See Figure 17.

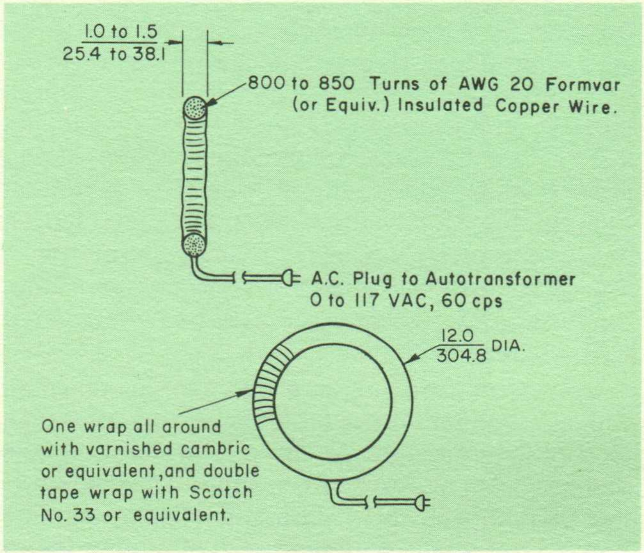

FIGURE 17: Degaussing coil suitable for degaussing magnetized 7 inch and smaller DSTs.

The mains voltage, 117 vac, 60 cps, should be applied to the coil and the DST passed slowly back and forth through it, particular attention being given the forward (large) end of the tube. The tube should be taken slowly from the coil and moved several feet away before removing power from the coil to avoid re-magnetizing the shield or internal parts if the coil current were interrupted at an a.c. cycle peak.

Alternatively, and this is preferred, the coil may be operated from the mains through an adjustable auto-transformer and both the application and removal of coil power may be done gradually. If this is done, the DST is left in the coil after degaussing and the coil power slowly decreased by adjustment of the auto-transformer until the voltage applied to the coil falls to zero. The DST may then be removed. The coil described in Figure 17 should be left off when not in use to avoid overheating.

Magnetic shields must be handled carefully to avoid impairing their shielding effectiveness. They should not be struck or bent, or worked by drilling or sawing.

Handling Precautions,

The DST should be handled carefully to reduce the risk of personnel injury. Never strike or scratch any portion of the glass envelope or the exposed electrode connectors. It is good practice to wear safety glasses whenever handling an unboxed DST. A sturdy, transparent facemask, designed to protect the wearer's eyes, face and neck is preferred and recommended whenever handling and installing DST's. These tubes are evacuated to a very high vacuum in order to achieve long gas viewing duration and can cause injury from flying glass particles if caused to implode through mishandling.

Cathode Life

To ensure long cathode life, the writing gun control grid in the DST should not be driven positive with respect to the cathode. Some type of protective circuit is recommended in the system in which the tube is used to ensure that positive grid operation cannot occur. In most applications a high surge-current semi-conductor diode tied from control grid to cathode will provide adequate protection, limiting positive grid excursions to approximately the forward voltage drop across the diode. The diode's anode should be tied to the control grid, its cathode to the write gun cathode. A fast turn-on diode having low capacitance is preferred.

Storage Surface Care

The DST storage surface is more susceptible to bombardment damage than the usual CRT phosphor and should be handled carefully. In order to prevent damage to the dielectric, no more write gun drive than is necessary to write to the required brightness at a given sweep speed should be used. A high-intensity focused spot should not be allowed to remain undeflected on the display. In applications requiring operation at several sweep speeds, the writing gun control grid bias or drive should be reduced closer to cutoff whenever operating at the lower sweep speeds to reduce the liklihood of dielectric damage.

If the DST is used in oscilloscope applications, it is advisable to have the control grid drive circuitry coupled to the time base selector in such a manner that the grid voltage is automatically reduced toward cutoff whenever a slower sweep speed is selected. With such a system, the drive will be increased when a higher sweep speed is chosen, tending to make the display brightness more nearly constant with sweep speed. Manual override control of bias might also be provided to permit the operator to optimize the brightness at any given sweep speed.

When designing a DST display system, provision should be made to ensure that the flood gun is operating and providing a properly collimated display before the write beam is allowed to land on the storage dielectric. At system turn-off, the writing beam should be turned off first and the flood gun last. These precautions will prevent excessive charge buildup across the storage dielectric with the possibility of dielectric breakdown.

Contrast Enhancement

Due to the high reflectivity of phosphors used in storage tubes, some form of contrast enhancement may be desirable when the tube is operated under high ambient light conditions (such as sunlight). Westinghouse has achieved contrast enhancement through a new black-face storage tube. This tube attenuates the ambient light both before and after reflection from the phosphor, thereby reducing it by a factor equal to the square of the transmission of the attenuator. The DST luminance, however, is decreased only by a factor equal to the transmission of the attenuator. The result is a high display luminance against a much less intense background luminance. This is contrast enhancement.

Westinghouse

Measurement of Contrast Enhancement

There are many methods of measuring the degree of contrast enhancement, but the following parameters need to be known: the DST display luminance, the background luminance and the effect of the two considered together, which is called contrast ratio. Expressed in db, contrast ratio is defined as:

Eq. 1) **Contrast Ratio (CR)** $= 20 \log_{10} \frac{L_1 + L_2}{L_2}$

where:

L_1 = **the luminance of the DST display at saturation, with zero ambient illumination on the face of the tube.**

L_2 = **the luminance of the DST due to the ambient illumination on the face of the tube with the DST erased to cutoff.**

In a practical measurement, the ambient illumination is directed at the DST face at a 45° angle of incidence. The measurements are made with a Spectra brightness meter, the readings being taken perpendicular to the face. The ambient intensity is assumed to be at the DST face.

Range

To illustrate the range of contrast enhancement available, Figure 18 shows a series of curves for various ambient light intensities and various transmission attenuators. The basis for Figure 18 is a high-brightness DST, with an unattenuated luminance of 8000 foot-lamberts. For example, with an ambient intensity of 2000 foot-lamberts at the DST face (curve #1), if we allow the DST luminance to be attenuated to 2000 foot-lamberts (attenuator transmission of 0.25), a maximum contrast ratio of 27.8 db can be achieved.

Ambient Light Levels

Figure 19 shows a series of curves for various ambient light intensities and a single attenuator of 0.20 transmission. The basis for Fig. 19 is several DST's with various levels of unattenuated luminance. For example, with an ambient intensity of 2000 foot-lamberts at the DST face (curve #1) and allowing that the DST luminance is 200 foot-lamberts (unattenuated luminance = 200/0.20 = 1000 foot-lamberts), a maximum contrast ratio of 13.4 db can be achieved.

Figure 18 and Figure 19 demonstrate the flexibility of the Westinghouse method of contrast enhancement.

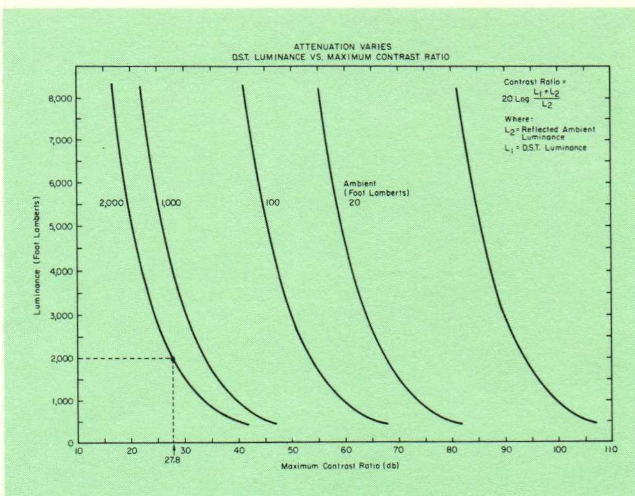

FIGURE 18. Attenuation varies - DST luminance vs maximum contrast ratio.

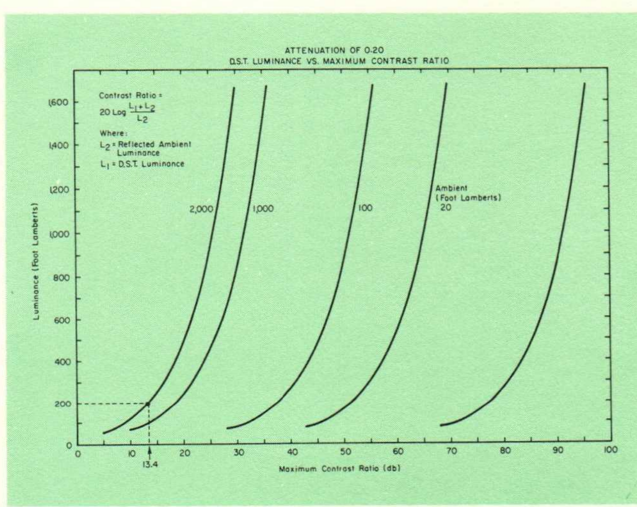

FIGURE 19. Attenuation of 0.20 - DST luminance vs maximum contrast ratio.

High Contrast Display Storage Tubes

One of the less desirable characteristics of display storage tubes in many applications is the change of background brightness with a change in operational modes. The high-contrast storage tube was developed specifically to eliminate this background brightness. With the elimination of background brightness, the high-contrast storage tube is capable of displaying information at very low light levels thus providing more gray shades than conventional tubes under similar operating conditions. This increase in realizable gray shades and in contrast ratio was obtained while retaining all the storage and integration features of conventional display storage tubes.

Description

The high contrast feature is realized through the use of an additional grid, a suppressor grid, in the viewing section of the tube and applying to this grid a low voltage negative pulse in phase with the erase pulse. This is described in U.S. Patent 3,088,048, by J.W. Ogland et al.

Figure 20 shows the cross section view of a typical conventional single writing gun display storage tube. The right hand portion of the tube contains the writing gun and flood gun. The left hand portion shows from left to right, the viewing screen, the storage grid, and the collector grid. These elements, including the flood gun comprise the viewing section of the tube. Figure 21 compares the viewing section of the conventional tube on the left, to the viewing section of the high contrast tube on the right. The only difference between the two is the presence of the suppressor grid between the viewing screen and the storage grid of the high contrast tube. Typically this suppressor grid is operated at a d.c. level of 25 to 75 volts positive; the high contrast pulse amplitude must be sufficient to drive the suppressor grid slightly negative with respect to the flood gun cathode potential. To achieve zero background brightness, the suppressor pulse width must be no less than width of the erase pulse which is applied to the storage grid. The purpose of this negative pulse is to prevent flood gun electrons from reaching the viewing screen during erase pulse on-time. When viewing conventional storage tubes, the observer's eye integrates the brief flashes of light caused by these flood electrons to an average level commonly referred to as background brightness.

Characteristics

The operating characteristics of the high contrast tube, persistence, erase time and writing speed are similar to those of conventional display storage tubes.

Persistence

When dynamic control of persistence is desired a positive pulse train is applied to the storage grid so that flood electrons land on the dielectric surface and uniformly charge it toward cut-off. Writing gun electrons simultaneously land on the dielectric in proportion to the modulation on the control grid. The resultant display persistence is a direct function of erase pulse duty cycle and amplitude. The suppressor pulse train applied to high contrast tubes does not effect the persis-

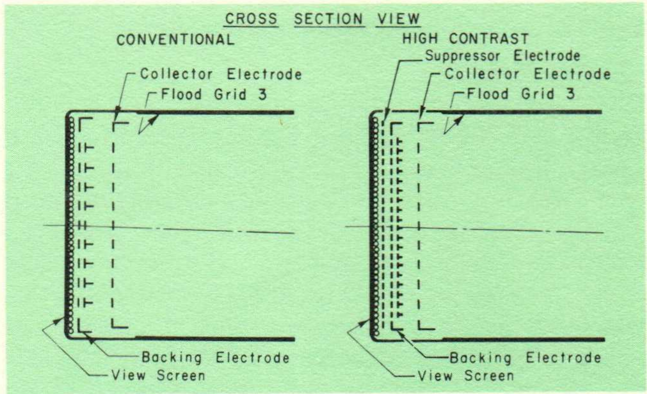

FIGURE 21: Comparison of viewing section of conventional vs high contrast DSTs.

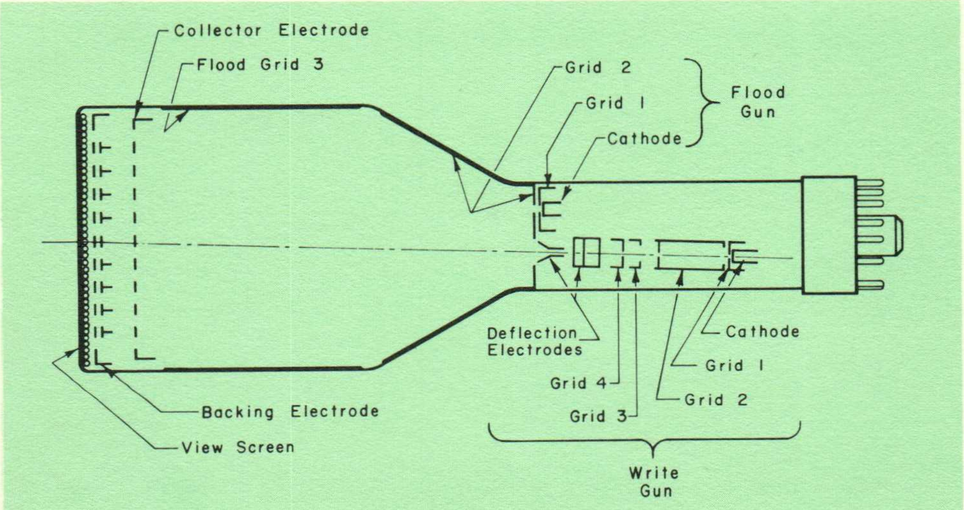

FIGURE 20: Cross-section view - typical single writing gun DST.

tence. Figure 22 shows a plot of erase pulse duty cycle versus persistence for a typical display storage tube. The persistence as shown on the graph is very nearly that of erase time divided by erase pulse duty cycle. Here the erase time is defined as the minimum pulse width of a single pulse to erase the display from saturation brightness to cutoff. The difference between calculated and measured values at long persistences and low duty cycles is thought to be due to ion bombardment of the storage surface.

Background brightness, as previously mentioned, is caused by flood electrons striking the phosphor viewing screen during the erase pulse on-time. This background brightness then, is a function of erase pulse duty cycle and is inversely proportional to persistence. Figure 23 shows the relationship of background brightness and persistence to erase pulse duty cycle. There is no background brightness in the high contrast tube when it is used in the high contrast mode.

Contrast Ratio

Since the contrast ratio may be expressed as saturation brightness divided by background brightness, the maximum contrast ratio that can be achieved in conventional storage tubes is dependent upon erase pulse duty cycle. The high contrast tube has a fixed contrast ratio for any erase pulse duty cycle. To illustrate the contrast ratios possible Figure 24 shows a high contrast tube without the suppressor pulse applied, to simulate a conventional storage tube. The bright dots on the bright background are simulated target returns. The erase pulse duty cycle is 1%, giving a persistence of about 1 second. Figure 25 illustrates the effect of the suppressor pulse. Except for the application of the suppressor pulse the setup conditions remained identical. The background brightness in Figure 24 is 16 foot Lamberts, corresponding to 1% of saturation brightness; the background brightness in Figure 25 is equal to ambient, about 3 foot Lamberts. Figure 26 is a simulated radar display, a B sweep scanning from left to right. 20 KC random noise is applied to illustrate the detail contrast ratio of the high contrast tube.

Useable Levels

With the elimination of background brightness, a wider dynamic brightness range is available and thus more useable brightness levels— or gray shades— may be realized than in conventional storage tubes. We can illustrate this by applying a staircase function to the write gun control grid. In Figure 27, eight useable levels are visible. Two additional steps were visible on the tube photographed, but were lost in the process of reproducing the photograph for Figure 27. The difference between each step of the staircase is one volt and the total dynamic range as viewed here is ten volts. The maximum number of useful levels specified for a standard display storage tube is 5, while 4 levels is more commonly specified. The increase in useable brightness levels obtained makes the high contrast tube more attractive for bright television and radar displays.

Specific Characteristics

Thus far only general characteristics of the high contrast tube have been discussed. Now two five

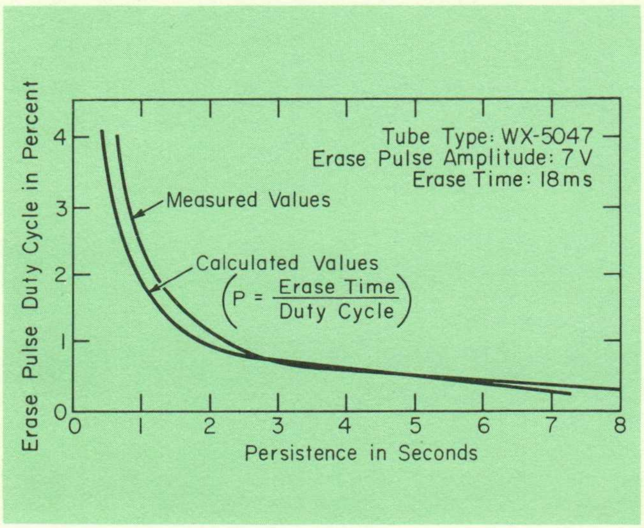

FIGURE 22: Persistence vs erase pulse duty cycle.

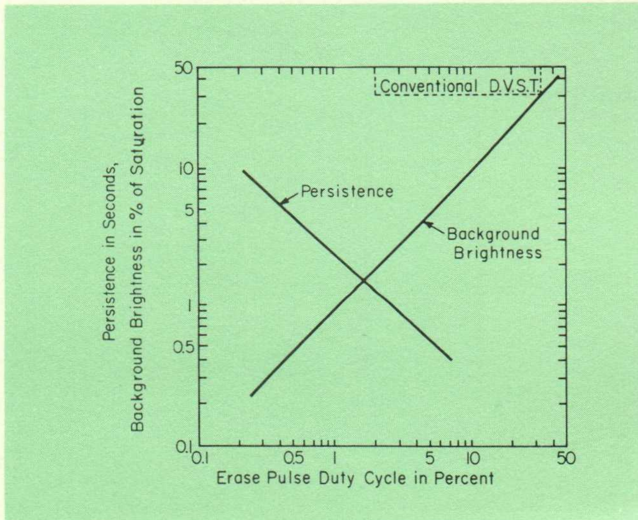

FIGURE 23: Background brightness and persistence vs erase pulse duty cycle.

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inch high contrast tubes, WX-5444 and the WX-4951 will be examined in more detail. The typical erase time for these two tube types is 7 milliseconds minimum. These two tubes are designed for different applications— the WX-5444 being a two writing gun, medium writing speed, low deflection factor tube, and the WX-4951 a high writing speed, single writing gun tube. These tubes are typical of the high contrast family. Other types, in a wide range of sizes and characteristics have shown that the high contrast feature can be incorporated in any standard size tube.

Figure 28 is a graph of persistence versus erase pulse duty cycle for the high contrast WX-5444. It will be noted that the persistence from saturation brightness to zero follows the formula; persistence equals erase time over erase pulse duty cycle, the same expression that was used to describe the persistence characteristic of a conventional tube in Figure 22. The erase time characteristic of this curve is 7.5 milliseconds, the measured erase time was 8 ±1 milliseconds. The relatively fast erase time of high contrast tubes enables the systems designer to use low erase duty cycles to obtain a

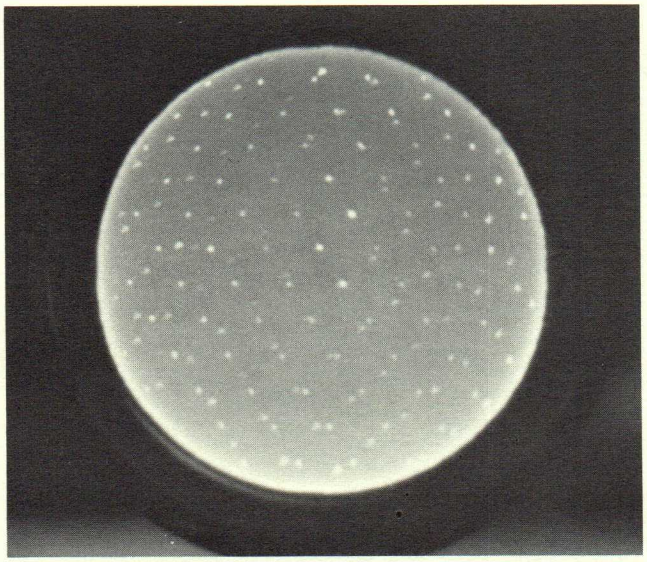


FIGURE 24. Conventional display, no suppressor pulse train applied.

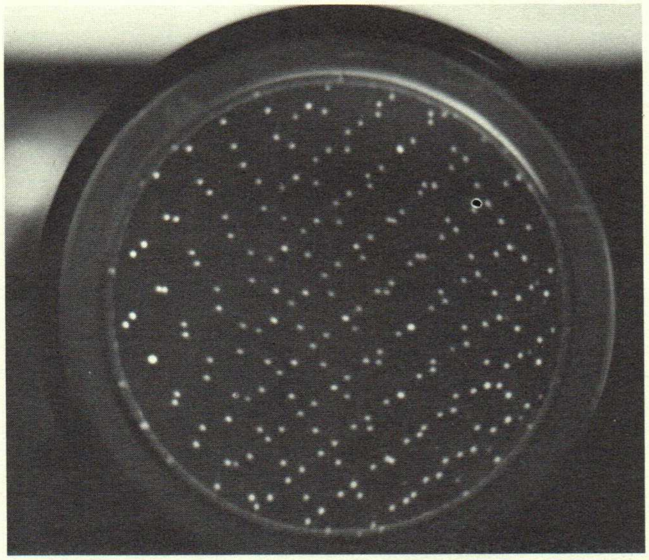


FIGURE 25. High contrast display, suppressor pulse applied.

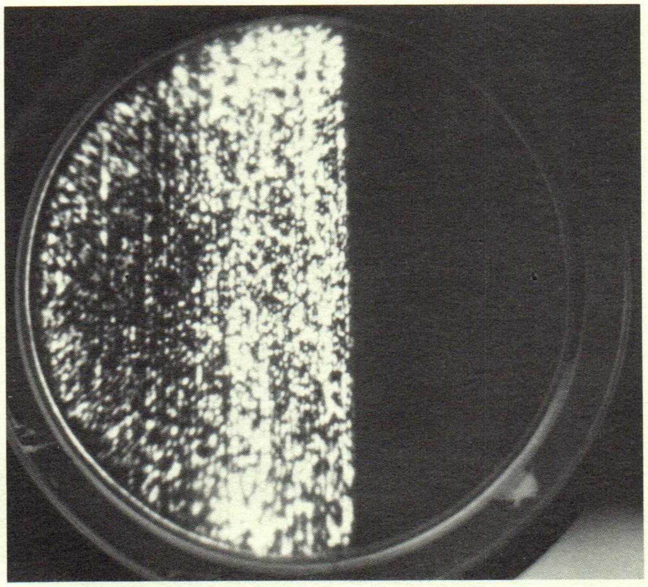


FIGURE 26. High contrast display, radar B-sweep.

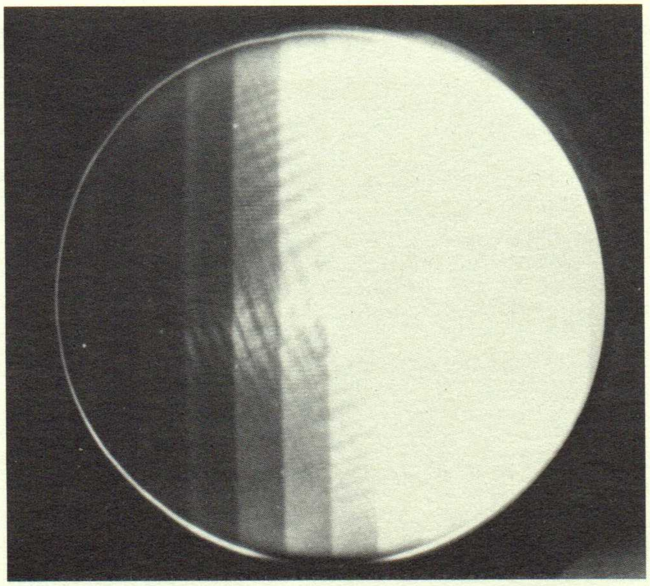


FIGURE 27: Response to a stairstep input signal, high contrast.

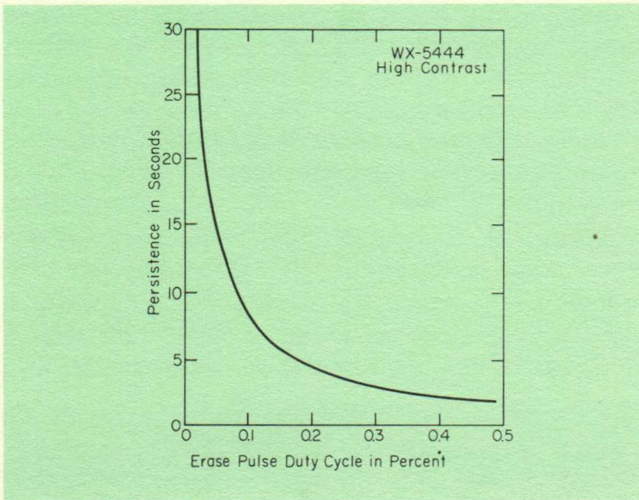


FIGURE 28: Persistence versus erase pulse duty cycle, high contrast.

given persistence. Since information is lost, that is, not visible during the up time of the erase pulse, a low erase duty cycle is desirable.

The same range of writing speeds that can be obtained in the typical non-high contrast storage tube are realized in the high contrast configurations. The writing speeds range from below 5×10^3 inches per second to 1×10^6 inches per second, depending upon the application and tube type chosen.

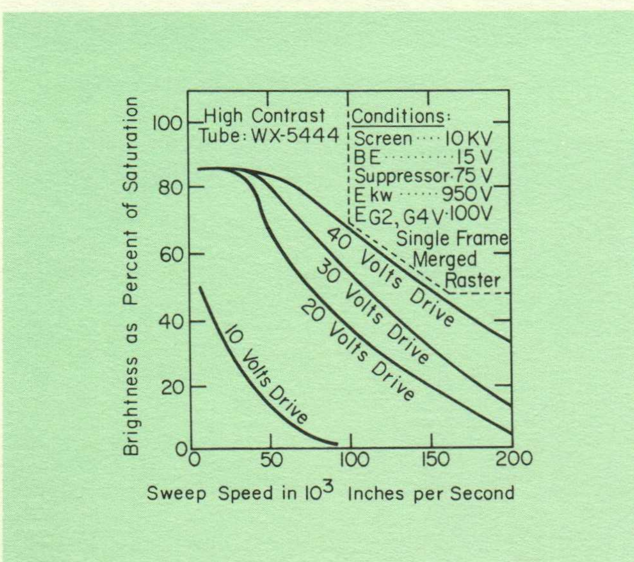


FIGURE 29: Brightness as a function of sweep speed.

The family of curves shown in Figure 29 illustrates the tradeoff between brightness and scanning speed typical of all display storage tubes. The one shown here is the high contrast WX-5444.

The brightness shown in the graph is for one scan only— that is, with no integration. This tube was designed to write to 90% of saturation brightness at 36000 inches per second with 30 volts drive. It will be seen here that the tube will write to about 50% of saturation at 125,000 inches per second.

Figure 30 is a summary of the electrical characteristics of the display storage tubes discussed in this section. The erase time of high contrast tubes is shorter than conventional tubes. They have several more useable brightness levels, and a much higher contrast ratio.

	High Contrast		Non-High Contrast	
Parameter	**WX-5444**	**WX-4951**	**WX-5047**	**WL-7268A**
Erase Time, Seconds	0.009	0.009	0.015	0.025
Usable Levels (Gray Scales)	7	7	4	5
Contrast Ratio	Very High	Very High	10:1	10:1
Brightness	2000	1000	1200	2000
Writing Speed	4×10^4	15×10^4	40×10^4	8×10^4
Maximum Resolution	60	65	90	65
Storage Time, Seconds	30	30	30	30
Screen Voltage, Volts	10,000	10,000	10,000	10,000
Display Diameter, Inches	4	4	4	4

FIGURE 30: Comparison of typical electrical characteristics.

DST Phosphors available from Westinghouse

Choice of the phosphor in a DST is usually based on visual efficiency and color. Largely because of their high visual efficiency and resistance to bombardment damage, P20 and P31 are the phosphors in most common use in DST's. Following is a listing of phosphors available and spectral-energy emission characteristic curves for P4, P20 and P31 phosphors.

PHOSPHORS AVAILABLE

PHOSPHORS AVAILABLE FROM WESTINGHOUSE

PHOSPHOR NUMBER	FLUORESCENT COLOR	PHOSPHORESCENT COLOR	RANGE (1) ANGSTROMS	PEAK(S) ANGSTROMS	CLASS (2)	PERSISTENCE (5) 10%	1%
1	Yellowish-Green	Yellowish-Green	4925 to 5775	5250	Medium	24 mSec.	48 mSec.
2	Yellowish-Green	Yellowish-Green	4350 to 6125	5350	Med. Short	100 μSec.	—
4	White	White	Note (3)	Note (3)	Med. Short	60 μSec.	470 μSec.
5	Blue	Blue	3525 to 5600	4150	Med. Short	26 μSec.	52 μSec.
7	White	Yellowish-Green	4000 to 6500	4400 & 5550	Long	0.3 Sec.	3 Sec.
11	Blue	Blue	4000 to 5500	4600	Med. Short	80 μSec.	—
12	Orange	Orange	5400 to 6800	5900	Long	0.21 Sec.	0.42 Sec.
14	Purplish-Blue	Yellowish-Orange	3900 to 7100	4400 & 6000	Medium	5 mSec.	115 mSec.
15	Green	Green	3850 to 6050	3910 & 5050	Short	2.8 μSec.	—
16	Bluish-Purple (4)	Bluish-Purple (4)	3500 to 4500	3850	Very Short	0.12 μSec.	—
17	White	Yellow	3800 to 6400	4500 & 5560	Long	0.4 Sec.	10.5 Sec.
18	White	White	3250 to 7025	4100 & 5400	Medium	13 mSec.	37 mSec.
19	Orange	Orange	5500 to 6725	5900	Long	0.22 Sec.	0.53 Sec.
20	Yellow-Green	Yellow-Green	4950 to 6725	5600	Med. Short	0.35 mSec.	1 mSec.
24	Green	Green	4325 to 6300	5100	Short	1.5 μSec.	—
25	Orange	Orange	5325 to 7150	6100	Medium	45 mSec.	115 mSec.
26	Orange	Orange	5450 to 6650	5950	Very Long	17 Sec.	190 Sec.
27	Reddish-Orange	Reddish-Orange	5825 to 7150	6310	Medium	27 mSec.	55 mSec.
28	Yellow-Green	Yellow-Green	4650 to 6325	5480	Long	0.6 Sec.	6.8 Sec.
31	Green	Green	4175 to 5975	5225	Med. Short	38 μSec.	250 μSec.
32	Purplish-Blue	Yellowish-Green	3850 to 6550	5540	Long	0.7 Sec.	6 Sec.
33	Orange	Orange	5450 to —	5875	Very Long	2.2 Sec.	15 Sec.
34	Bluish-Green	Yellow-Green	3900 to 6800	5290	Very Long	100 Sec.	—

NOTES

1. Between 10% response points.

2. Classification Key based on time to 10%:
   - Very Long - > 1 Second
   - Long - 100 mSec. to 1 Sec.
   - Medium - 1 to 100 mSec.
   - Med. Short - 10 μSec. to 1 mSec.
   - Short - 1 to 10 μSec.
   - Very Short - < 1 μSec.

3. P4 comes in 3 types:

Type	Range	Peaks
Sulfide	4125 to 6700	4600 & 5600
Silicate-Sulfide	3875 to 7000	4500 & 5400
Silicate	3275 to 7030	4100 & 5400

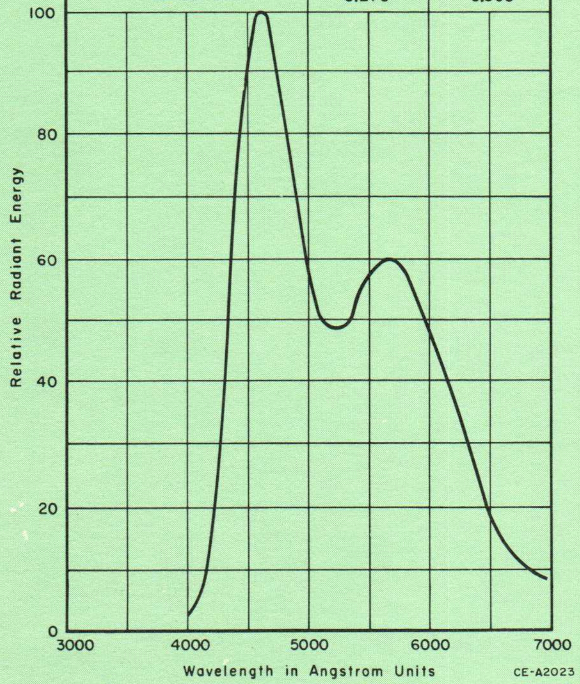
4. Visible Component.

5. Persistence of the phosphor only, independent of display persistence obtained electronically under dynamic write-erase conditions. The dynamic write-erase display for a given DST cannot have shorter persistence than is provided by the phosphor chosen for that tube.

Westinghouse

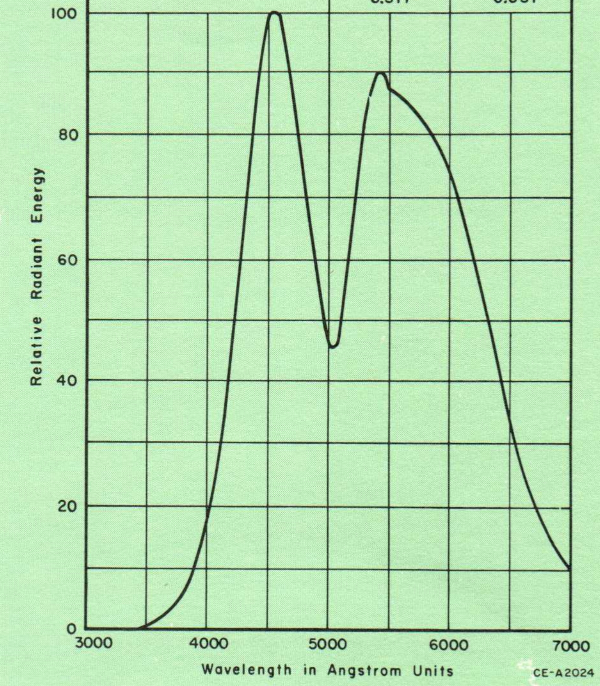
PHOSPHOR P4 - SULFIDE TYPE
SPECTRAL-ENERGY EMISSION CHARACTERISTIC

COLOR	ICI COORDINATES	
	X	Y
White 11000° K +32 M.P.C.D.	0.270	0.300



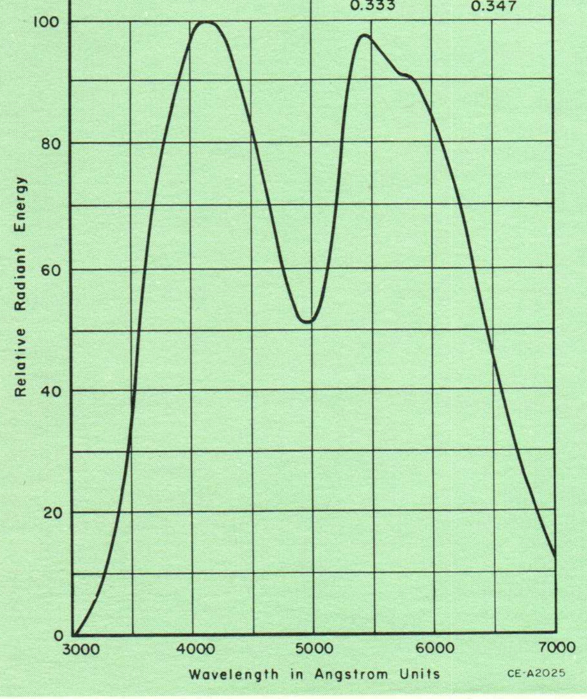
PHOSPHOR P4 SILICATE-SULFIDE TYPE
SPECTRAL-ENERGY EMISSION CHARACTERISTIC

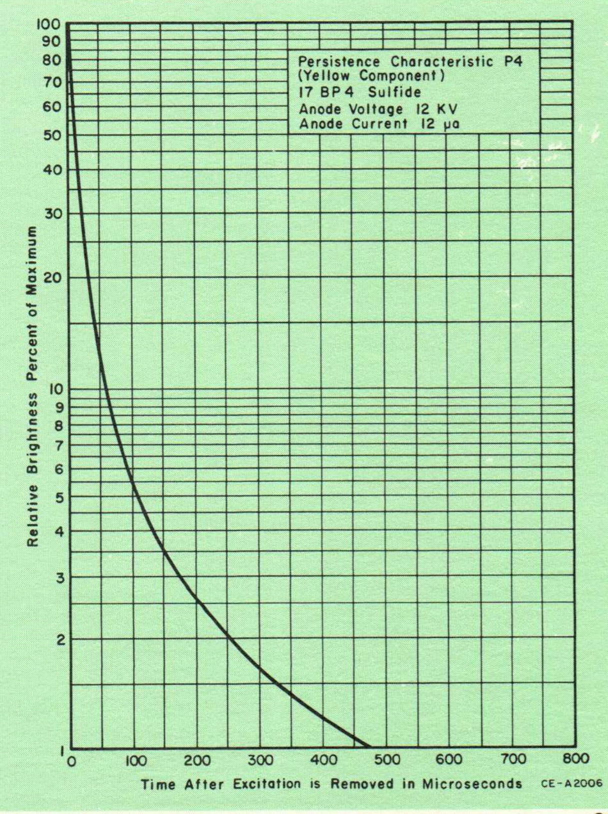
COLOR	ICI COORDINATES	
	X	Y
6300° K	0.317	0.331



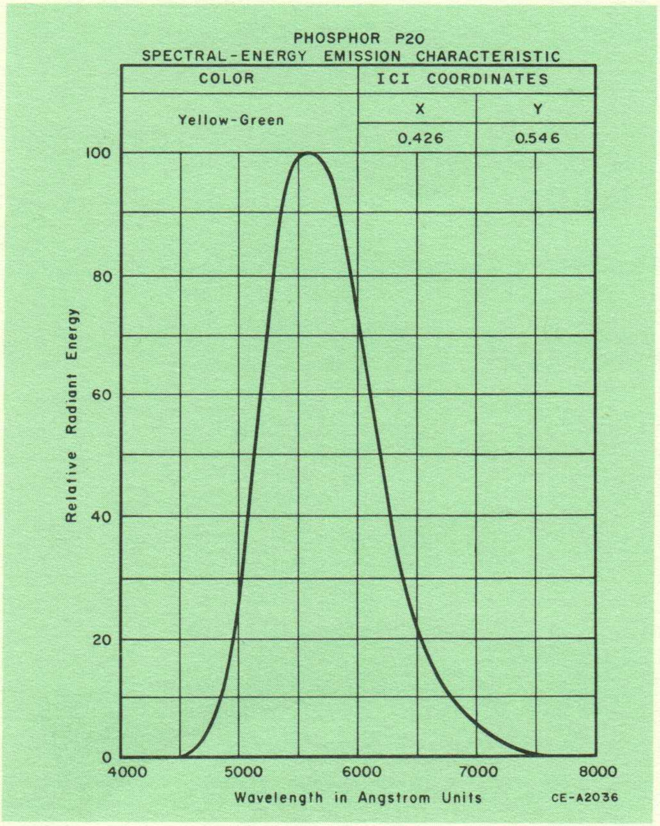
PHOSPHOR P4 - SILICATE TYPE
SPECTRAL-ENERGY EMISSION CHARACTERISTIC

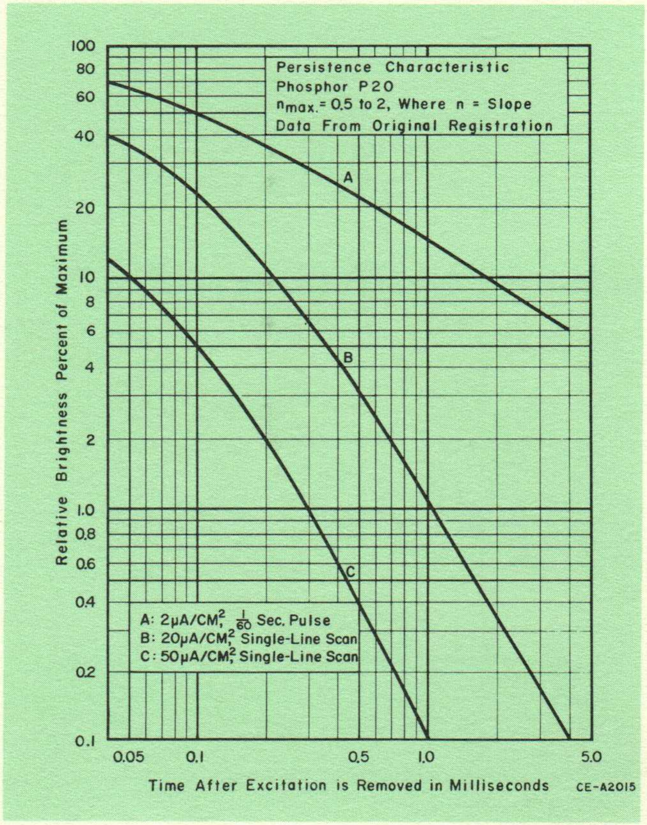
COLOR	ICI COORDINATES	
	X	Y
5500° K	0.333	0.347

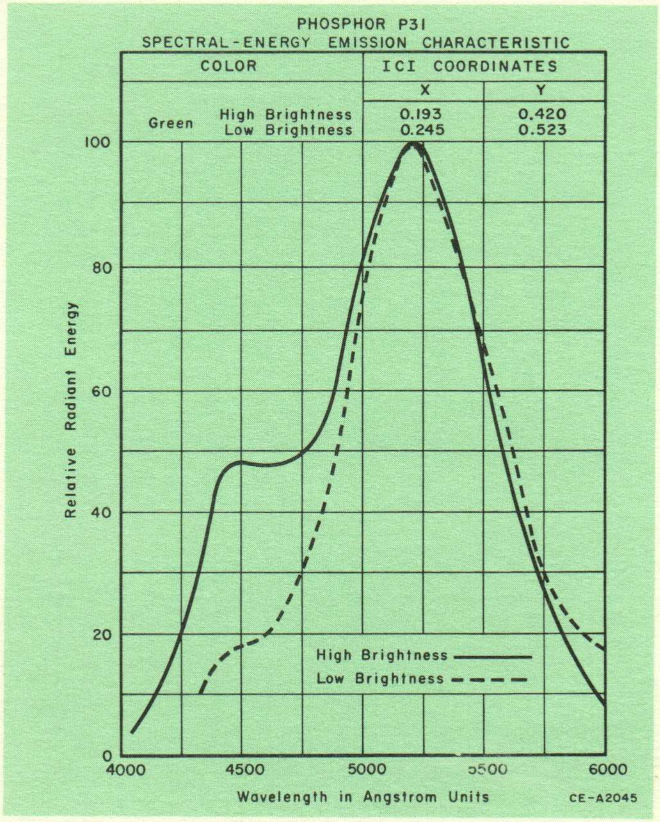


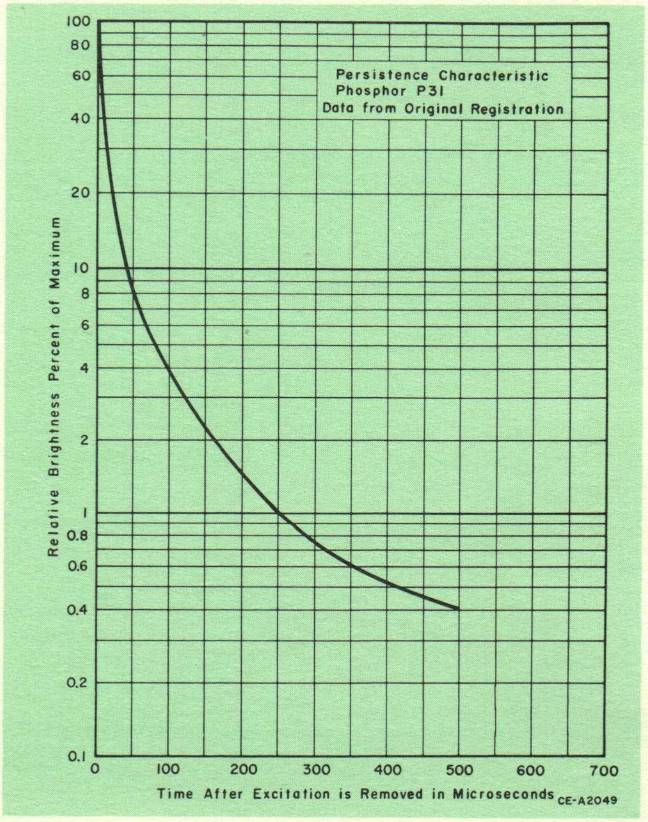


PHOSPHORS AVAILABLE









Westinghouse Electronic Tube Organization

The Westinghouse Electronic Tube Division is one of 68 within the Corporation. The Display Storage Department is one of five within the Division. This Department maintains a research-development staff and a manufacturing engineering staff, as well as a manufacturing organization. Backing up this activity are the resources and in-depth scientific knowledge of the Westinghouse Research Center at Pittsburgh, Pennsylvania.

ORGANIZATION

ENGINEERING

The Display Storage Tube engineering staffs employ some of the finest design and process engineers in the industry. Their skills cover the fields of electrical engineering, physics, chemistry, mechanical engineering and vacuum technology.

MANUFACTURING

The manufacturing organization includes direct first-line supervision, manufacturing engineering, production and inventory control, industrial engineering and facilities engineering. The manufacturing engineering and production control groups are aided by a sophisticated computerized manufacturing control system which gives complete process performance, operator efficiency and material control information.

APPLICATION ENGINEERING

In addition, a staff of application/design engineers has the in-field application knowledge to provide liaison and assure the smooth integration of equipment design considerations with the design and manufacturing capabilities of the Display Storage Tube Department.

RELIABILITY AND QUALITY CONTROL

Development and production of display storage tubes are included in the Reliability and Quality Control Program at Westinghouse Electronic Tube Division. This plant-wide program applies equally to all products produced by the Division. The program is designed to meet all of the requirements of MIL-Q-9858A "Quality Program Requirements" and other industry-accepted Reliability and Quality specifications. Frequent audits by industrial government and prime contractor teams have verified the program. Product reliability levels are specified as needed, and detailed reliability program factors established as required. The awareness of quality and reliability requirements is prevalent throughout all functions in the Division, from early design concepts through careful manufacture of the product, to application and end use. Previous program experience with contracts containing stringent reliability and quality requirements assures that any new requirements can be undertaken and achieved. This overall attitude and approach assures reliability in supplying Display Storage Tubes designed for long life.

The Reliability and Quality Control Department consists of experienced supervisory, engineering and technical personnel. These specialists participate in design reviews, review and control product specifications for quality, assist in preparing processing procedures, develop inspection operations, specify test procedures and equipment, design mechanical and electrical calibration tools and conduct failure analyses. Through this total effort, they help to ensure that proper and effective utilization is made of the equipment, processes, and tests necessary in developing and producing reliable Display Storage Tubes.

The Reliability and Quality Control Department has specific responsibility for Design Review; Incoming Material Control; In-Process Inspection; Final Product Inspection, including environmental and life testing; and Failure Analysis. The Dimensional Standard and Electrical Instrument Lab maintains control over tools, meters, and gages used in the above functions.

A Quality Engineering group plans and monitors the inspection and tests conducted by the above activities. They review specifications, processing procedures, inspection instructions and test procedures and ensure that gages and/or test equipment are available and adequate.

These Engineers also participate in product design review. They assist the design engineer in selecting materials and in the proper application of these materials. When the design is finalized and the part, assembly, tool, etc., is specified, the Specification is again reviewed by Reliability and Quality Control, and, if acceptable, is approved. A failure analysis group prepares detailed analyses on all tube failures that occur. Failure causes are determined and corrective action specified. This information is immediately fed back to the operating groups.

Supporting the above departments is the Chemical-Physical Laboratory, which provides chemical, spectroscopic and microscopic analyses of materials and finished parts.

Special Design Services

The Display Storage Tubes listed in this publication are currently in production or are proven designs. Westinghouse also provides special design services to develop and produce the Display Storage Tube best suited to your system requirements.

Special Tube Design

All new tubes can be custom designed to have the special characteristics which will make the performance of your system unique and provide a competitive edge. This custom design service will be performed in close coordination with your system designers to insure maximum performance and reliability.

Special Characteristics

All Display tubes may be operated at various operating points providing special characteristics often without physical modification to the tube. Characteristics listed in the "Display Storage Tube Quick Reference" chart on pages 38, 39 and 40 were selected to optimize one or more parameters such as storage time, writing speed, resolution, etc. To discuss any special conditions you require, please contact the Westinghouse sales engineers in your area (locations shown on last page).

Modifications

When specific characteristics cannot be obtained from existing designs, special design modifications can be effected. Often these modifications require no major tube redesign, thus minimizing cost and providing a competitive position for your system.

Factory Collimated

A collimating circuit can be selected to match the performance characteristics of each specific tube to facilitate easier set up.

Flying Leads and Connectors

Flying leads and special connectors, as well as standard basing, can be provided.

Environmental

Westinghouse Display Storage tubes are designed for reliable operation in airborne and surface applications requiring rugged protection from shock and vibration.

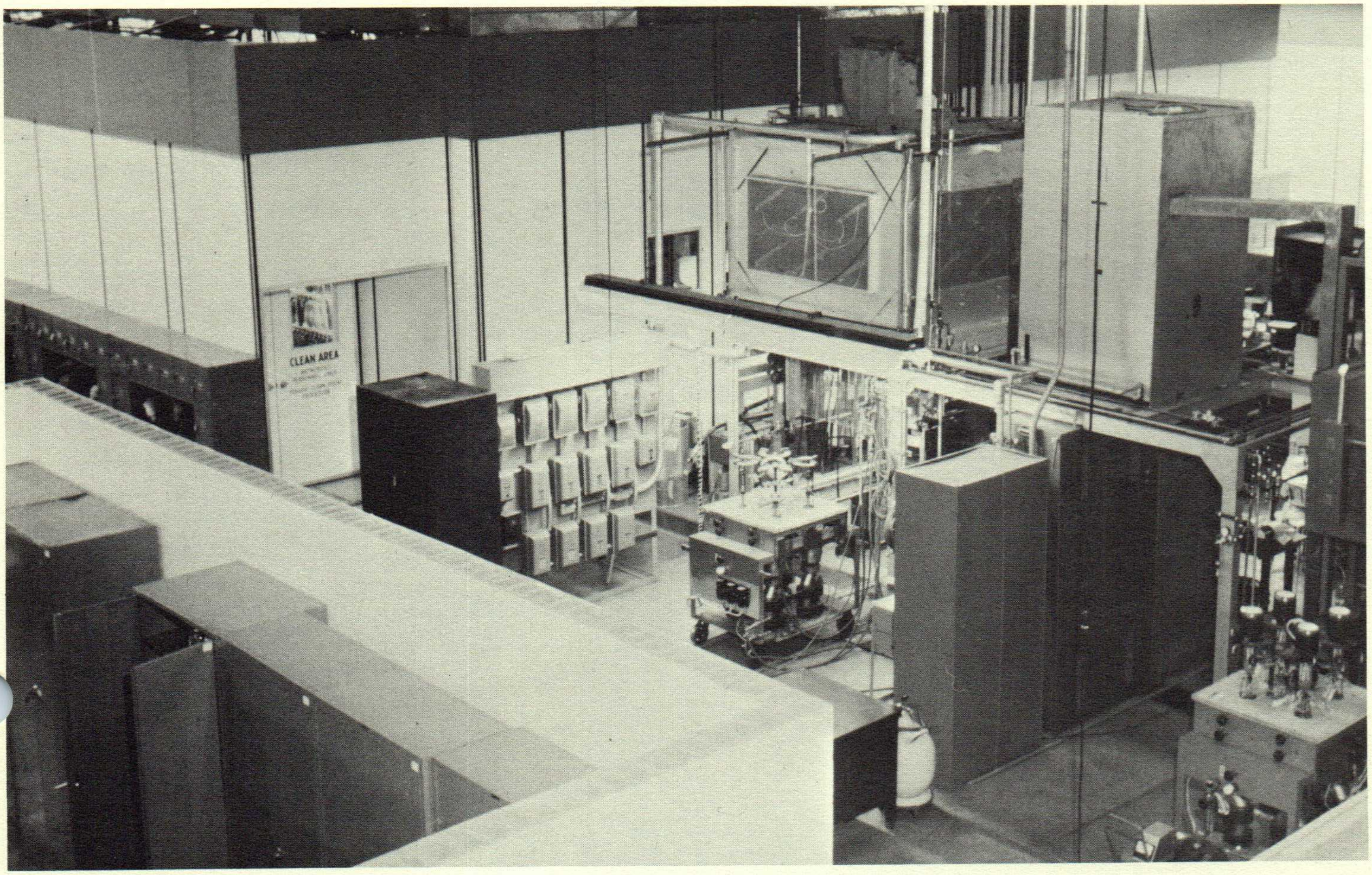
Facilities

Westinghouse Display Storage tubes are designed, developed and manufactured within the Electronic Tube Division plant located 90 miles southwest of Syracuse, New York, immediately adjacent to NYS Route 17.

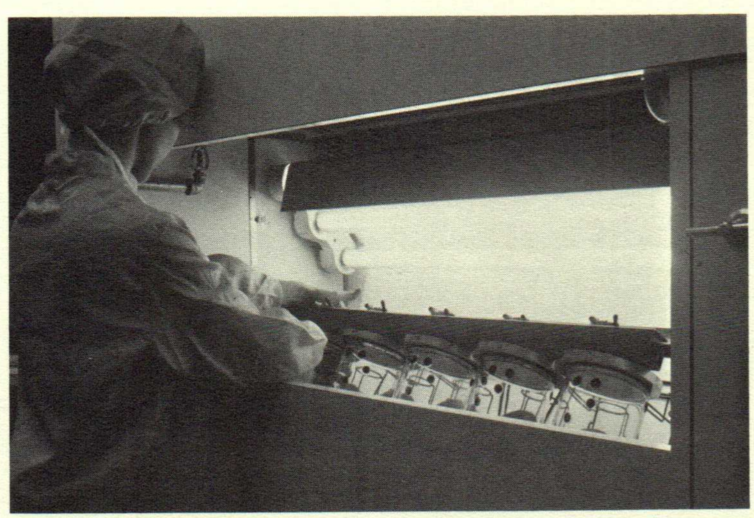
Within this plant, design, development, and manufacturing is also done for TV picture tubes, image camera tubes and devices, I & M cathode ray tubes, power tubes, radiation detectors, vacuum interrupters, and special devices.

The Display Storage Tube department occupies a 25,000 foot area where modern facilities and the latest manufacturing techniques are combined with the skills of highly trained and experienced personnel to maintain Westinghouse leadership with high quality, high performance products.

Westinghouse

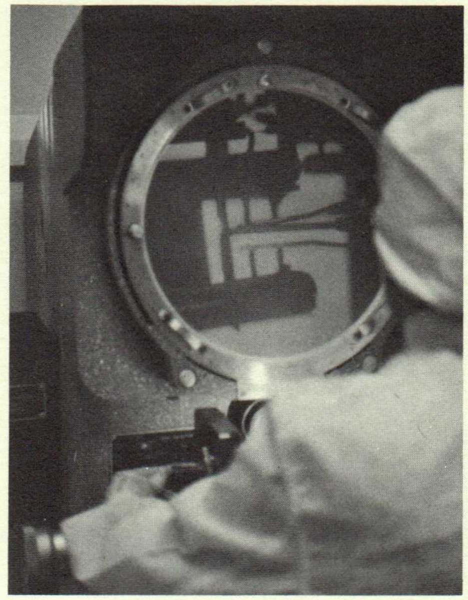


This vertical laminar flow cleanroom houses all mesh operations and sealing of glass envelopes. Outside is an exhaust section which employs ion pumps for better ultimate vacuum in Display Storage tubes.

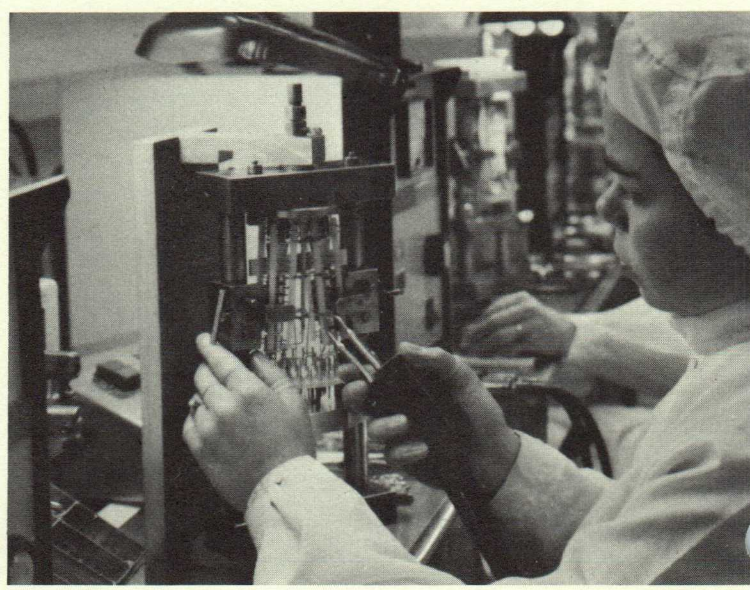


Clean operations make clean tubes. Settling a good screen is done in a horizontal laminar flow room. Good yields of high quality screens result from this care.

High standards are maintained through continuous in-process inspection of precision built gun structures.

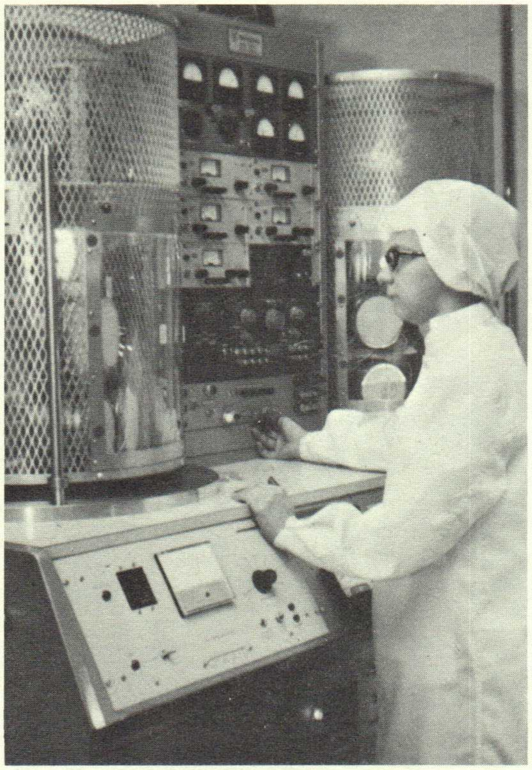


In this horizontal laminar flow room, one of three cleanrooms, high quality screens are prepared under stringent manufacturing and environmental control.

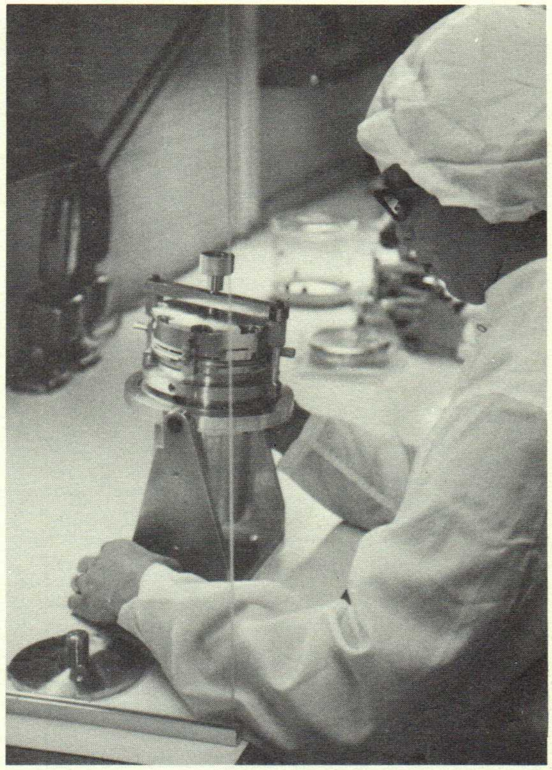


Skilled operators with precision fixturing build quality and reliability into mounts.

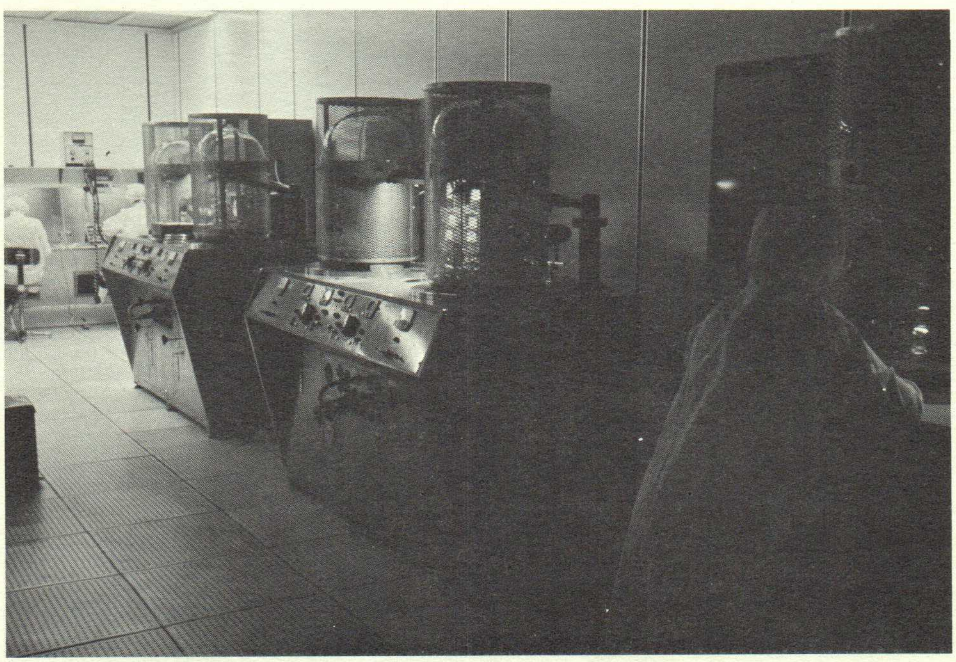
Westinghouse



The screen mesh assembly of each Direct View Storage Tube is thoroughly tested under actual tube operating conditions *prior* to the tube assembly.

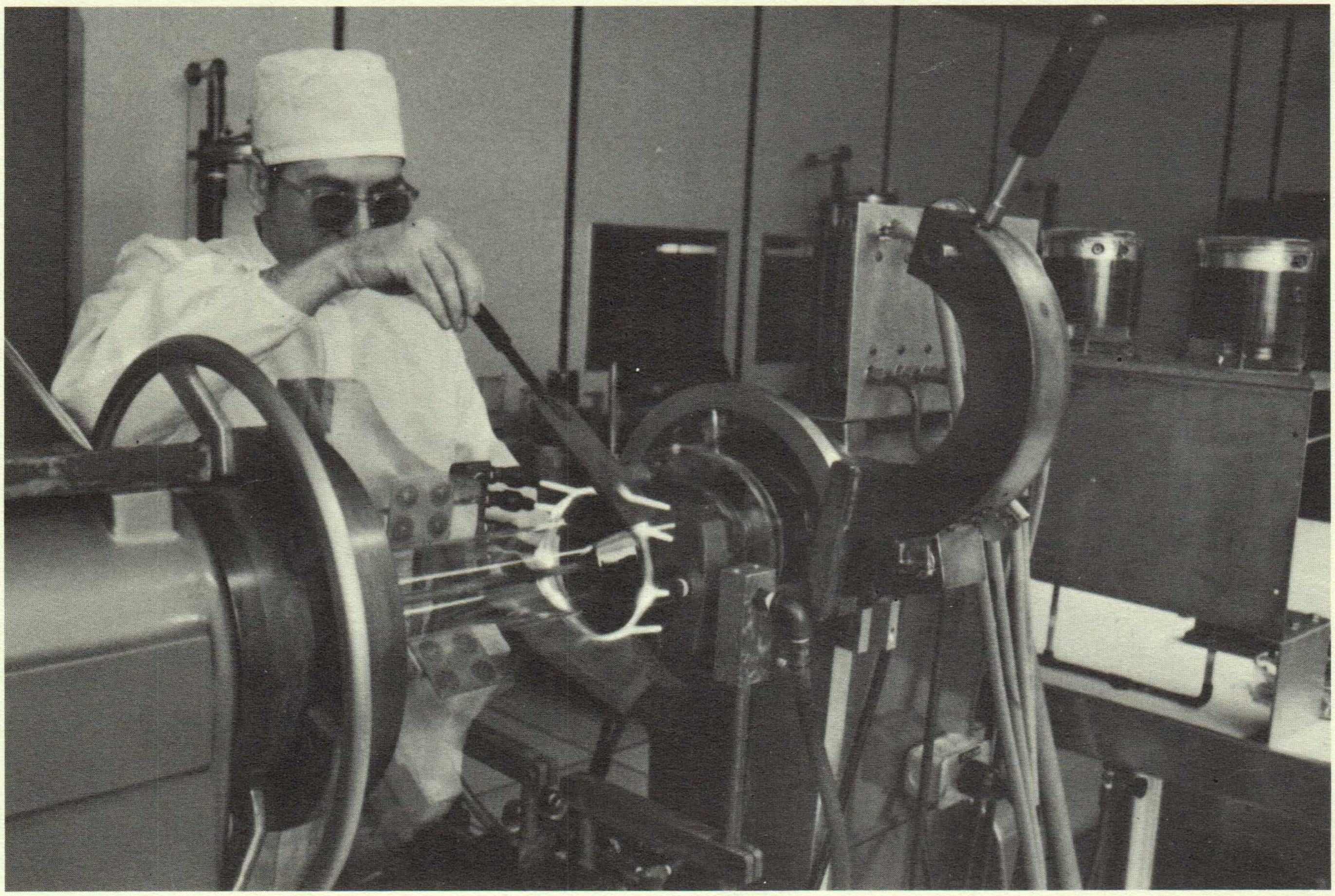


The screened bulb and the mesh are assembled at a clean horizontal-flow bench with unique fixtures used to accomplish the required precision.

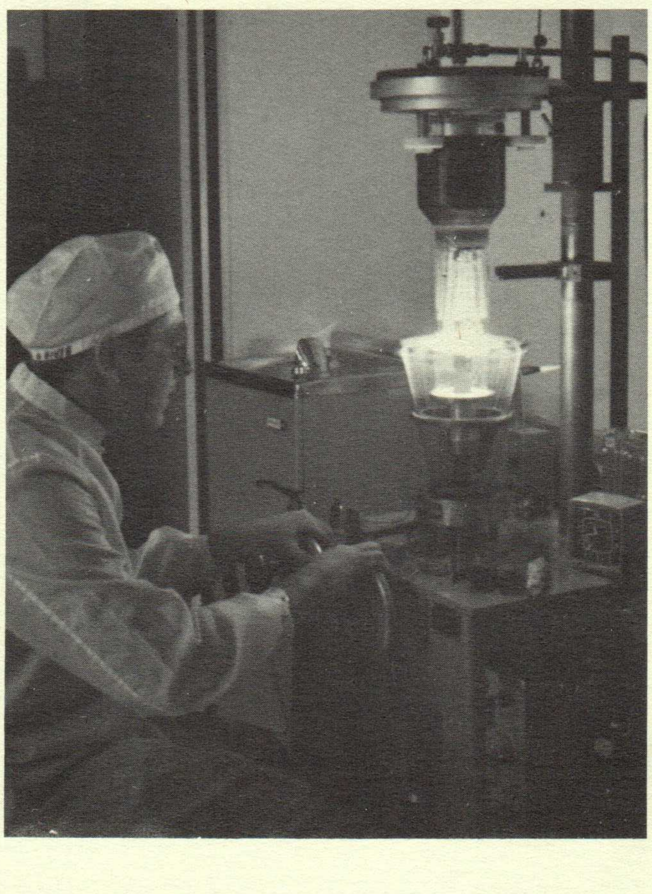


The mesh is the heart of a storage tube. The development of new manufacturing methods produce reliable, precise products. Here, precision evaporation of dielectric on the mesh structure takes place in a vertical laminar flow room to preserve product quality.

Careful monitoring of dielectric parameters assure continuous control in display storage tube production.



Sealing the envelope is done in a vertical laminar flow cleanroom to assure continual cleanliness of assembly throughout all operations.



Final sealing of each tube is precisely controlled.

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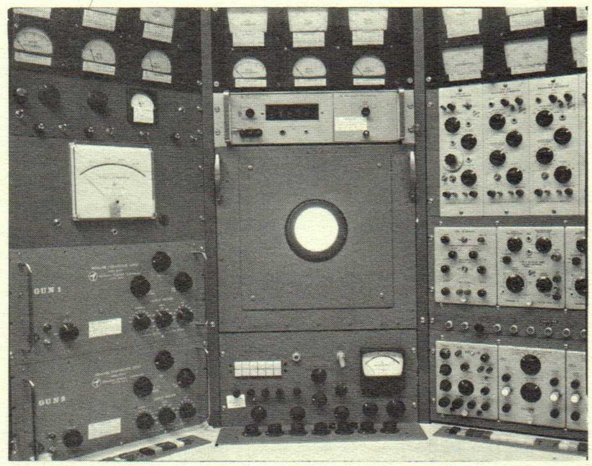
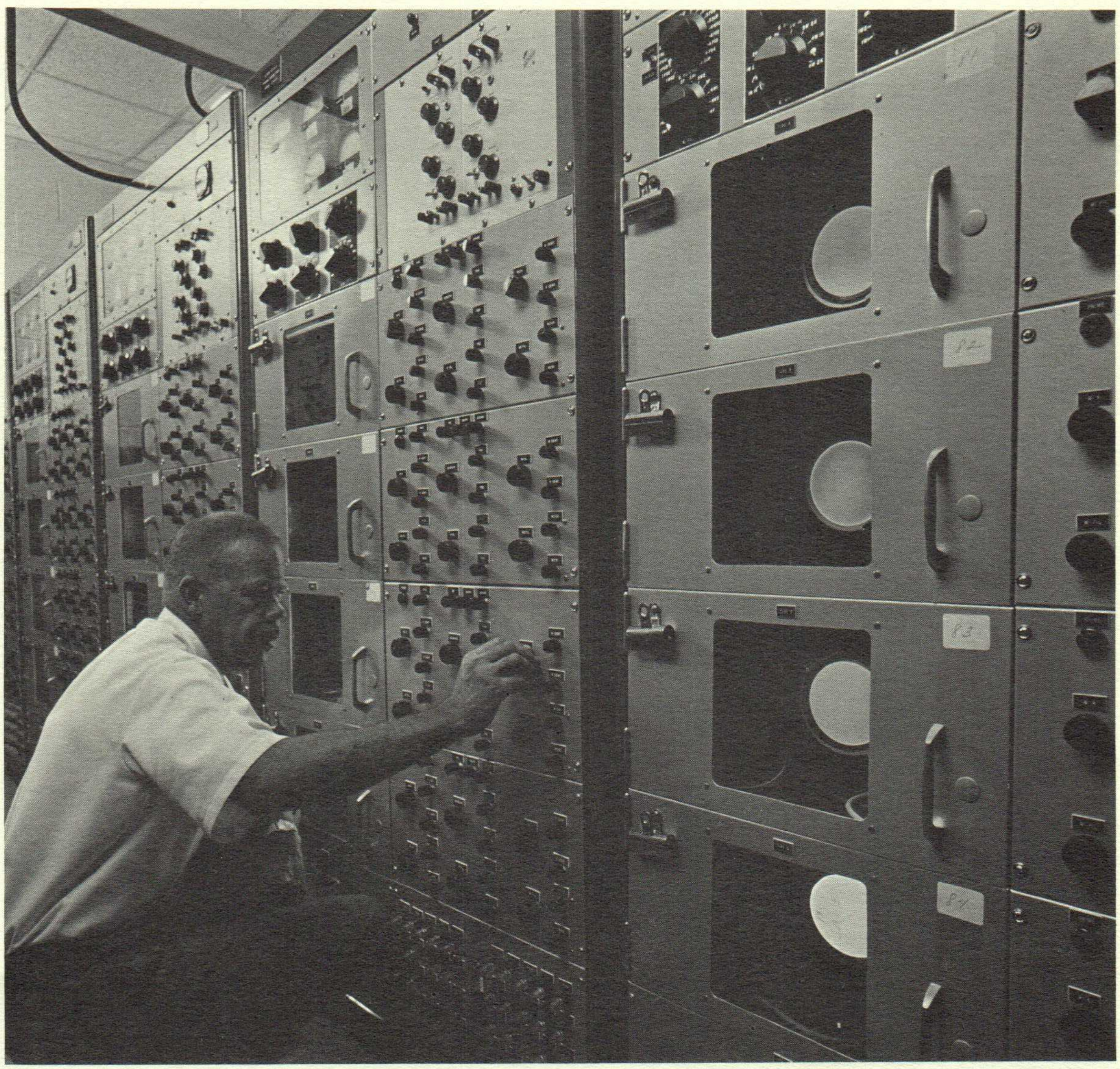
Quality assurance of all tube characteristics is checked by the use of modern electronic test equipment.



Reliability of Westinghouse storage tubes is assured by pre-test burn-in. Stability of tube operation is a major advantage of this activity.



DISPLAY STORAGE TUBE – QUICK REFERENCE CHART

The types listed are currently in production or are proven designs. The listing is divided in these main groups: Electrostatic Deflection - Standard, Electrostatic Deflection - High Contrast, and Magnetic Deflection. All types are electrostatic focus and are shown, left to right, by size of useful viewing diameter.All voltages are with respect to the flood gun cathode, which is assumed to be at ground potential. All types listed are provided with encapsulated high voltage cables. All types listed are fully potted except for the 31931, 7183A, and 31720. All types listed except the 7183A and 31720 are supplied with magnetic shields.

Characteristics listed were selected to optimize one or more parameters such as storage time, writing speed, resolution, etc. To discuss any special conditions you require, please contact the Westinghouse sales engineer in your area (locations are shown on the last page).

NOTES:

- * Factory collimated; voltage shown is a required input (positive and/or negative).
- △ Storage area.
- ° Non-Storage area.

- a. At radar sweep and erase rates.
- b. At television sweep and erase rates.
- c. Control electrode voltage.
- d. Time required for the visual output to increase from visual cutoff to 10% of saturated luminance without application of a writing signal or erase pulses.
- e. The width of a single rectangular erase pulse, one volt greater than backing electrode cutoff which erases the display from saturated luminance to visual extinction.
- f. The difference between the amplitude of an erase pulse required to illuminate any area of an unwritten screen, and the amplitude of an erase pulse required to evenly illuminate the screen is the Erasing Uniformity (Δep

ELECTROSTATIC DEFLECTION - STANDARD

TYPE NUMBER	WX 30059	WX5308	WX5047	WX5314	7268A	WX31370	WX31684	WX[illegible]54
MINIMUM USEFUL VIEWING DIAMETER (INCHES)	2.25	3	4	4	4	4	5.7	[illegible].8
PAGE NUMBER FOR OUTLINE AND BASING	41	41	44	44	42 & 43	45	45	48
NUMBER OF WRITE GUNS	2	1	1	1	2	1	1	1
TYPE OF FOCUS	ES	ES	ES	ES	ES	ES	ES	ES
GAS VIEWING DURATION (SECONDS) NOTE d	10	30	10	60	15	10	30	40
MINIMUM WRITING SPEED INCHES/SECOND	$5x10^3$	$1x10^4$	$4x10^5$	$1x10^4$	$4x10^4$	$5x10^4$	$4.5x10^5$	$5x10^4$
TYPICAL ERASE TIME (MILLISECONDS) NOTE e	7	45	40	75	45	80	4	100
MINIMUM DISPLAY LUMINANCE (FT-L)	500	1000	1000	200	2200	800	1000	750
MINIMUM CENTER SHRINKING RASTER RESOLUTION (LINES/INCH)	130	50	90	90	70	75	70	45
ERASE UNIFORMITY (△ ep) NOTE f	1.0	1.0	1.0	1.0	1.1	-	-	1.4
BRIGHTNESS LEVELS (GRAY SCALES)	4a	4a	4a	4a	4a	4a	4a	4a
SCREEN VOLTAGE (KILOVOLTS)	5	8	10	5	10	10	10	[illegible]
BACKING ELECTRODE VOLTS	4	2	2	2	2	2	6	2
COLLECTOR VOLTS	160	200	200	200	265	200	250	210
COLLIMATOR C VOLTS (TYPICAL)	40	40	60	60	80	70	90	75
COLLIMATOR D VOLTS (TYPICAL)	-	-	-	-	-	60 to 90	55	70
COLLIMATOR E VOLTS (TYPICAL)	-	-	-	-	-	-	-	-
CONTROL GRID 1 FLOOD GUN (VOLTS)	0 to -50	0 to -10	0 to -50	0 to -50	0 to -50	0 to -30	0 to -35	0
WRITE GRID 2 & 4 VOLTS	90 to 110	75 to 95	25 to 75	90 to 110	95 to 105	25 to 75	150 to 170	160
WRITE GRID3 FOCUS (VOLTS)	-1200 to -1500	-395 to -415	-1850 to -2150	-2000 to -2300	-1975 to -2325	-1850 to -2150	-1300 to -1700	-1600 to -2000
WRITE GRID 1 CUTOFF RANGE (VOLTS)	-1510 to -1550	-512 to -518	-2500 to -2570	-2400 to -2470	-2460 to -2500	-2350 to -2575	-1700 to -1775	-2560 to -2590
WRITE CATHODE VOLTS	-1500	-500	-2500	-2400	-2400	-2500	-1700	-2500
DEFLECTION FACTOR VOLTS D.C./INCH/ K.V.	12 to 50	50 to 70	28 to 35	28 to 35	28 to 35	20 to 45	14 to 35	18 to 30
SUPPRESSOR ELECTRODE VOLTS	-	-	-	-	-	-	-	[illegible]
COMMENTS	Compact, Dual Gun	Compact	High Resolution	Long Gas Viewing Duration	Available with Factory Collimation	Commercial single gun electrostatic	Large Display, Fast Writing Speed	Large Viewing Area

ELECTROSTATIC DEFLECTION - HIGH CONTRAST

WX31931	WX5444	WX30533	WX31016	WX30808	WX30593	WX30930	WX4951	WX31933	WX31812	WX31966	WX31368	TYPE NUMBER
2.25	4	4	4	4	4	4	4	4	4	4	5.5	MINIMUM USEFUL VIEWING DIAMETER (INCHES)
48	42 & 43	42 & 43	42 & 43	42 & 43	45	49	44	42 & 43	42 & 43	42 & 43	42 & 49	PAGE NUMBER FOR OUTLINE AND BASING
1	2	2	2	2	1	1	1	2	2	2	2	NUMBER OF WRITE GUNS
ES	ES	ES	ES	ES	ES	ES	ES	ES	ES	ES	ES	TYPE OF FOCUS
20	30	30	15	15	30	30	15	15	15	15	20	GAS VIEWING DURATION (SECONDS) NOTE d
5x10^5	3.6x10^4	3.6x10^4	7.2x10^4	7.2x10^4	1x10^5	5x10^3	1x10^5	7.2x10^4	7.2x10^4	7.2x10^4	4.5x10^4	MINIMUM WRITING SPEED INCHES/SECOND
5	18	10	5	5	12	70	30	5	5	4	7	TYPICAL ERASE TIME (MILLISECONDS) NOTE e
2000	1500	1500	1800	1800	1000	400△ 10°	1200	4000	1500	4000	1000	MINIMUM DISPLAY LUMINANCE (Ft-L)
125	60	65	70	70	60	50	60	80	110	110	70	MINIMUM CENTER SHRINKING RASTER RESOLUTION (LINES/INCH)
-	-	-	-	-	-	-	1.0	-	-	-	-	ERASE UNIFORMITY (△ ep) NOTE f
7b	7b	7b	7b	7b	7b	5b	6b	7b	7b	7b	7b	BRIGHTNESS LEVELS (GRAY SCALES)
10	10	10	10	10	10	8	10	10	10	10	10	SCREEN VOLTAGE (KILOVOLTS)
15	15	15	15	15	12.5	12	10	15	15	5	15	BACKING ELECTRODE VOLTS
250	250	250	300*	265	200*	120	200	265	265	265	250	COLLECTOR VOLTS
100	80	80	-	80	-	40	60	80	80	75	100	COLLIMATOR C VOLTS (TYPICAL)
-	-	-	-	-	-	-	-	-	-	-	70	COLLIMATOR D VOLTS (TYPICAL)
-	-	-	-	-	-	– 5c	-	-	-	-	-	COLLIMATOR E VOLTS (TYPICAL)
0 to -50	0	0	-80*	0 to -50	0 to -50	0 to -50	0 to -50	0 to -50	0 to -50	0 to -50	0 to -35	CONTROL GRID 1 FLOOD GUN (VOLTS)
75 to 125	100	100	90 to 110	90 to 110	120	100	90 to 110	90 to 110	90 to 110	90 to 110	90 to 110	WRITE GRID 2 & 4 VOLTS
-1350 to -1700	10.8 ±0.15% WG 2-4	10.8 ±0.15% WG 2-4	-2000 to -2300	-2000 to -2300	-1800 to -2100	-1600 to -2300	-2000 to -2300	-2000 to -2300	-1200 to -1700	-1300 to -1700	-1200 to -1400	WRITE GRID 3 FOCUS (VOLTS)
-1750 to -1830	-945 to -975	-1165 to -1215	-2460 to -2500	-2460 to -2500	-2400 to -2475	-2560 to -2590	-2400 to -2470	-2460 to -2500	-1700 to -1775	-1720 to -1730	-1600 to -1670	WRITE GRID 1 CUTOFF RANGE (VOLTS)
-1750	-900 (nom)	-1100 (nom)	-2400	-2400	-2400	-2500	-2400	-2400	-1700	-1700	-1600	WRITE CATHODE VOLTS
40 to 65	35	40	32 to 40	32 to 40	28 to 35	25 to 35	28 to 35	32 to 40	40 to 55	28 to 40	14 to 35	DEFLECTION FACTOR VOLTS D.C./INCH/ K.V.
75	75	75	75	75	75	75	75	75	75	150	75	SUPPRESSOR ELECTRODE VOLTS
Compact	Precision Deflection System	High Contrast Radar and Television Capability			Fast Writing Speed	Split Screen (CRT/ DST)	High Contrast	High Brightness	High Resolution	High Res. & High Bright. Well suited for radar & T.V. applications	Large Display Dual Gun	Comments

DISPLAY STORAGE TUBE – QUICK REFERENCE CHART

MAGNETIC DEFLECTION										
TYPE NUMBER	WX31829	WX31805	7183A	WX31734	WX31720	WX31724	WX31461	WX31412	WX31411	WX30811
MINIMUM USEFUL VIEWING DIAMETER (INCHES)	4	4	4	4	4	4	4	4	4	4
PAGE NUMBER FOR OUTLINE AND BASING	46	46	47	50	52	51	52	52	52	52
NUMBER OF WRITE GUNS	1	1	1	1	1	1	1	1	1	1
TYPE OF FOCUS	ES	ES	ES	ES	ES	ES	ES	ES	ES	ES
GAS VIEWING DURATION (SECONDS) NOTE d	30	30	15	30	10	30	15	15	15	30
MINIMUM WRITING SPEED INCHES/SECOND	$9x10^4$	$1x10^5$	$1.2x10^4$	$1x10^4$	$7x10^4$	$3x10^4$	$7.5x10^4$	$5.6x10^4$	$7x10^4$	$7x10^4$
TYPICAL ERASE TIME (MILLISECONDS) NOTE e	3		40	30	2	20	1.5	3	3	3
MINIMUM DISPLAY LUMINANCE (FT-L)	1200	1000	700	180	1000	500	1000	1000	800	1000
MINIMUM CENTER SHRINKING RASTER RESOLUTION (LINES/INCH)	130	85	45	55	80	50	150	120	100	100
ERASE UNIFORMITY (△Cp) NOTE f	-	-	-	-	-	-	-	-	-	-
BRIGHTNESS LEVELS (GRAY SCALES)	7b	7b	4a	3a	8b	4a	8b	8b	8b	9b
SCREEN VOLTAGE (KILOVOLTS)	10	8	8.5	7.5	8.5	6	10	10	9.5	9.5
BACKING ELECTRODE VOLTS	0	5 to 12	0	5	0	1 to 5	5 to 12	5 to 12	5 to 12	5 to 12
COLLECTOR VOLTS	200	35 to 40	250	115	200	120	200*	200*	100	80
COLLIMATOR C VOLTS (TYPICAL)	65 to 105	0 to 25	80 to 110	35 to 75	65 to 105	20 to 40	-	-	20 to 50	20 to 45
COLLIMATOR D VOLTS (TYPICAL)	-	0 to 20	10 to 38	10 to 30	15 to 55	0 to 30	-	-	15 to 45	15 to 45
COLLIMATOR E VOLTS (TYPICAL)	110	15 to 30	100	75	110	80	-	-	5 to 30	5 to 30
CONTROL GRID 1 FLOOD GUN (VOLTS)	0 to -30	0 to -15	0 to -35	0 to -30	0 to -35	0 to -30	0 to -20	0 to -20	0 to -20	0 to -20
WRITE GRID 2 & 4 VOLTS	10 to 40	-	-	WG 2 Only -1600	-	-	-	-	95	50
WRITE GRID 3 FOCUS (VOLTS)	-1900 to -2200	-1500 to -1400	-1600 to -1900	WG 4 Only -1865 to -2100	-1600 to -1900	-1050 to -1325	-1100 to -1300	-1100 to -1300	-1300 to -1500	-1300 to -1500
WRITE GRID 1 CUTOFF RANGE (VOLTS)	-3070 to -3130	-1525 to -1590	-2500 to -2630	-1815 to -1845	-2500 to -2630	-1520 to -1550	-1530 to -1560	-1530 to -1560	-1730 to -1760	-1730 to -1760
WRITE CATHODE VOLTS	-3000	-1500	-2500	-1800	-2500	-1500	-1500	-1500	-1700	-1700
DEFLECTION FACTOR VOLTS D.C./INCH/ K.V.	-	-	-	-	-	-	-	-	-	-
SUPPRESSOR ELECTRODE VOLTS	75	-	-	-	-	-	-	-	-	-
COMMENTS	High resolution, High Contrast	Compact	Weather Radar Capabilities	Enhanced Contrast Display	Weather Radar & T.V. capability	Extendable storage time capability	High Resolution	Radar & T.V. capability, factory collimated	Radar & T.V. capabilities	

OUTLINES AND BASING DIAGRAMS

(Dimensions in $\frac{\text{inches}}{\text{mm}}$ unless otherwise shown). The millimeter dimensions are derived from the original inch dimensions, 1" = 25.4 mm exactly.

(W) = Write Gun (F)=Flood Gun

Westinghouse

WX-30059

INDEX OF LEADS

8 LEAD GROUP
DEFLECTION PLATES

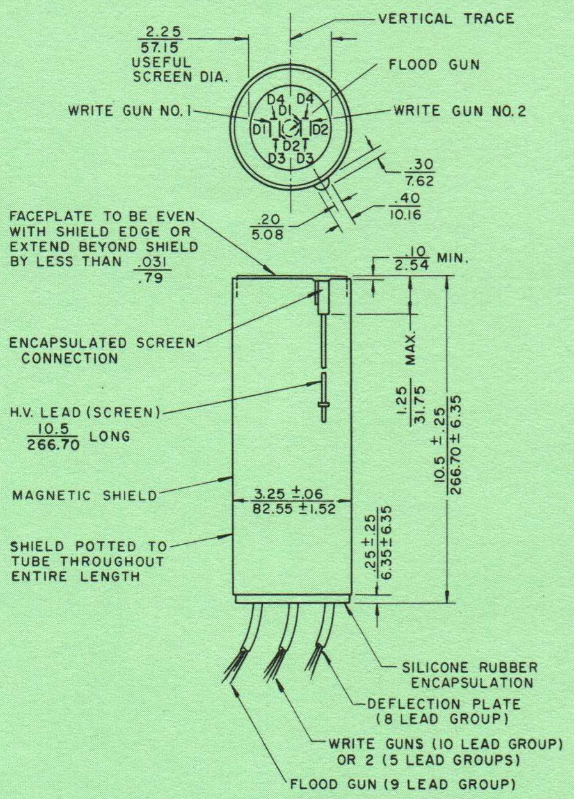
D1, D2, D3, D4 — Write Gun No. 1 & Gun No. 2

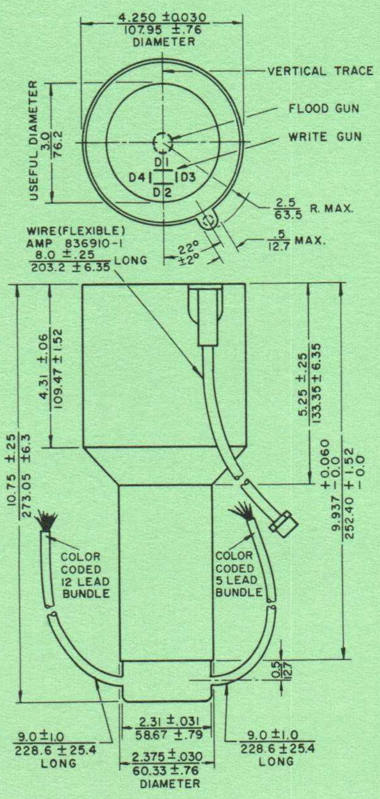
9 LEAD GROUP
FLOOD GUN

BE	Heater
G4	Heater
G3	K
G2	Ground
G1	

10 LEAD GROUP
WRITE GUNS

G1, G3, Heater, Heater, K — Write Gun No. 1 & Gun No. 2





WX-5308

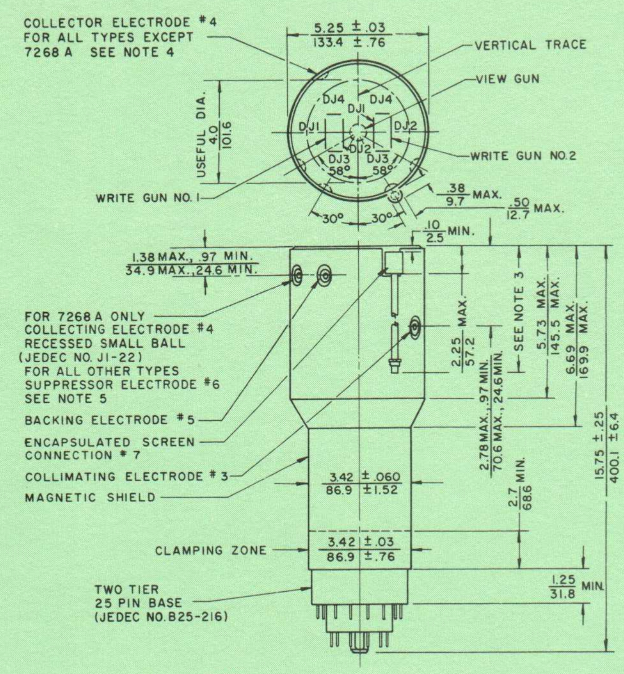
12 LEAD GROUP

White/Black	D3
White/Red	D4
Orange	G2, G4 (W)
Green	G1 (F)
Yellow	Heater (F)
White/Yellow	Heater, Cathode (F)
White/Green	D1
White/Red	D2
Black	Shield Ground
Blue	G2, G3 (F) Collimator
Red	G4, (F) Collector
Violet	Backing Electrode

5 LEAD GROUP

Brown	Heater (W)
White	G1 (W)
Gray	Cathode (W)
White/Blue	G3 (W)
White/Brown	Heater (W)

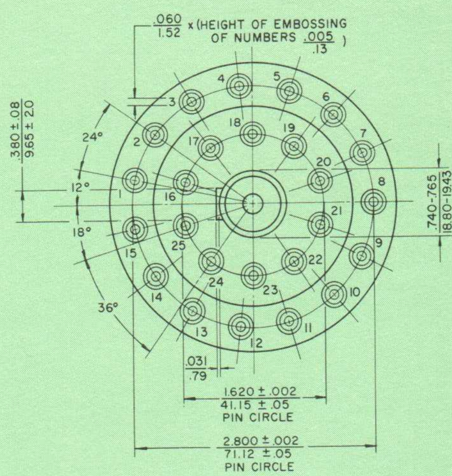
OUTLINES AND BASING DIAGRAMS

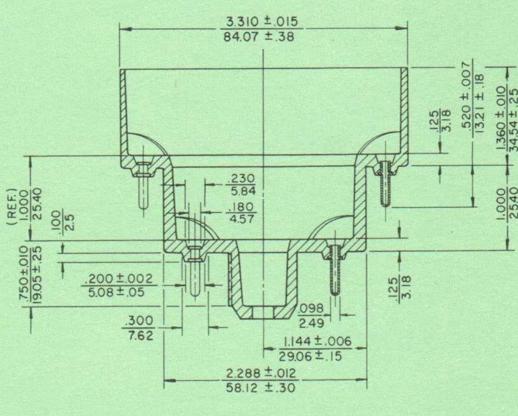


WX 5444
7268A
WX 30533
WX 30808
WX 31016
WX 31812
WX 31933
WX 31966

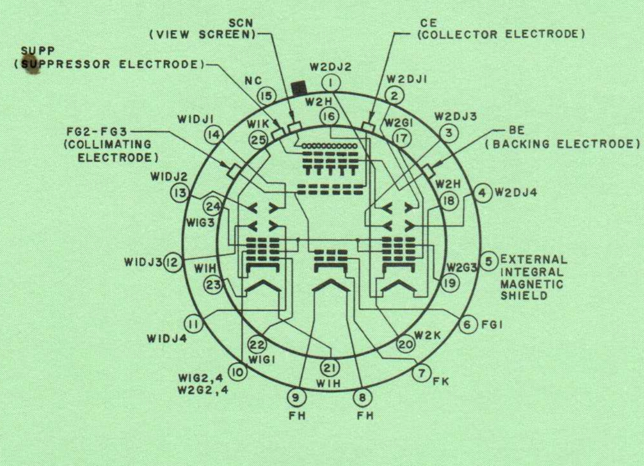
NOTES:

1. CENTERLINE OF BULB AXIS TO BE NOT MORE THAN 3° FROM A PERPENDICULAR ERECTED AT CENTER OF FACEPLATE.
2. FACEPLATE TO BE EVEN WITH SHIELD EDGE OR EXTEND BEYOND SHIELD BY LESS THAN .06" (1.6mm).
3. LEAD LENGTHS:
   WX-31016, WX-30808, 31933, 31812, 31966, 7268A – 20.0"±.3" (508.0 ± 7.6mm)
   WX-5444, WX-30533 – 14.3"±.3" (363.2 ± 7.6mm)
4. COLLECTOR ELECTRODE FOR WX-31016, 30808, 31933, 31812, 31966, 5444, 30533.
5. SUPPRESSOR ELECTRODE FOR WX-31016, 30808, 31933, 31812, 31966, 5444, 30533.





OUTLINE FOR 25 – PIN BASE



INTERNAL CONNECTIONS
SEE NOTES ABOVE AND CONNECTION DETAIL ON NEXT PAGE.

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BASE CONNECTIONS FOR 7268 A

BASE PINS

Pin No.	Gun	Element
1	Write (2)	Deflection Electrode 2
2	Write (2)	Deflection Electrode 1
3	Write (2)	Deflection Electrode 3
4	Write (2)	Deflection Electrode 4
5	External	Integral Magnetic Shield
6	Flood	Grid 1
7	Flood	Cathode
8	Flood	Heater
9	Flood	Heater
10	Write (1)	Grids 2 & 4
	Write (2)	Grids 2 & 4
11	Write (1)	Deflection Electrode 4
12	Write (1)	Deflection Electrode 3
13	Write (1)	Deflection Electrode 2
14	Write (1)	Deflection Electrode 1
15	NO CONNECTION (DO NOT USE)	
16	Write (2)	Heater
17	Write (2)	Grid 1
18	Write (2)	Heater
19	Write (2)	Grid 3
20	Write (2)	Cathode
21	Write (1)	Heater
22	Write (1)	Grid 1
23	Write (1)	Heater
24	Write (1)	Grid 3
25	Write (1)	Cathode

CAPS ON LARGE END OF BULB

Gun	Element
Flood	Collimating Electrode
Flood	View Screen
Flood	Collector Electrode
Flood	Backing Electrode

BASE CONNECTIONS FOR WX-31016

Base Pin No.	ELECTRODE
1	Def. Elect. DJ2 of WG2
2	Def. Elect. DJ1 of WG2
3	Def. Elect. DJ3 of WG2
4	Def. Elect. DJ4 of WG2
5	Ext. Magnetic Shield
6	Negative Input
7	Cathode of the V.G.
8	Heater of V.G.
9	Heater of V.G.
10	Grids 2 & 4 of each WG
11	Def. Elect. DJ4 of WG1
12	Def. Elect. DJ3 of WG1
13	Def. Elect. DJ2 of WG1
14	Def. Elect. DJ1 of WG1
15	No Connection
16	Heater of WG2
17	G1 of WG2
18	Heater of WG2
19	G3 of WG2
20	Cathode of WG2
21	Heater of WG1
22	G1 of WG1
23	Heater of WG1
24	G3 of WG1
25	Cathode of WG1

BASE CONNECTIONS FOR WX-5444 WX-30533, WX-31812, WX-31933 & WX-31966

Base Pin No.	ELECTRODE
1	Def. Elect. DJ2 of WG2
2	Def. Elect. DJ1 of WG2
3	Def. Elect. DJ3 of WG2
4	Def. Elect. DJ4 of WG2
5	Ext. Magnetic Shield
6	No Connection
7	Cathode of the V.G.
8	Heater of V.G.
9	Heater of V.G.
10	Grids 2 & 4 of each WG
11	Def. Elect. DJ4 of WG1
12	Def. Elect. DJ3 of WG1
13	Def. Elect. DJ2 of WG1
14	Def. Elect. DJ1 of WG1
15	No Connection
16	Heater of WG2
17	G1 of WG2
18	Heater of WG2
19	G3 of WG2
20	Cathode of WG2
21	Heater of WG1
22	G1 of WG1
23	Heater of WG1
24	G3 of WG1
25	Cathode of WG1

BASE CONNECTIONS FOR WX-30808

Base Pin No.	ELECTRODE
1	Def. Elect. DJ2 of WG2
2	Def. Elect. DJ1 of WG2
3	Def. Elect. DJ3 of WG2
4	Def. Elect. DJ4 of WG2
5	Ext. Magnetic Shield
6	Grid 1 of V.G.
7	Cathode of the V.G.
8	Heater of V.G.
9	Heater of V.G.
10	Grids 2 & 4 of each WG
11	Def. Elect. DJ4 of WG1
12	Def. Elect. DJ3 of WG1
13	Def. Elect. DJ2 of WG1
14	Def. Elect. DJ1 of WG1
15	No Connection
16	Heater of WG2
17	G1 of WG2
18	Heater of WG2
19	G3 of WG2
20	Cathode of WG2
21	Heater of WG1
22	G1 of WG1
23	Heater of WG1
24	G3 of WG1
25	Cathode of WG1

OUTLINES AND BASING DIAGRAMS

WX 4951, WX 5047

(10 LEAD GROUP)

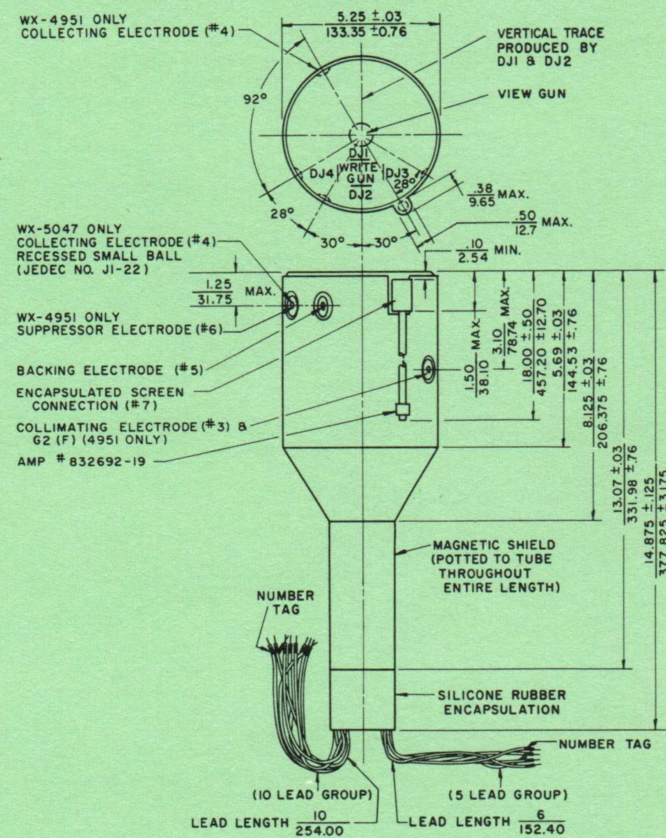
Lead Electrode

1. DV3
2. DV4
3. G2, G4(W) [G2(F) 5047 Only]
4. G1(F)
5. NC
6. Heater (F)
7. Heater (F) & Cathode(F) (Shield Ground 5047 Only)
8. DV1
9. DV2
10. Ground for Shield (4951 Only)

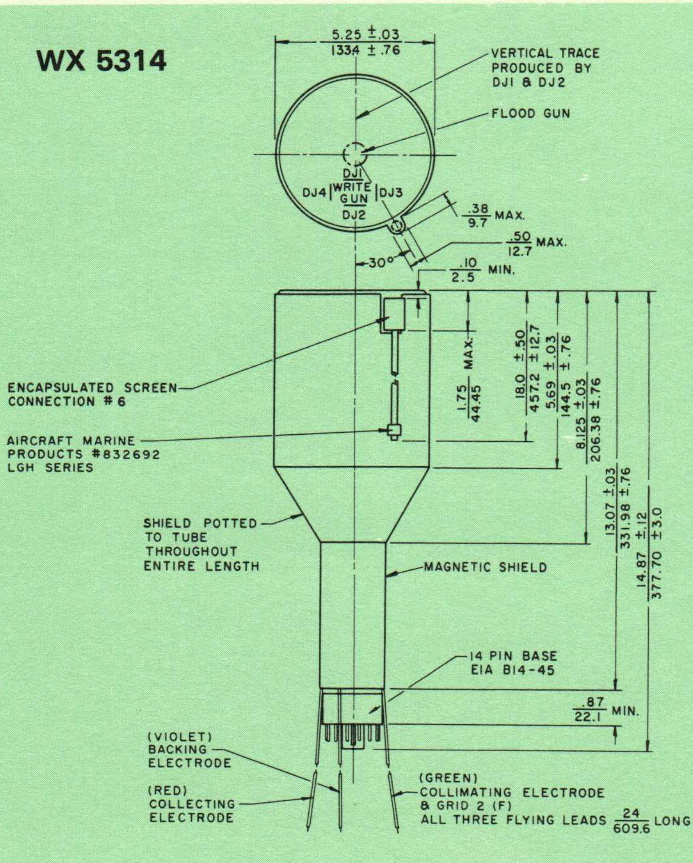
(5 LEAD GROUP)

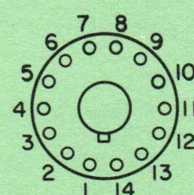
Lead Electrode

1. Heater (W)
2. G1 (W)
3. Cathode (W)
4. G3 (W)
5. Heater (W)



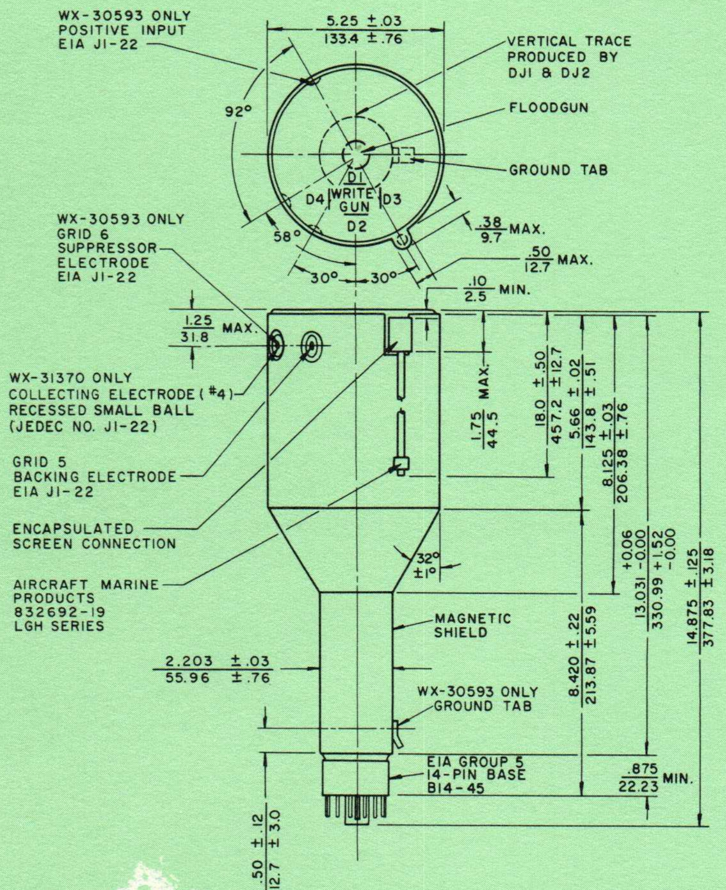
WX 5314





Base Connections

Pin	Element
1	Heater (W)
2	Grid 1 (W)
3	Grid 3 (W)
4	D3 (W)
5	D4 (W)
6	Grids 2 & 4 (W)
7	Grid 1 (F)
8	Internal Connection
9	Heater (F)
10	Heater & Cathode (F)
11	D1 (W)
12	D2 (W)
13	Cathode (W)
14	Heater (W)



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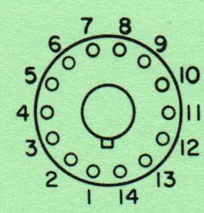
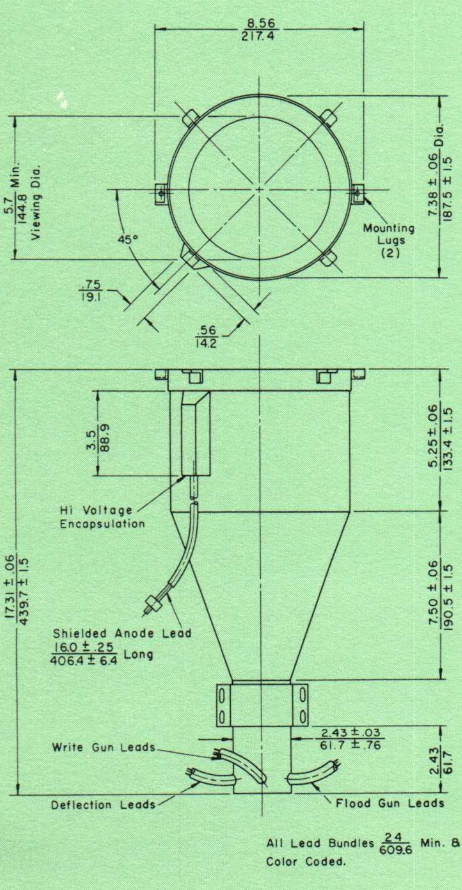


WX-30593
WX-31370

Base Connections

Pin	Element
1	Heater (W)
2	Grid I (W)
3	Grid 3 (W)
4	D3 (W)
5	D4 (W)
6	Grids 2 & 4 (W)
7	Grid I (F)
8	Internal Connection
9	Heater (F)
10	Heater & Cathode (F)
11	DI (W)
12	D2 (W)
13	Cathode (W)
14	Heater (W)



All Lead Bundles 24/609.6 Min. & Color Coded.

WX-31684

FLYING LEADS

Small Bundle

Backing Electrode - Purple	)	
Collector - Red	)	#22 Teflon Wire
Flood Grid No. 3 - Green	)	

Also:

White/red	W_{G2-G4}	)	
White/brown	F_H	)	
White/blue	F_{G2}	)	#22 Teflon Wire
White/green	F_{G1}	)	
Brown	$F_H - F_K$	)	

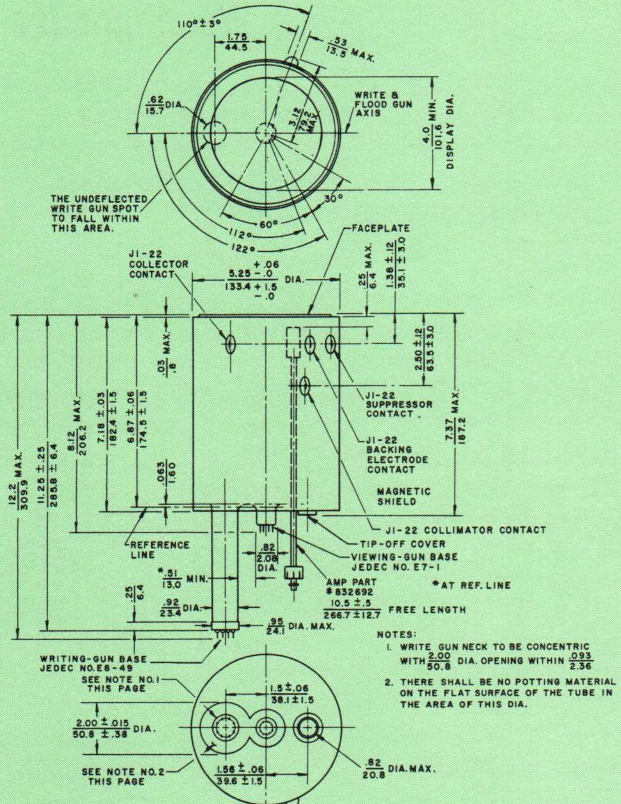
Large Bundle [H.V. Wire such as SE-HV(5)]

Yellow	DJ1	)	Shrink sleeving coded
Blue/yellow	DJ2	)	1" primary color,
White/black	DJ3	)	1/4" secondary color
Black	DJ4	)	

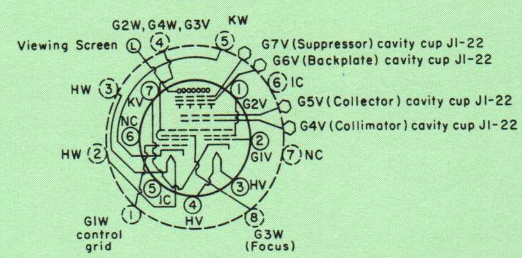
White	Heater-write	)	#1	
Blue/black	Heater-write	)	#2	Numbered
Yellow	Cathode	)	#3	and shrink sleeving
Black	Control Grid	)	#4	color coded
Blue	Focus	)	#5	

OUTLINES AND BASING DIAGRAMS

WX-31829



BASING DIAGRAM
Bottom View



Solid-Line Circles Depict Miniature 7-Pin Base JEDEC No. E7-1

Broken-Line Circles Depict Neoditetrar 8-Pin Base JEDEC No. E8-49

VIEWING SECTION

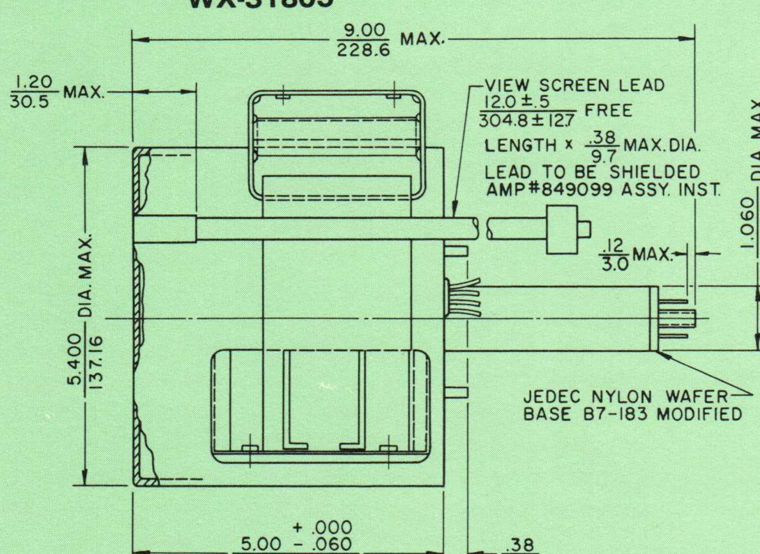
Pin 1. Grid No. 2 (first anode)
Pin 2. Grid No. 1 (control grid)
Pin 3. Heater
Pin 4. Heater
Pin 5. Internal Connection - do not use
Pin 6. No Connection
Pin 7. Cathode
Flexible Lead (Large): Viewing Screen
Note: Grid No. 3 of viewing gun is connected internally to write gun grids No. 2 and 4.

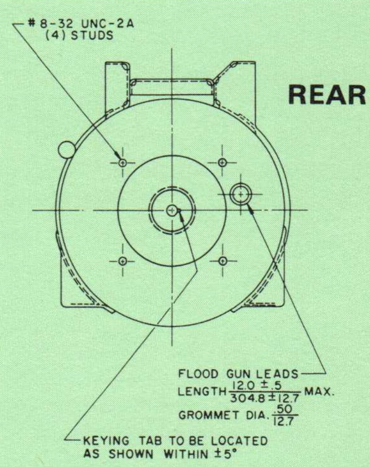
WRITING SECTION

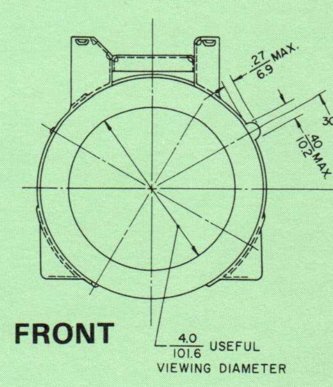
Pin 1. Grid No. 1 (control grid)
Pin 2. Heater
Pin 3. Heater
Pin 4. G2W, G4W, G3V
Pin 5. Cathode
Pin 6. Internal Connection - do not use
Pin 7. No Connection
Pin 8. Grid No. 3 (focus)

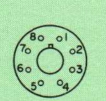
CAVITY CUP CONNECTIONS, JI-22
Grid 7. Suppressor Grid
Grid 6. Backing Electrode (Storage Grid)
Grid 5. Collector Grid
Grid 4. Collimator Grid

WX-31805









Terminal Index

Pin No.	Connection
1	Heater (WH)
2	Control-Grid (WG1)
3	No Connection
4	Focus Grid (WG3)
5	No Connection
6	Control-Grid (WG1)
7	Cathode (WK)
8	Heater (WH)

WX-31805

Flood Gun Leads	Wire Designation
FG 6 (If applicable)	Violet
FG 2	White/Blue
FG 3	White/Orange
FG 4	Yellow
FG 5	Blue
FG Heater (2)	Black
FG Cathode	White/Yellow
FE	Green
CE	Red
FG 1 (If applicable)	White/Green

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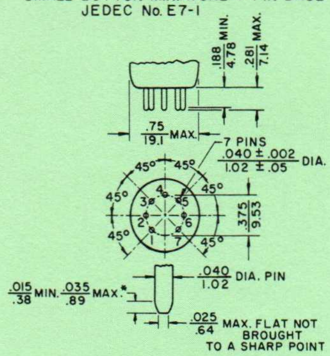
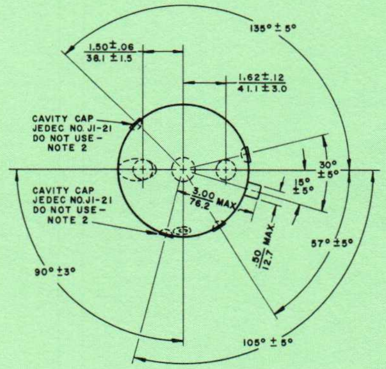
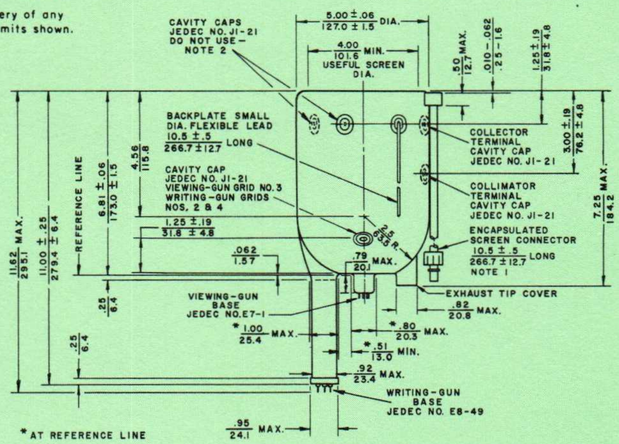
7183 A

SMALL-BUTTON MINIATURE 7-PIN BASE
JEDEC No. E7-1

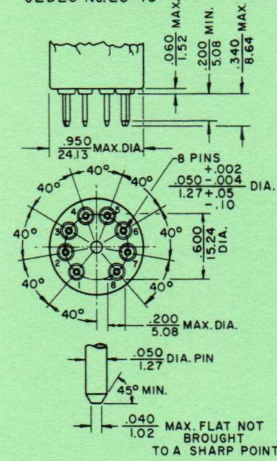


*The dimensions around the periphery of any individual pin may vary within the limits shown.





SMALL-BUTTON NEODITETRAR 8-PIN BASE
JEDEC No. E8-49



NOTE 1: Aircraft-Marine Products, Inc., type LGH Part No. 832692, or equivalent. This part mates with Aircraft-Marine Products, Inc., Part No. AMP 833589, ceramic terminal, or equivalent.

NOTE 2: Do not use these cavity caps for connection. The caps are connected internally and may be at a potential which could constitute a shock hazard. It is recommended that these caps be covered with electrical insulation.

VIEWING SECTION
Small-Button Miniature 7-Pin Base
JEDEC No. E7-1

Pin 1: Grid No. 2

Pin 2: Grid No. 1

Pin 3: Heater

Pin 4: Heater

Pin 5: Internal Connection-Do Not Use

Pin 6: Internal Connection-Do Not Use

Pin 7: Cathode

Flexible Lead (Large): Screen

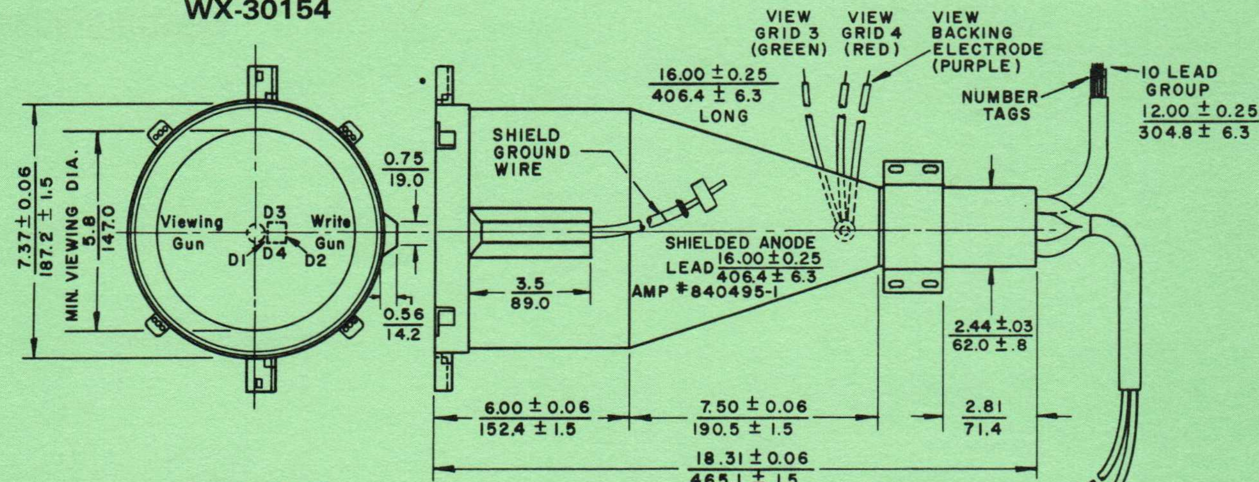
Flexible Lead (Small): Backplate

WRITING SECTION
Small-Button Neoditetrar 8-Pin Base
JEDEC No. E8-49

Pin 1: Grid No. 1
Pin 2: Heater
Pin 3: Heater
Pin 4: Internal Connection-Do Not Use
Pin 5: Cathode
Pin 6: Internal Connection-Do Not Use
Pin 7: Internal Connection-Do Not Use
Pin 8: Grid No. 3
Note: Grid No. 4 & No. 2 are connected internally to Grid No. 3 of viewing gun.

OUTLINES AND BASING DIAGRAMS

WX-30154



FLYING LEADS

10 - Lead Group

1 - Heater(W)
2 - Grid 1 (W)
3 - Grid 3 (W)
6 - Grids 2 & 4 (W)
7 - Grid 1 (F)
8 - Grid 2 (F)
9 - Heater (F)
10 - Heater & Cathode (F)
13 - Cathode (W)
14 - Heater (W)

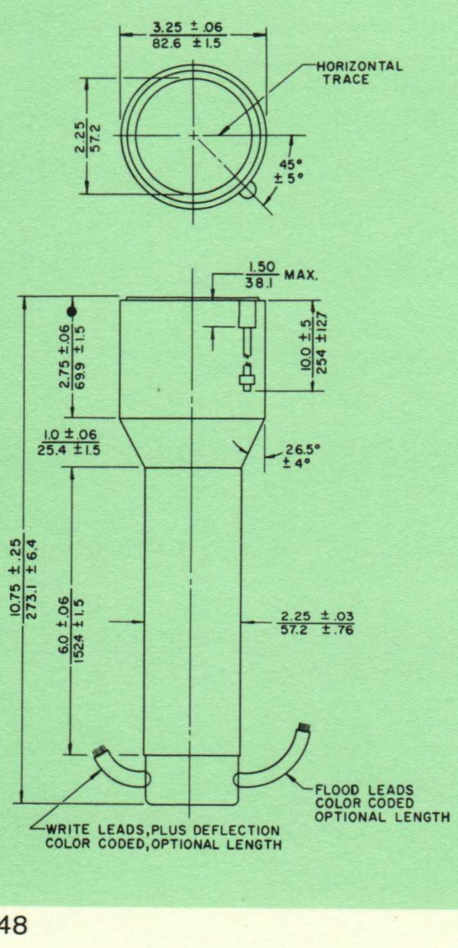
2 - Lead Group

4 - D3 (W)
5 - D4 (W)

2 - Lead Group

11 - D1 (W)
12 - D2 (W)

WX-31931



FLYING LEADS

Small Bundle

#1 Suppressor	)	All red wire
#2 Backing Electrode	)	
#3 Collector	)	
#4 Flood Grid #5	)	
#5 Flood Grid #4	)	
#6 Flood Grid #3	)	

Also:

White/red	W_{G2-G4}	)	#22 Teflon wire
White/brown	F_H	)	
White/blue	F_{G2}	)	
White/green	F_{G1}	)	
Brown	$F_H - F_K$	)	

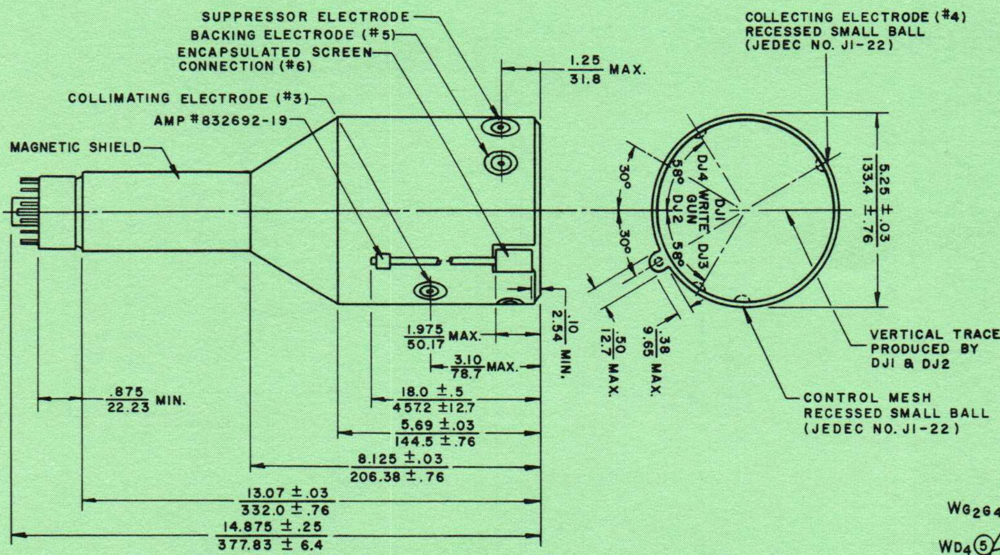
Large Bundle [H.V. Wire such as SE-HV(5)]

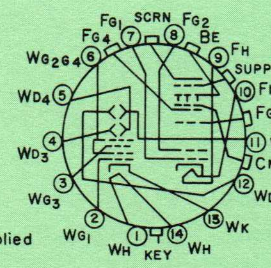
Yellow	DJ1	)	Shrink sleeving coded
Blue/yellow	DJ2	)	1" primary color,
White/black	DJ3	)	1/4" secondary color
Black	DJ4	)	

White	Heater-write	)	#1	
Blue/black	Heater-write	)	#2	Numbered
Yellow	Cathode	)	#3	and shrink sleeving
Black	Control grid	)	#4	color coded
Blue	Focus	)	#5	

Westinghouse

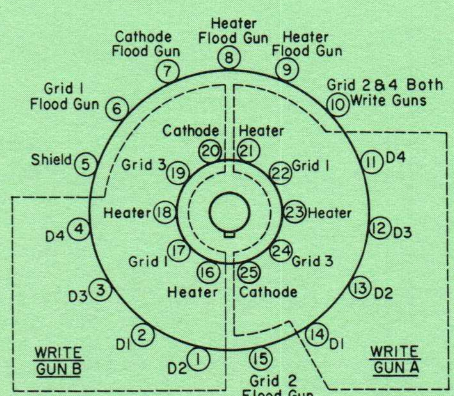
WX-30930



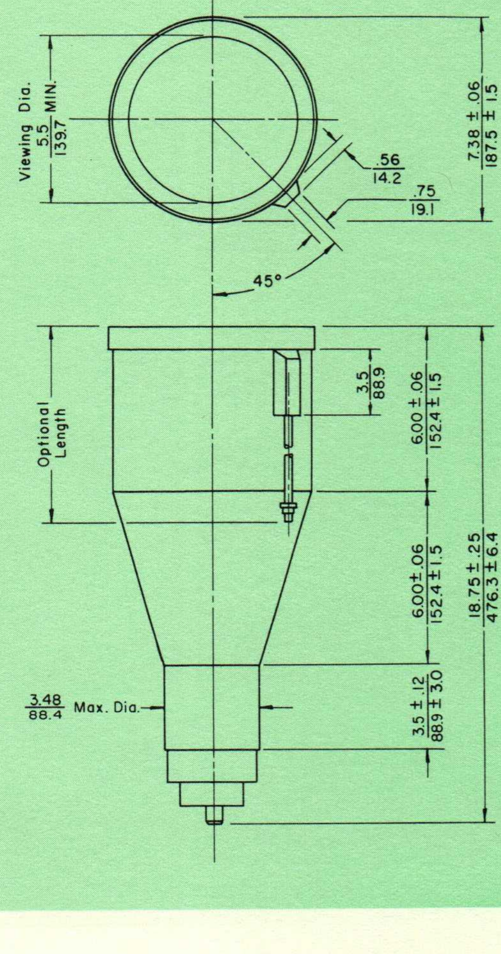


NOTE: FG_2 voltage supplied to pin 8.

WX-31368



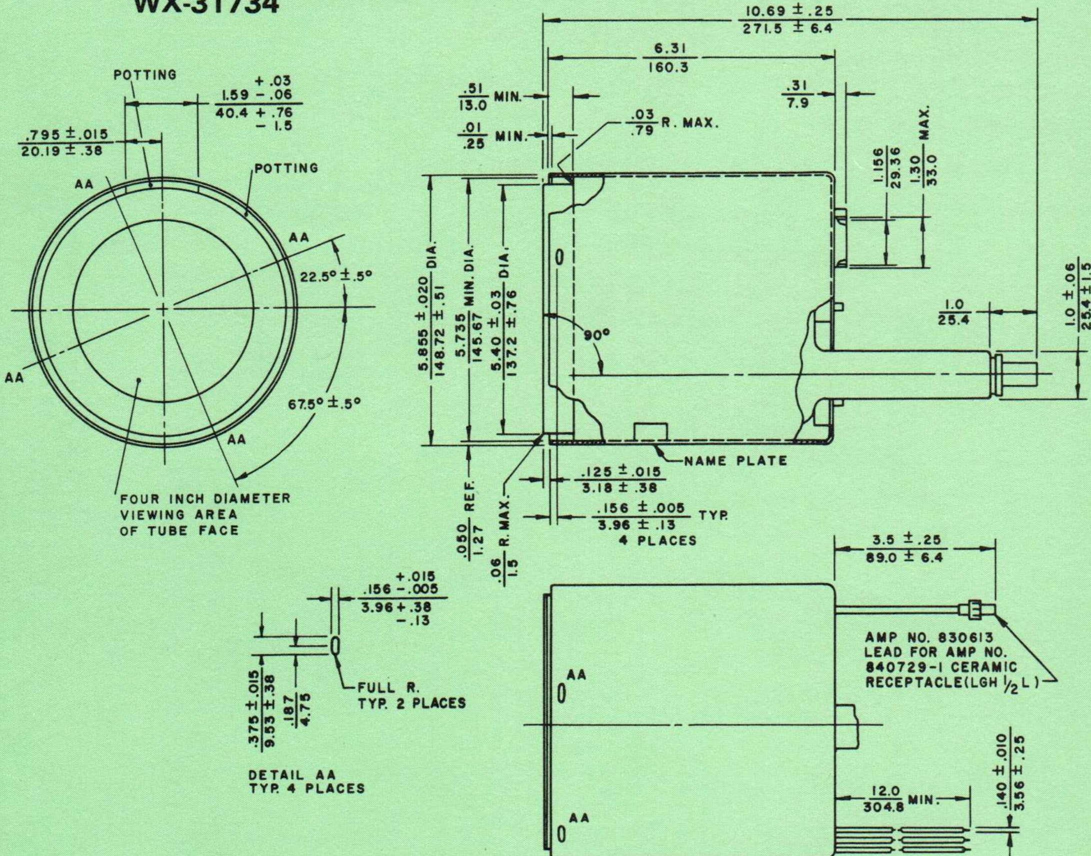
TWO-TIER, 25-PIN BASE, JEDEC NO. B25-216

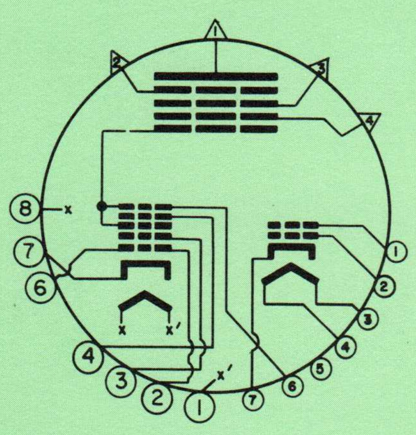


In the shielded unprecollimated version the following electrodes use flying leads flood grids 3, 4, 5 and 6. The screen connection is encapsulated and a high voltage cable provided, with the length dependent on the application.

OUTLINES AND BASING DIAGRAMS

WX-31734





CONNECTION SCHEMATIC

△ FLEXIBLE LEAD WIRES

LEAD WIRE	CONNECTION
1	VIEWING SCREEN
2	BACKING ELECTRODE
3	COLLECTOR ELECTRODE
4	FLOOD GUN GRID 4

○ WRITE GUN SOCKET JEDEC B 7-183

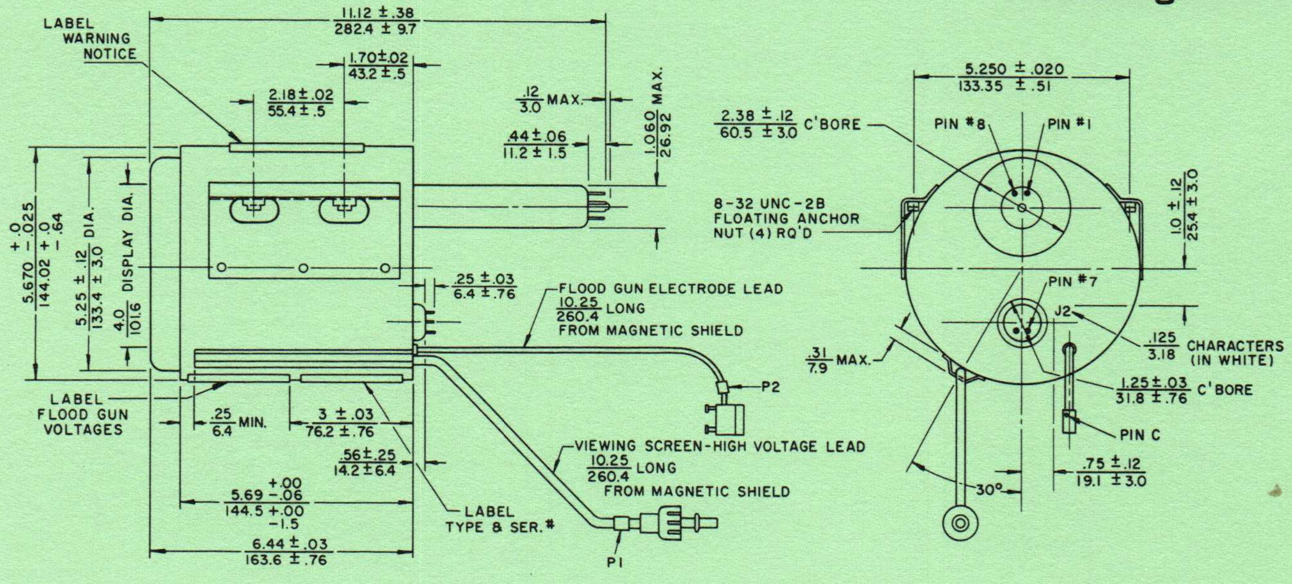
PIN NO.	CONNECTION
1	HEATER
2	GRID #1
3	GRID #2
4	GRID #4 (FOCUS)
5	VACANT PIN POSITION
6	GRID #1
7	CATHODE
8	HEATER

○ FLOOD GUN SOCKET JEDEC E 7-1

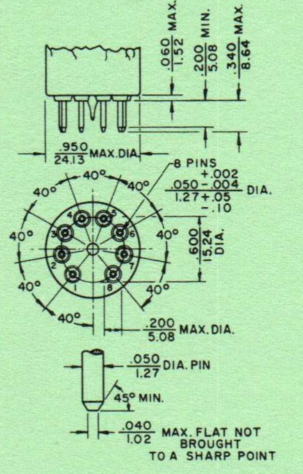
PIN NO.	CONNECTION
1	GRID #2
2	GRID #1
3	HEATER
4	HEATER
5	INTERNAL CONNECTION
6	GRID #3 (ALSO WRITE GUN GRIDS 3 & 5)
7	CATHODE

WX-31724

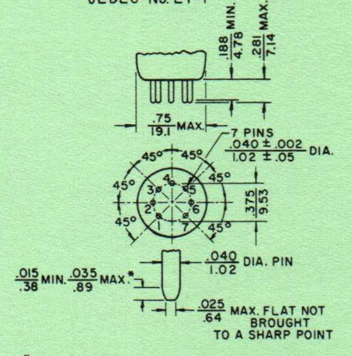
Westinghouse



SMALL-BUTTON NEODITETRAR 8-PIN BASE
JEDEC No. E8-11



SMALL-BUTTON MINIATURE 7-PIN BASE
JEDEC No. E7-1



*The dimensions around the periphery of any individual pin may vary within the limits shown.

WRITING SECTION
Small-Button Neoditetrar 8-Pin Base
JEDEC No. E8-49

Pin 1: Grid No. 1
Pin 2: Heater
Pin 3: Heater
Pin 4: Internal Connection-Do Not Use
Pin 5: Cathode
Pin 6: Internal Connection-Do Not Use
Pin 7: Internal Connection-Do Not Use
Pin 8: Grid No. 3
Note: Grid No. 4 & No. 2 are connected internally to Grid No. 3 of viewing gun.

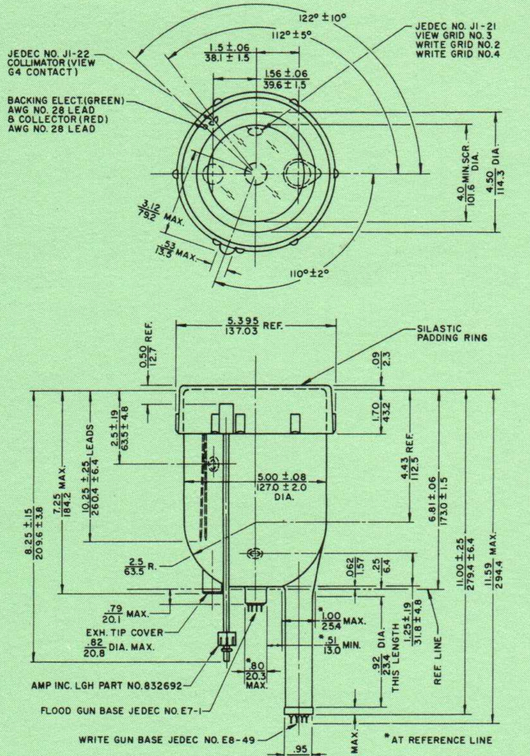
VIEWING SECTION
Small-Button Miniature 7-Pin Base
JEDEC No. E7-1

Pin 1: Grid No. 2
Pin 2: Grid No. 1
Pin 3: Heater
Pin 4: Heater
Pin 5: Internal Connection-Do Not Use
Pin 6: Grid No. 3 Writing grid Nos. 2 & 4
Pin 7: Cathode

Flying lead connections
Red-Collector
Orange-Flood Grid No. 4 (Collimator)
Yellow-Backing Electrode

OUTLINES AND BASING DIAGRAMS

WX-31720



WRITING SECTION

Write Gun Base
- Pin 1. Grid No. 1 (control grid)
- Pin 2. Heater
- Pin 3. Heater
- Pin 4. Internal Connection - do not use
- Pin 5. Cathode
- Pin 6. Internal Connection - do not use
- Pin 7. No Connection
- Pin 8. Grid No. 3 (focus)

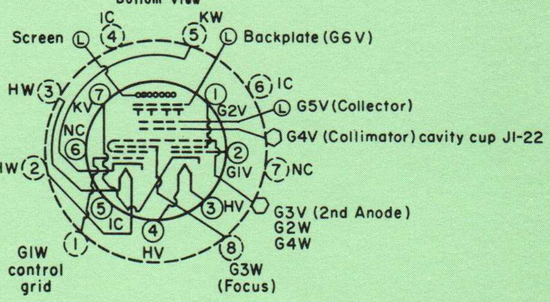
Note: Grids No. 4 and No. 2 are Connected Internally to Grid No. 3 of Viewing Gun.

VIEWING SECTION

Flood Gun Base
- Pin 1. Grid No. 2 (first anode)
- Pin 2. Grid No. 1 (control grid)
- Pin 3. Heater
- Pin 4. Heater
- Pin 5. Internal Connection - do not use
- Pin 6. No Connection
- Pin 7. Cathode

Flexible Lead (Large): Screen
Flexible Lead (Small): Backplate (G6V) (Green)
Collector (G5V) (Red)

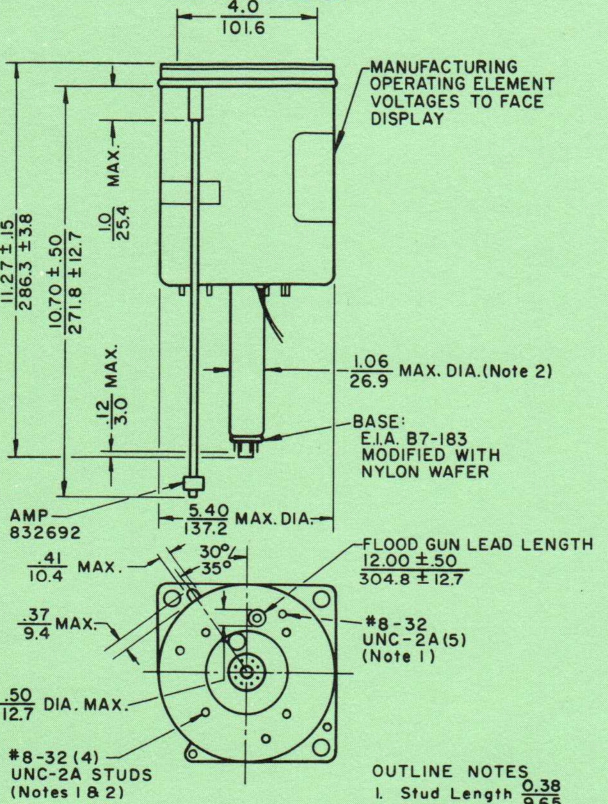
BASING DIAGRAM
Bottom View

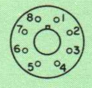


Solid-Line Circles Depict Miniature 7-Pin Base JEDEC No. E7-1

Broken-Line Circles Depict Neoditetrar 8-Pin Base JEDEC No. E8-49

WX-30811
WX-31411
WX-31412
WX-31461





Pin No.	Connection
1	Heater (WH)
2	Control-Grid (WG1)
3	No Connection
4	Focus Grid (WG3)
5	No Connection
6	Control-Grid (WG1)
7	Cathode (WK)
8	Heater (WH)

Flood Gun Leads

WX-30811 and WX-31411

(2) Black - Heaters
White / Yellow - Cathode
White / Green - Control Grid
White / Blue - Anode G2
Yellow - Collimator G3
Blue - Collimator G4
Purple - Collimator G5
Red - Collector
Green - Backing Electrode

WX-31412 and WX-31461

(2) Black - Heaters
White - Ground - Cathode
White - Control Grid G1
Blue - Backing Electrode BE
Red - Collimator Input

OUTLINE NOTES
1. Stud Length $\frac{0.38}{9.65}$
2. Tube neck must be contained within $\frac{1.080}{27.43}$ Dia. concentric with Bolt Circle.

Ordering Information

The Westinghouse Electronic Tube Division sales offices in the U.S., are listed below. Please feel free to call concerning your inquiries on Display Storage Tubes or any other electronic tube products.

CALIFORNIA

Los Angeles 90017	600 St. Paul Avenue	(213) 482-9660
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