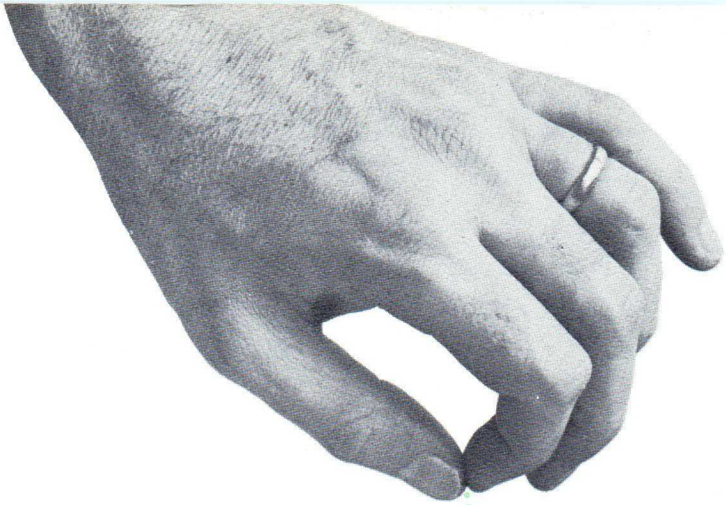
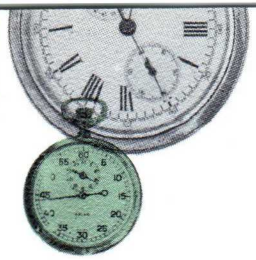


HUGHES *direct-display storage* tubes

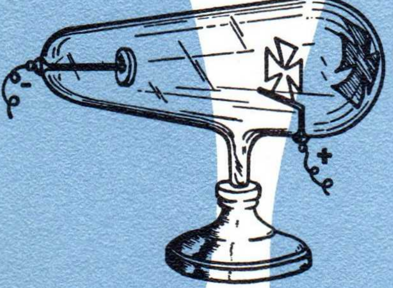
making *time* *stand still...*

HUGHES INTERNATIONAL

HUSINT S.A.



making TIME stand still



modified **Crookes Tubes...** *forerunner of the modern cathode-ray tube*

a new dimension in cathode-ray tubes

Basic cathode-ray tube principles have been long established. Early forms (primarily modified Crookes tubes) were demonstrated during the first decade of the Twentieth Century, and various applications are evident everywhere — in radar displays, TV picture and camera tubes, direct pick-up X-ray tubes.

In its widest technical use — the universally known oscilloscope — the CR tube has become as standard a tool for electronic measurement as the voltmeter. However, anyone who has ever used a conventional oscilloscope in studying non-recurrent phenomena — whether it be digital information, wave forms or images — has at one time or another voiced one desire: If it were only possible to *retain* the image on the tube face long enough to study it.

In the new family of Hughes storage tubes — Typotron, Memotron and Tonotron — this wish becomes a reality. To the traditional cathode-ray tube have been added two vital elements: First, a *flood gun* and, second, a *storage target or dielectric mesh.* These innovations make possible presentations of a display of infinite or extended persistence through electrostatic storage *built into the tube.*

Hughes storage tubes offer several important advantages over conventional cathode-ray tubes. Because they hold their displays in *detail* for an extended length of time, it is possible to make a comprehensive study of non-recurrent phenomena...without the former necessity of making superfluous photographs. Uniform, high light output permits full-daylight viewing without hoods and greatly simplifies the desired photography of selected waveforms. The displays do not fade or bloom, but retain their sharpness until intentionally erased.

Each of the three Hughes storage tubes — Typotron, Memotron and Tonotron — opens many new possibilities for application. Test equipment, communication, computation, medical diagnosis and radar are but a few of the potential applications already proven for these radically different, unusually flexible cathode-ray storage tubes.

Hughes applications engineers invite inquiries regarding specific uses of standard models or special modifications adaptable to new types of equipment or circuitry.

new tubes • new uses

tonotron ... to present "A" scan, "B" scan, weather radar, and plan position indicator information ... also for viewing "frozen action" in half-tone image form ... closed-circuit TV, slow scan narrow-band TV, ship-to-shore map or chart transmission, instrumentation and process monitoring, ground-to-air map or traffic-pattern transmissions.

typotron ... for high-speed read-out (25,000 characters/second) from digital computers ... display of computed radar-tracking information ... monitoring analog-to-digital conversion equipment. Ideal for visual reference; eliminates need for intermediate storage facilities to match slow, mechanical read-out devices to high-speed electronic computing units. Data can be presented in words, numbers or symbols — 63 characters are available.

memotron ... for the display of single transients, or superimposing transients for direct analysis and comparison ... plotting a family of curves ... viewing transients from shock or vibration tests and ballistics or missile tests ... monitoring phase relationships ... electrocardiographic and vectorcardiographic diagnosis ... presentation of tube or transistor characteristics.

tonotron*

The Tonotron storage tube presents a complete spectrum of grey shades for high-fidelity picture reproduction. High brightness and controlled persistence are the outstanding characteristics of the Tonotron tube. This new method of direct display may be presented at brightness in excess of 1500 foot lamberts. A conventional cathode ray tube used in radar environment operates with brightness of less than one foot lambert.

The Tonotron has the elements of a standard cathode-ray tube in addition to a storage surface, a secondary-electron collector, and a flood gun. Writing guns are available with electrostatic focus and either electrostatic or electromagnetic deflection.

The storage surface is an electroformed nickel mesh coated with dielectric on the side facing the electron guns. Initially, the dielectric has a negative potential with respect to the flood-gun cathode, so that the tube surface appears black. When the writing gun bombards the dielectric with high energy electrons, secondary emission causes the storage mesh to become more positively charged in the written areas. The secondary electrons liberated from the storage dielectric are attracted to the secondary-electron collector. Flood electrons penetrating the storage surface in the charged areas are accelerated to the viewing screen where they produce the corresponding pattern. The storage surface, acting like a control grid, regulates the quantity of flood electrons striking the viewing screen. A high positive charge corresponds to a bright area. At intermediate potentials only part of the flood beam passes through the viewing screen, thus producing intermediate shades of grey or half tones.

Since the flood electrons reproduce the charge pattern but do not regenerate it, the maximum retention time is limited. Degeneration of the charge is produced primarily by the positive ions produced from residual gas molecules. Thus, the maximum storage time for the tube operating in standard conditions is approximately 60 seconds. It is possible, however, by utilizing pulsing techniques, to extend this time to more than five minutes. Either instantaneous erasure or a controlled gradual decay may be effected by applying a single positive pulse or series of pulses to the storage electrode.

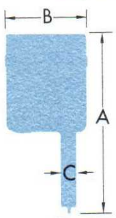
persistence and rate of decay can be controlled to suit specific application

*TRADEMARK OF HUGHES AIRCRAFT COMPANY

TYPE 7033 5 INCH DIRECT DISPLAY HALF-TONE STORAGE TUBE

GENERAL SPECIFICATIONS

Heaters (two) .... 6.3 volts
Phosphor .... Green-Yellow P20, aluminized (others available on special order)
Focusing method .... Electrostatic
Deflection method .... Magnetic
Resolution .... 65 lines/inch avg.
Writing speed .... 100,000 inches/second avg.
Erasure time .... 125 milliseconds avg.
Brightness at 9000 volts .... 2000 foot lamberts
at 4000 volts .... 300 foot lamberts



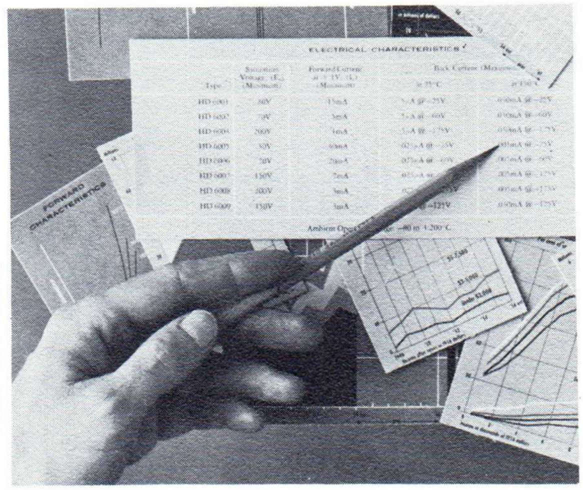
Dimensions

A. Overall length .... 11-1/8 ± 3/8″

B. Greatest diameter of bulb... 5-5/8″ max.

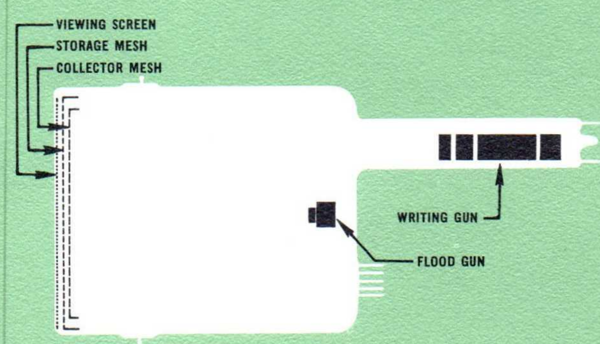
C. Neck diameter .... 1″ ± 1/16″

Useful screen diameter.......... 4″
Body base connections (Miniature 7-pin JEDEC No. E7-1)
Neck base connections (Miniature 7-pin JEDEC No. E8-11)



With a Tonotron tube, sharp, clear pictures may be transmitted over conventional telephone lines through use of slow-scan, narrow-band, closed-circuit television. This eliminates the need for costly coaxial cable transmission. High fidelity pictures may be examined at very slow rates, even "frozen" for photographing.

High light output of the Tonotron storage tube presents a brilliant half-tone picture on weather radar even when viewed in full daylight without the requirement for a hood. Length of persistence and rate of decay may be selected.



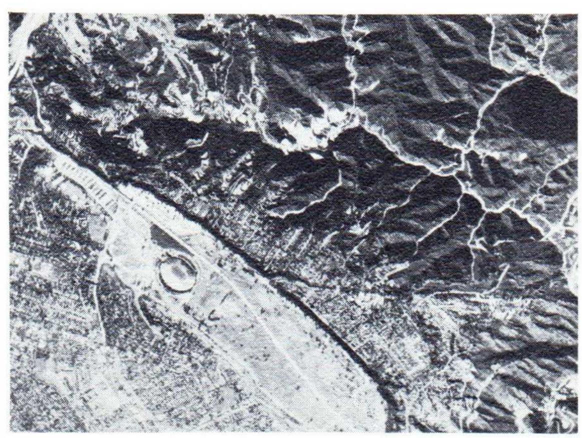
TYPICAL OPERATING CONDITIONS*

Viewing-screen voltage .... 4000 to 8000 volts
Storage-electrode voltage (DC bias) .... 5 volts
Collector-electrode voltage .... 120 volts
Third-anode voltage .... 20 to 40 volts
Second-anode voltage .... 5 to 30 volts
First-anode (flood gun) voltage .... 80 volts
Cathode (flood gun) voltage .... 0 volts
Control-grid (writing gun) voltage*..........—30 to —90 volts
First-anode (writing gun) voltage for focus*.... 350 to 750 volts

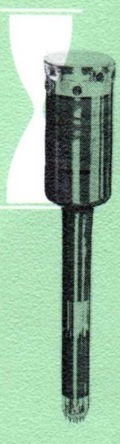
*All voltages are given with respect to the flood-gun cathode, except those starred, which are given with respect to the writing-gun cathode.

OTHER MODELS AVAILABLE:

3 inch, One gun, electrostatic deflection
4 inch, Two gun, electrostatic deflection
5 inch, One and Two gun, electrostatic deflection
21 inch, One gun, magnetic deflection



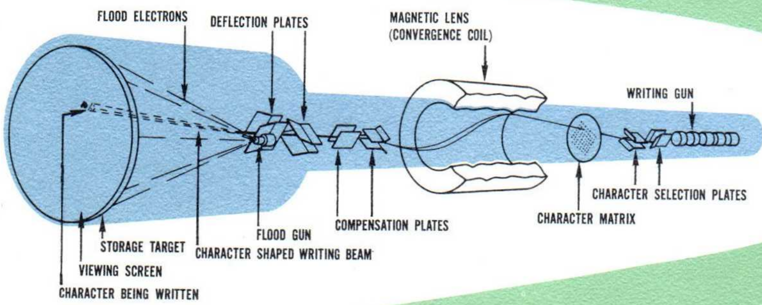
Used in a radar PPI display scope, the Tonotron electron tube has the ability to cover the complete grey scale spectrum and provides maximum contrast for easy identification of cloud formations, ground clutter, and targets. Persistence may be adjusted for maximum duration over most of the 360 degrees, fading to black just ahead of the sweep.

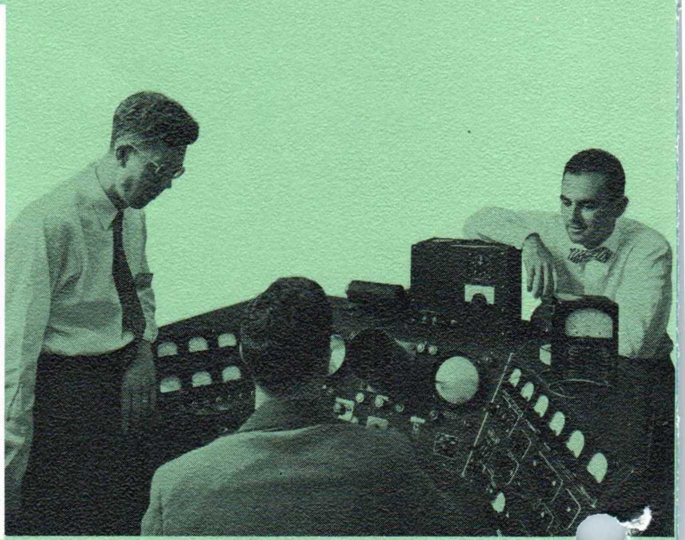


typotron®

In the Typotron storage tube a choice of 63 characters is available for the presentation of data in words, numbers or symbols. The Typotron tube writes characters 1/8 inch in size at speeds of at least 25,000 characters per second; the characters can be photographed or recorded for later examination. Able to present information which remains visible indefinitely without fading or blooming until intentionally erased, the Typotron is used as a read-out computer device in such applications as the radar-tracking console shown in the accompanying illustration.

Heart of the Typotron electron tube is a character matrix or stencil comprising the letters, numbers and symbols. The desired character is selected by applying the proper voltage to the two pairs of selection plates. The magnetic lens or convergence coil inverts the image of the character and focuses it on the storage screen. Compensation plates redirect the image along the tube axis and between the deflection plates. Positioning voltages applied to these deflection plates place the image at any desired place on the tube face. A flood gun mounted alongside one of the deflection plates covers the entire storage target with a barrage of low-velocity electrons to produce a bright visible picture. The bistable storage target is described under "Memotron."





TYPE 6577 5 INCH CHARACTER WRITING CATHODE-RAY STORAGE TUBE

GENERAL SPECIFICATIONS

Heaters (two)	6.3 Volts
Phosphor	Green PI
Focusing Method	Electrostatic
Deflection Method	Electrostatic
Imaging of Characters	Magnetic
Writing Speed	25,000 characters/sec
Erasure Time	200 milliseconds
Light Output, typical	18-20 foot lamberts @ 3KV on view screen

Dimensions

A. Overall Length	30-1/4″ maximum
B. Greatest Diameter of Bulb	5-5/8″ maximum
C. Neck Diameter	2-1/4″ ± 3/32″

Useful Screen Diameter	4″
Base	13 Pin Glass Stem
Mounting Position	Any

TYPICAL OPERATING CONDITIONS

Viewing Screen	3000 volts
Ion Repeller Mesh Voltage	250 volts
Second Anode Voltage	200 volts
Collector Mesh Voltage	150 to 200 volts
Third Anode Voltage	150 volts
Storage Mesh Voltage	0 volts
Control Grid (Flood Gun) Voltage	—50 to —200 volts
Cathode (Writing Gun) Voltage	—3100 volts
First Anode (Writing Gun) Voltage, for focus	300 to 800 volts*
Control Grid (Writing Gun) Voltage, for cutoff	—40 to —70 volts*
Convergence Coil Current	50 mA

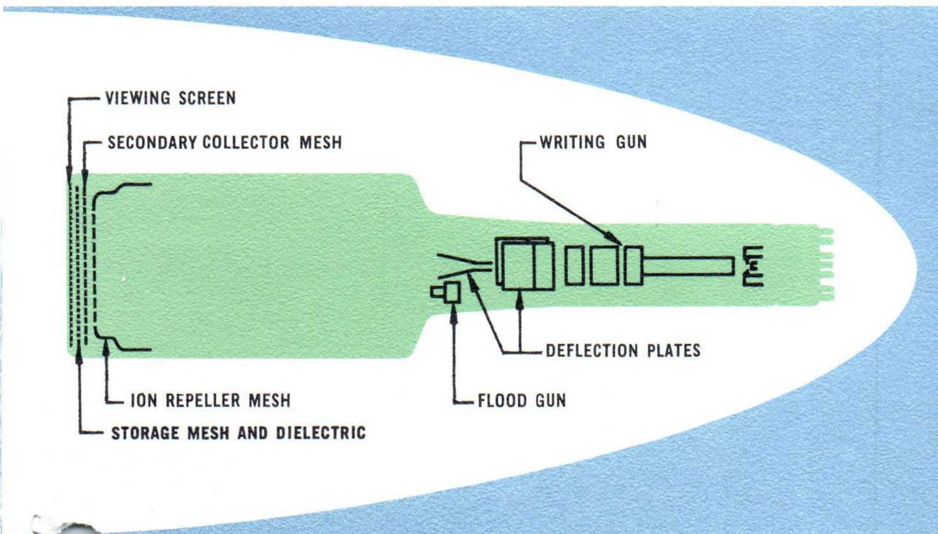
*All voltages are given with respect to the flood gun cathode potential except those marked (*) which are given with respect to the writing gun cathode.

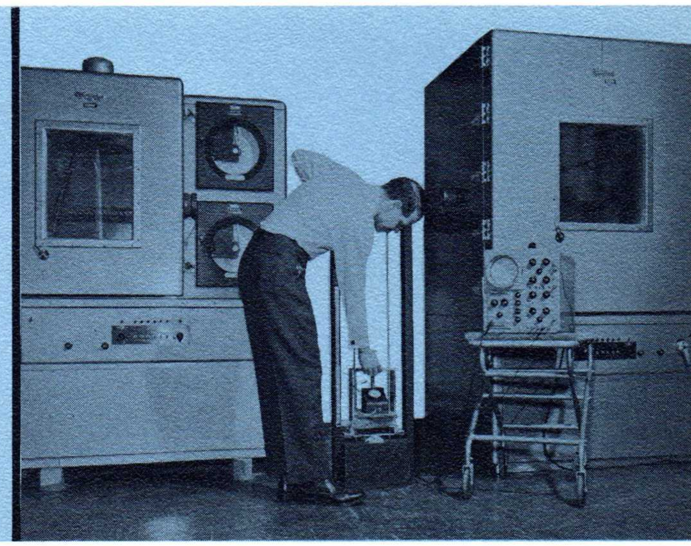
Special matrices can be designed to suit specific applications.

memotron®

The Memotron storage tube captures and retains electrical traces and transients which could formerly be analyzed only after elaborate photography or reliance on the operator's visual acumen. For comparison of successive wave forms, transients may be superimposed one upon the other or vertically stacked. Displays occur at uniform brightness regardless of writing speeds, so are easily photographed. The presentation will remain bright enough for viewing in a well lighted laboratory or even in broad daylight until intentionally erased. A typical application — a Hughes Memo-Scope® oscilloscope applied to view transients in shock testing — is shown in the accompanying illustration.

The unique storage feature of the Memotron tube is made possible by an arrangement of meshes behind the viewing screen. A storage mesh coated with a dielectric retains a positive charge pattern, due to secondary emission wherever it is struck by the writing beam. A positively charged collector mesh — directly behind the storage mesh — collects secondary electrons, preventing them from neutralizing the charge formed on the storage dielectric. The stored image, achieved by the bistable characteristics of the storage dielectric, is continuously maintained and visually displayed on the phosphor-coated tube face by a low-velocity beam of electrons from the flood gun. The flood electrons are passed through the charged areas and receive additional energy from the post-accelerating potential applied to the viewing screen. The image is erased by momentarily lowering the secondary-collector voltage. This prevents collection of secondary emission electrons from the dielectric, causing "written" portions of the dielectric to be neutralized by flood-gun electrons.

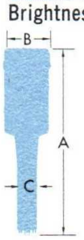




TYPE 6498 5 INCH DIRECT DISPLAY BISTABLE STORAGE TUBE

GENERAL SPECIFICATIONS

Heaters (two)	6.3 volts
Standard phosphor	Green PI (others available on special order)
Focusing method	Electrostatic
Deflection method	Electrostatic
Resolution	60 lines/inch avg.
Writing speed	100,000 inches/second avg.
Erasure time	100 milliseconds avg.
Brightness	40 foot lamberts avg.



Dimensions

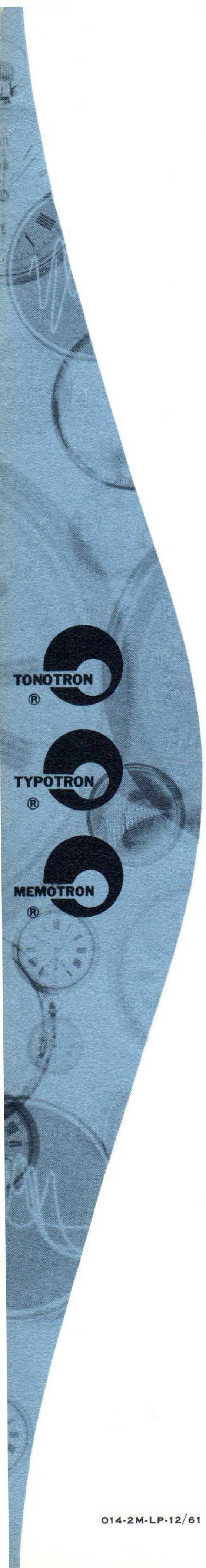
A. Overall length	18-1/2″ ± 1/2″
B. Greatest diameter of bulb	5-5/8″ maximum
C. Neck Diameter	2-1/4″ ± 3/32″

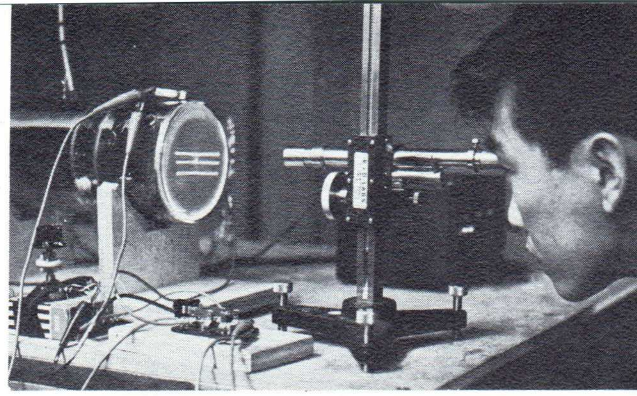
Useful Screen Diameter	4″
Base (JEDEC No. B14-38)	Small-shell di-heptal 14 pin

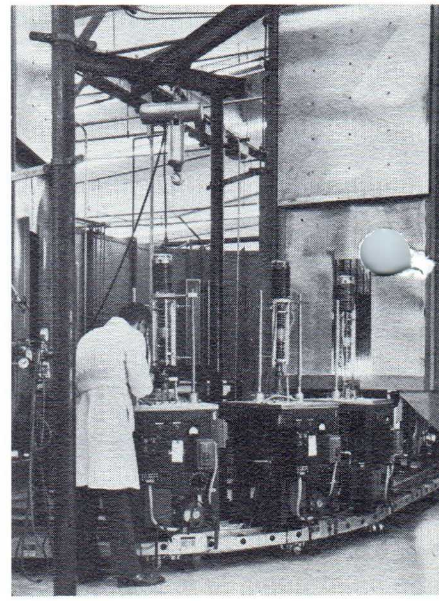
TYPICAL OPERATING CONDITIONS

Viewing screen voltage	3000 volts
Ion repeller mesh voltage	250 volts
Second anode voltage	200 volts
Collector mesh voltage	85 to 200 volts
Third anode voltage	150 volts
Storage mesh voltage	0 volts
Control grid (flood gun) voltage	—20 to —100 volts
Cathode (writing gun) voltage	—3000 volts
First anode (writing gun) voltage, for focus	450 to 1050 volts*
Control grid (writing gun) voltage, for cutoff.	—40 to —80 volts*

*All voltages are given with respect to the flood gun cathode potential except those marked (*) which are given with respect to the writing gun cathode.







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CREATING A NEW WORLD WITH ELECTRONICS

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CREATING A NEW WORLD WITH ELECTRONICS

HUGHES

HUGHES AIRCRAFT COMPANY
VACUUM TUBE PRODUCTS DIVISION

TYPE H-1084 — 5" MULTI-MODE TONOTRON TUBE

TYPE H-1084AP20* AND H-1084BP20* MULTI-MODE TONOTRON**

5-inch direct view half-tone storage tube, capable of simultaneous presentation of stored and non-stored information, selective erasure, and high resolution light or dark trace display.

GENERAL DESCRIPTION

The Type H-1084 multi-mode Tonotron tube is a 5-inch direct view half-tone storage tube whose designation, "multi-mode", is descriptive of its capability to perform several functions unique in storage tube operation: (1) Simultaneous display of both stored and non-stored information plus simultaneous erasure, (2) Selective erasure, whereby any or all storage surface elements may be erased gradually or rapidly - or a combination of both simultaneously, and (3) Dark trace display, enabling presentation of a "negative" picture having an inherent resolution twice that of a normal display, and accomplished by "erasing" information into a fully written storage pattern.

These functions are made possible by utilizing a "dual-effects" dielectric at the storage structure and employing four electron guns: a low energy flood gun (f) and three high energy guns whose designations suggest their normal application – write gun (w), erase gun (r), and non-store write gun (n). Electrostatic focus and deflection are used.Internal construction of the tube is illustrated in Fig. 1, Schematic Diagram.

OPERATING PRINCIPLES

DUAL-EFFECT STORAGE SURFACE

The principles of operation of this tube are based on the ability of the storage surface dielectric to demonstrate the property of secondary emission, and/or that of BOMBARDMENT-INDUCED-CONDUCTIVITY, depending wholly upon the level of the incident-beam energy. At low beam energies, secondary emission is the predominant effect, charging the storage surface in a positive direction, resulting in stored writing. Conversely, at high beam energies, the bombardment-induced-conductivity effect takes precedence, discharging the storage surface and thus erasing. At some intermediate level the two effects balance, permitting the display of non-stored information, a function sometimes referred to as "write-through".

SELECTIVE ERASURE

The property of the storage surface dielectric in the Type H-1084 multi-mode tube is such that the bombardment-induced-conductivity effect becomes substantial when the energy level of the erase gun is 6 KV. or greater.

Storage action in this tube is the same as that observed in conventional half-tone storage tubes when written upon by the moderately high energy write beam. A positive

SELECTIVE ERASURE (CONTINUED)

charge pattern is established on the dielectric surface by this gun because of the secondary emission property of the dielectric material.

When the higher energy erase gun bombards the storage surface with its electrons, the surface potential of the dielectric is conducted toward the backing electrode potential (negative) by the currents induced in the dielectric. This condition occurs ONLY in the bombarded areas. The degree of erasure is controllable by varying the beam current; therefore, half-tones are capable of being erased into a written area.

Erasure speed is determined by two operating parameters, beam energy and backing electrode potential; both have a threshold which must be reached before successful erasure can occur. The erase beam voltage must be at least 5.9 KV. to cause appreciable bombardment-induced-conductivity, and the negative backing electrode potential must be at least equal to the storage surface cut-off potential. Erase speed increases when the beam voltage increases, or when the backing electrode is made more negative.

In practice, erase speeds in the order of 50,000 to 100,000 inches per second may be obtained at beam voltages between 6 and 6.5 KV. The backing electrode voltage can be varied between −5 and −25 volts; its exact value is determined by the storage time desired, and will vary from tube to tube. Increasing backing electrode voltage in a positive direction results in increasing storage time.

NON-STORE DISPLAY (WRITE-THROUGH)

Since the secondary emission writing and bombardment-induced-conductivity erasure are examples of the addition and subtraction of charges, and their rates are finite and controllable, it is possible by adjusting the energy of the bombarding electrons to cause these opposing effects to become equal. In other words, as much charge is deposited on the surface by secondary emission as is conducted to the backing electrode by bombardment-induced currents. When this occurs, the beam is seen on the tube view screen in its unstored mode, without serious disturbance to the information already stored in that area.

The presentation of non-stored information in this tube is accomplished by using a separate non-storage write gun (n) which is operated at the required non-store level, approximately 4.5 KV.

** These are developmental tubes. Data presented herein are accurate as of Feb. 15, 1962 but are subject to change without notice. No obligation for future manufacture is assumed unless specifically arranged.*

*** Tonotron is a trademark of the Hughes Aircraft Company.*

OPERATING PRINCIPLES (CONT.)

DARK-TRACE DISPLAY (INCREASING RESOLUTION)

When operating in the normal manner, that is, writing and storing information with the low energy write beam, the resolution of the Type H-1084 multi-mode Tonotron tube is equivalent to that of conventional Tonotron tube types. However, if the low energy write gun is utilized as a "white erase gun" and the video information is applied to the high energy erase gun grid no. 1, so that a picture is erased into the storage surface, resolution is approximately doubled; 100 to 120 written lines per inch are representative values. This greater resolution is produced by the higher beam energy of the erase gun. If normal aspect pictures are desired rather than the "negative" effect resulting from this method, the video information can be inverted before application to the erase gun grid.

For a more detailed discussion of the operating principles of cathode-ray charge storage display tubes having selective erase capabilities, please refer to "Operation of the Hughes Multi-mode Tonotron", Engineering Application Note 91-19A-13, which is available on request.

GENERAL SPECIFICATIONS

OPTICAL DATA

Phosphor number . . . . P20* aluminized
Fluorescent color . . . . Green-yellow
Phosphorescent color . . . . Green-yellow
Face plate . . . . Flat, clear glass

MECHANICAL DATA (SEE OUTLINE DRAWINGS)

MAXIMUM ELECTRICAL RATINGS

All voltages are given with respect to the flood gun cathode (fk) except those indicated by the symbol ▲ , where values are given with respect to the particular high-energy gun cathode — write gun cathode (wk), erase gun cathode (rk), or non-store write gun cathode (nk). The figures represent MAXIMUM RATINGS, NOT OPERATING VOLTAGES and therefore should not be exceeded under any circumstances.

Cathode, flood gun (fk) . . . . 0 volts
Cathode, write gun (wk) . . . . –3000 volts
Cathode, erase gun (rk) . . . . –6500 volts
Cathode, non-store write gun (nk) . . . . –5500 volts
Grid No. 1, flood gun (fg1)
- Negative bias . . . . –200 volts
- Positive bias . . . . 0 volts
- Positive peak voltage . . . . 2 volts

Grid No. 1, write gun (wg1), erase gun (rg1), and non-store write gun (ng1)▲
- Negative bias . . . . –250 volts
- Positive bias . . . . 0 volts
- Positive peak voltage . . . . 2 volts

Grid no. 2, all guns . . . . 200 volts
Grid no. 3, flood gun (fg3) . . . . 200 volts
Grid no. 4, flood gun (fg4) . . . . 200 volts
Collector electrode (ce) . . . . 250 volts
Backing electrode (be) . . . . –25, +25 volts
View screen (vs) . . . . 7500 volts
Grid No. 3, all guns except flood gun (wg3, rg3 and ng3) ▲ . . . . 2000 volts
Peak Heater-to-cathode voltage, all guns except flood gun . . . . ±125 volts

MAXIMUM CIRCUIT VALUES

Grid No. 1 circuit resistance, each gun . . . . 1 megohm
Backing electrode . . . . 5000 ohms

MINIMUM CIRCUIT VALUES

Collector electrode (ce) . . . . 1000 ohms
View screen (vs) . . . . 1 megohm

TYPICAL OPERATING CONDITIONS

All voltage values are given with respect to the flood gun cathode except those indicated by the symbol ▲ , which are given with respect to the particular gun cathode specified.

VIEWING SECTION

View screen voltage (Evs) . . . . +7000 volts
Backing electrode voltage (Ebe) . . . . . . –5 to –25 volts**
Collector electrode voltage (Ece) . . . . +160 volts
Grid no. 4 voltage (fEc4); adjust for optimum collimation . . . . +30 to +100 volts
Grid no. 3 voltage (fEc3); adjust for optimum collimation . . . . +30 to +100 volts
View screen current . . . . 0 to 700 μa
Backing electrode current . . . . –15 to +75 μa
Collector electrode, grid no. 4 and grid no. 3 currents (Ice, fIc4 and fIc3), each less than . . . . 2 ma.

FLOOD-GUN

Cathode voltage (fEk) . . . . 0 volts
Cathode current (fIk) . . . . 0 to 4 ma.
Grid no. 1 operating bias (fEc1), adjusted for full coverage of the view screen . . . . 0 to –30 volts
Grid no. 1 cut-off voltage . . . . –60 to –120 volts
Grid no. 2 voltage (fEc2) . . . . +100 volts
Heater voltage (fEh) . . . . 6.3 volts, ±5 percent, AC or DC
Heater current (fIh) . . . . 0.6 amp.

HIGH ENERGY GUNS

	WRITE GUN	ERASE GUN	NON-STORE WRITE GUN
Cathode voltage	–2000 volts	–6200 volts	–4500 volts
Cathode current	0 to 2000 μa	0 to 2000 μa	0 to 2000 μa
Grid no. 1 voltage for undeflected focused spot cut-off ▲	–70 to –140 v.	–70 to –140 v.	–65 to –135 v.
Grid no. 3 voltage at optimum focus▲	275 to 550 v.	925 to 1425 v.	600 to 1100 v.
Deflecting plates, average voltage	+100 volts	+100 volts	+100 volts
Deflection factor, horiz. and vert. Plate pairs	60 volts/in.	160 volts/in.	135 volts/in.
	(wD1, wD2)	(rD1, rD2)	(nD1, nD2)
	(wD3, wD4)	(rD3, rD4)	(nD3, nD4)

Orientation (looking at the tube face when the view screen lead is at top of the tube)

wD3, wD4, rD1, rD2, nD3 and nD4 produce vertical deflection.

wD1, wD2, rD3, rD4, nD1 and nD2 produce horizontal deflection.

Relative deflecting plate locations

wD1, wD2, rD1, rD2, nD1, and nD2 are closer to the view screen.

wD3, wD4, rD3, rD4, nD3 and nD4 are closer to their cathodes.

* *Other phosphors available on request*

** *These values apply when the various guns are operated in their designated functions; however, if it is desirable to operate the tube in conventional half-tone mode-that is, obtain the same high light output performance but without the selective erasure or non-store display features, +5 volts may be applied to the backing electrode and the write gun employed to write half-tone stored information.*

TYPICAL OPERATING CONDITIONS

HIGH ENERGY GUNS (CONTINUED)

Deflection direction

Positive voltage at wD4, rD1 or nD4 deflects beam toward bulb contact no. 1 (view screen) for H-1084AP20* Positive voltage on wD1, rD3 or nD1 deflects beam toward bulb contact no. 6 (backing electrode) for H-1084AP20**

Heater voltage, all guns
6.3 volts, ±5 per cent, AC or DC

Heater current, all guns
0.6 amp

Examination of Fig. 1, Cut-away diagram of the Type H-1084 multi-mode Tonotron reveals that both the writing and non-stored writing guns are aligned parallel to the longitudinal axis of the tube, while the selective erase gun is inclined with respect to that axis.

Looking at the tube face, with the viewing screen contact or lead at the top of the tube, undeflected spot positions are approximately as follows: (1) for the selective erase gun, the center of the viewing screen; (2) for the writing gun, 0.4 inches above and 0.55 inches to the right of the viewing screen horizontal and vertical center lines, and (3) for the non-store writing gun, 0.4 inches above and 0.55 inches to the left of the respective center lines.

CIRCUITRY

The circuits required to operate the Type H-1084 multi-mode Tonotron tube fall into three categories: signal (video and deflection) circuits, static voltage supplies, and protective circuits.

SIGNAL CIRCUITS

A video signal of approximately 70 volts is required to drive the erase gun at lineal speeds of 100,000 inches per second. As writing speed is decreased, the required video drive also decreases until, at 8,000 inches per second, it is reduced to about 15 volts. Similar considerations also apply for drive requirements of the write and non-storage write guns.

Deflection circuitry for the high energy (write, erase, and non-storage write) beams is conventional; however, since appreciable currents are drawn by the deflecting plates, coupling to them with cathode followers is recommended.

STATIC-VOLTAGE SUPPLIES

Static voltages required are listed under TYPICAL OPERATING CONDITIONS and may be readily furnished by conventional power supplies. There should be provisions for convenient adjustment of several electrode voltages: (1) Flood gun grid no. 4 (fEc4), for collimation of the floodbeam, (2) Flood gun grid no. 1 voltage (fEc1), to obtain full beam coverage of the storage area, (3) Backing electrode voltage (Ebe), for optimum storage over a range of conditions, and (4) High energy gun grid no. 3 voltages (wEc3, nEc3 and rEc3) for proper focus. Since the high energy gun cathodes do not operate at ground potential, either grid no. 1 (control-grid) driving circuits must be referenced to the cathodes or exceptionally good regulation must be incorporated into the cathode potential power supplies. Since electrostatic focusing is proportional, care must be taken to preserve the focusing ratio in order to maintain a good spot. This implies either a proportional focus voltage or well regulated cathode and focus voltages. Approximately equal deflecting electrode circuit resistances are recommended.

PROTECTIVE CIRCUITS

Due to the high internal voltage gradient between the backing electrode and the view screen, it is advisable to provide protection against excessive surge currents. For the view screen, a limited-energy-type power supply with a 1 ma., maximum, short circuit current is preferred. In any event, a high voltage protective resistor of at least 1 megohm should be connected in series with the view screen lead.

COLLIMATION ADJUSTMENT

For proper collimation of the Type H-1084 multi-mode Tonotron tube, the following relatively simple, yet effective collimating procedure is recommended:

1. Set collimating voltages (flooding gun grid no. 3 and no. 4) to the values specified in the data which accompanies each tube, and set the backing electrode to the positive end of its range, −5 volts.
2. Apply potentials to the viewing section and to the electrodes of all guns.
3. With the writing gun, write the display to equilibrium brightness.
4. Adjust flooding gun grid no. 4, then grid no. 3 for the brightest and most uniform display possible.
5. Increase backing electrode voltage in a negative direction to bring the display to a low half-tone level. Carefully check display uniformity.
6. Reset backing electrode voltage, then repeat steps 3 and 4.
7. Repeat step 5. If uniformity is essentially the same as before, optimum collimation is indicated; if not, repeat steps 3, 4, and 5 until such condition is reached.

MECHANICAL NOTES, TYPE H-1084AP20

GENERAL

The Type H-1084AP20 multi-mode Tonotron tube may be mounted in any position required for viewing. Where application of the tube under conditions of extreme shock or excessive vibration is contemplated, the use of shock or vibration mounts, as applicable, is recommended to minimize possibility of damage.

When installing the tube, support should be provided by felt or rubber bumper strips placed inside the magnetic shield (see following paragraph); install four of these bumper strips around the major diameter of the tube between the face plate and bulb contacts, and four more behind the bulb contacts about one-inch in front of the bulb to neck junction.

CAUTION: Under no circumstances should the weight of the tube be supported by the tube neck or by the base-lead encapsulant.

MAGNETIC SHIELDING

Proper performance of the tube requires that it be installed within a suitable magnetic shield fabricated from a special metal alloy. This is necessary because flood beam collimation may be seriously impaired if influenced by undesirable magnetic fields — even one of such low intensity as that of the earth.

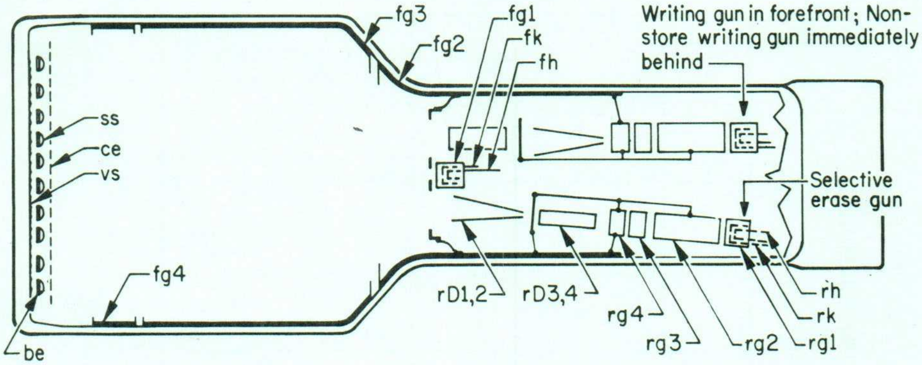
MECHANICAL NOTES, TYPE H-1084BP20

Type H-1084BP20 is operationally identical to Type H-1084AP20, but is furnished with an integral magnetic shield, and with all leads potted for improved environmental resistance.

** Deflection is toward bulb lead no. 1 for H-1084BP20*

*** Deflection is 90° to the right of bulb lead no. 1 for H-1084BP20*

FIGURE 1 SIMPLIFIED CUT-AWAY DIAGRAM



Electrode designations for the writing gun and non-store writing gun are the same as those shown for the selective erase gun except that the initial letter becomes "w" and "n" respectively, rather than "r".

FIGURE 2 OUTLINE DRAWING H-1084AP20

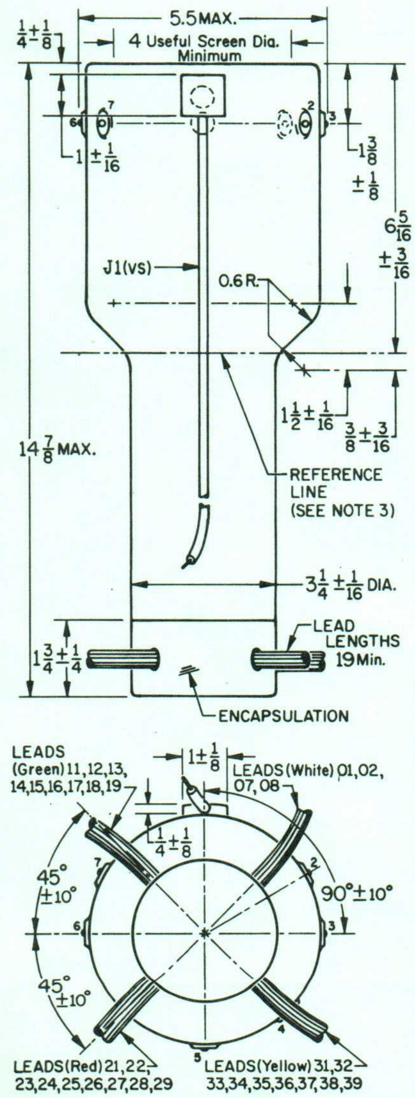
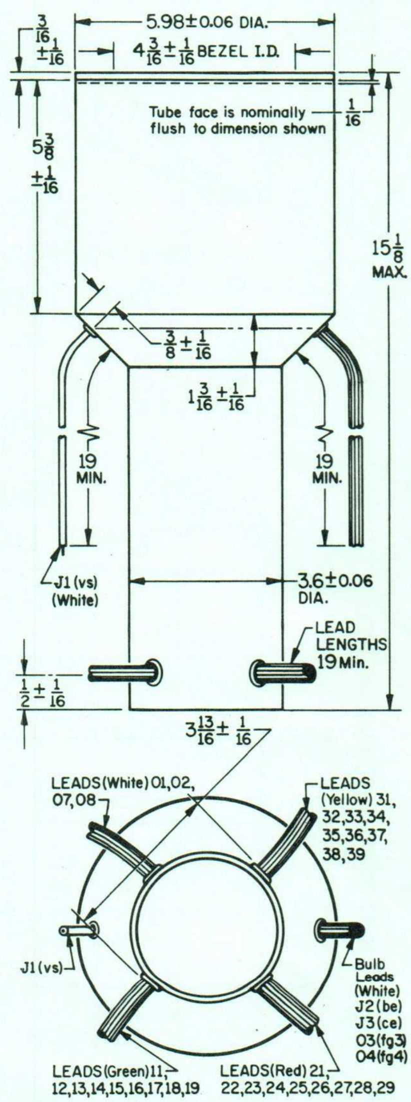


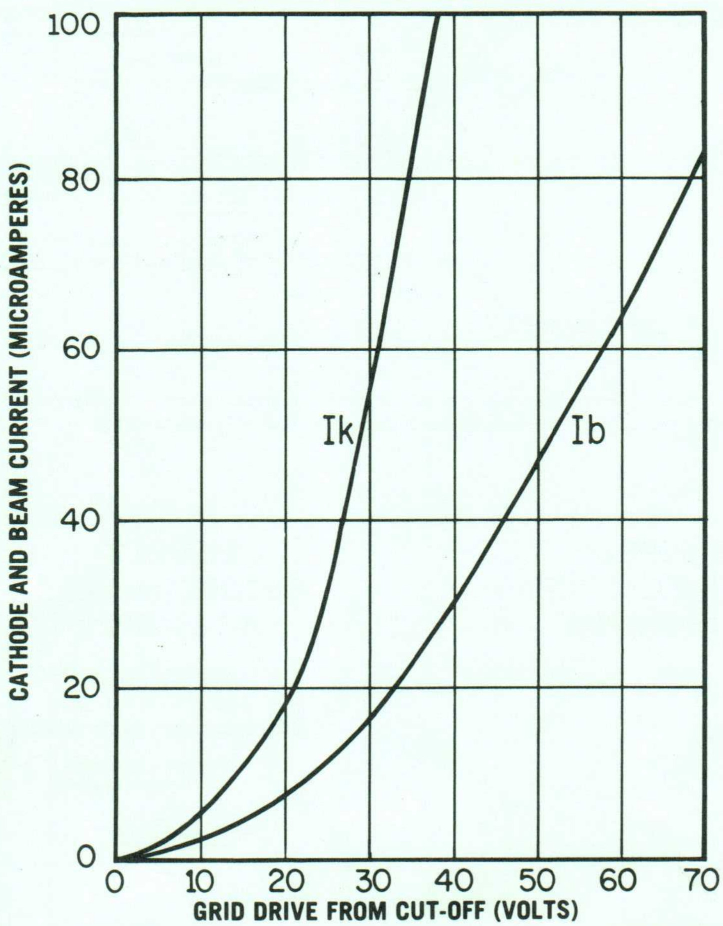
FIGURE 3 OUTLINE DRAWING H-1084BP20



NOTES:

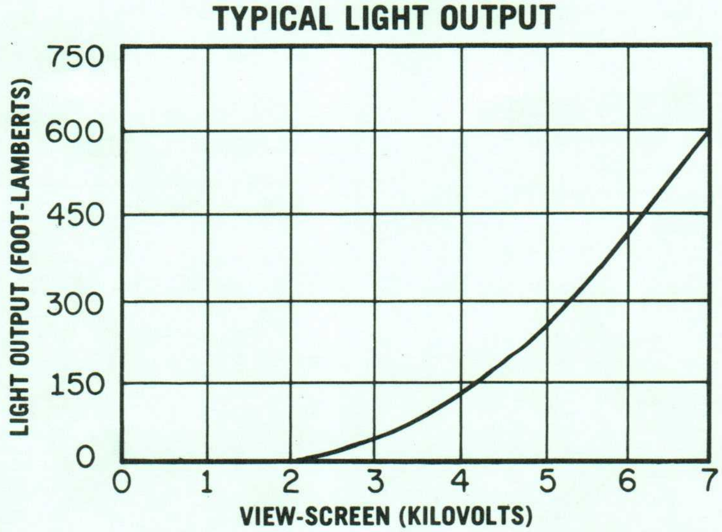
1. *All dimensions in inches.*
2. *Minimum lead length 19 inches.*
3. *Reference line is that point where a 3.500 I.D. Ring Gauge comes to rest against body of funnel neck.*

FIGURE 5
TRANSFER CHARACTERISTICS FOR ALL HIGH ENERGY GUNS



wEk . . . . −2500 volts
nEk . . . . −4500 volts
rEk . . . . −6200 volts
wEc3, nEc3, rEc3, ... Adjust for focus
wEc2, nEc2, rEc2 . . . . +100 volts
Front-end Electrodes . . . . all +160 volts

FIGURE 6
TYPICAL LIGHT OUTPUT



Ebe . . . . Optimum erase *
Ece . . . . +160 volts
fEc2 . . . . +100 volts
fEc3, fEc4 . . . . Adjust for most uniform display

* *The value of backing electrode potential between limits of −5 and −25 volts at which the best balance between storage time and completeness of selective erasure occurs.*

FIGURE 4
SCHEMATIC/CONNECTION DIAGRAM
TYPE H-1084AP20

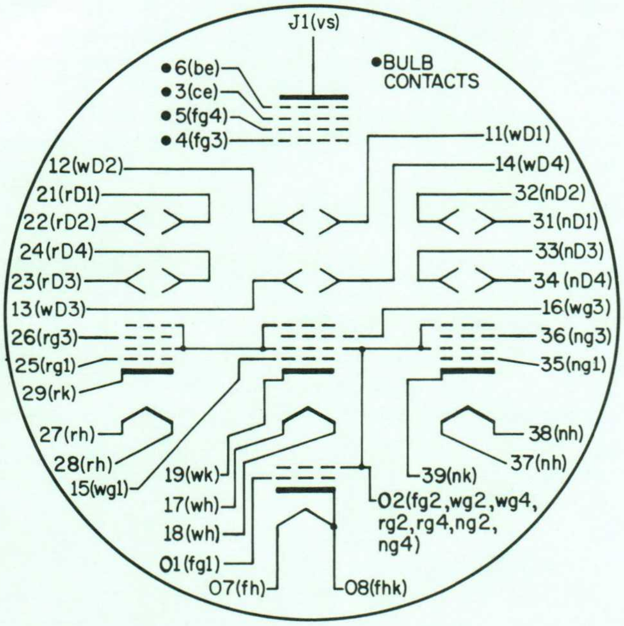
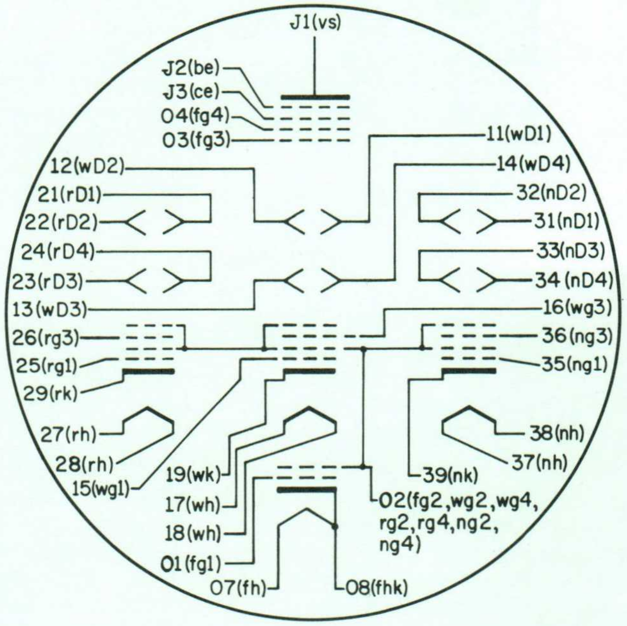


FIGURE 4A
SCHEMATIC/CONNECTION DIAGRAM
TYPE H-1084BP20



WIRE LIST (BASE CONNECTIONS) H-1084AP20 AND H-1084BP20

WIRE NO.	ELECTRODE	SYMBOL
01	Grid no. 1	fg1
02	Grid nos. 2 and 4	fg2, wg2, wg4, ng2, ng4, rg2, rg4
07	Heater	fh
08	Heater-cathode	fhk
11	Deflecting plate	wD1
12	Deflecting plate	wD2
13	Deflecting plate	wD3
14	Deflecting plate	wD4
* 15	Grid no. 1	wg1
* 16	Grid no. 3	wg3
* 17	Heater	wh
* 18	Heater	wh
* 19	Cathode	wk
21	Deflecting plate	rD1

WIRE NO.	ELECTRODE	SYMBOL
22	Deflecting plate	rD2
23	Deflecting plate	rD3
24	Deflecting plate	rD4
* 25	Grid no. 1	rg1
* 26	Grid no. 3	rg3
* 27	Heater	rh
* 28	Heater	rh
* 29	Cathode	rk
31	Deflecting plate	nD1
32	Deflecting plate	nD2
33	Deflecting plate	nD3
34	Deflecting plate	nD4
* 35	Grid no. 1	ng1
* 36	Grid no. 3	ng3
* 37	Heater	nh
* 38	Heater	nh
* 39	Cathode	nk

BULB CONTACT CONNECTIONS H-1084AP20

**J1	Viewing screen	vs
2	Unused; internal connection	
3	Collector electrode	ce
4	Grid no. 3	fg3
5	Grid no. 4	fg4
6	Backing electrode	be
7	Unused; internal connection	

BULB WIRE CONNECTIONS, H-1084BP20

**J1	Viewing screen	vs
J2	Backing electrode	be
J3	Collector electrode	ce
03	Grid no. 3	fg3
04	Grid no. 4	fg4

Wires are color coded as follows: WHITE - Flooding gun and viewing section. GREEN - Writing gun. YELLOW - Non-store writing gun. RED - Selective erase gun.

* *SEHV (5) 19/34A-45*
** *SEHV (15) 19/32A (66)*
All other leads MIL-W-16878C, Type B.

CRST-18/3M/SDB/7-62

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MINIATURIZED 5-INCH DIRECT VIEW DISPLAY HALF-TONE STORAGE TUBE WITH ELECTROSTATIC FOCUS AND ELECTROMAGNETIC DEFLECTION

T5M-4C
8-63

VTP

TYPE H-1076AP20* TONOTRON***

AVERAGE PERFORMANCE SUMMARY**

Viewing screen brightness . . . . 2000 foot-lamberts
Viewing time . . . . 180 seconds
Writing speed . . . . 60,000 inches per second
Written resolution . . . . 60 lines per inch
Erase time . . . . 160 milliseconds
Usable levels . . . 7, including extremes of "black" and "white"

1.0 GENERAL DESCRIPTION

The Type H-1076AP20 Tonotron is a 5-inch cathode ray charge storage display tube which provides a bright visual presentation, for direct viewing, of electrically stored information. Because of its short overall length and light weight, the tube is especially suitable for airborne service in radar, navigational aid, and other specialized applications where bright, flicker free patterns are required for observation or for photographic record. Electrostatic focus and electromagnetic deflection are employed.

Bulb connections are encapsulated, and the tube is furnished with a magnetic shield. Principal dimensions and details are shown in Fig. 2, Outline Drawing, page 7.

2.0 GENERAL SPECIFICATIONS

2.1 OPTICAL DATA

Phosphor number . . . . P20 (aluminized)
  Fluorescent color . . . . Yellow-green
  Phosphorescent color . . . . Yellow-green
Face plate
  Radius of Curvature . . . . Flat
  Useful screen diameter . . . . 4 inches, minimum

2.2 MECHANICAL DATA

Dimensions . . . . Refer Fig . 2, page 7
Base and lead connections . . . . Refer to ELECTRODE CONNECTIONS, back cover
Operating position . . . . Any
Base and socket . . . . JEDEC B7-183 (modified); requires socket Type S-650R manufactured by Methode Mfg. Co., Chicago, Ill., or equivalent
Weight (tube integral with shield) . . . . 3¼lb., approx.
Ambient temperature range,
  operating and non-operating . . . . −55° to +85°C.

**Type H-1076AP20 is a developmental tube. Data presented herein are accurate as of 1 May 1963, but are subject to change without notice. No obligation for future manufacture is assumed unless specifically arranged.*

***Specified conditions for these values are given in Paragraph 6.0, "Average Performance Notes", page 4.*

**** TONOTRON is a trademark of Hughes Aircraft Company.*

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TABLE OF CONTENTS

DRAWINGS AND CURVES

3.0 MAXIMUM ELECTRICAL RATINGS

All voltages are given with respect to the flooding gun cathode (fk), except those indicated by the symbol ▲, where values are referenced to the writing gun cathode (wk). MAXIMUM ELECTRICAL RATINGS define those voltages which may be applied to the tube without damage, but which may not give required performance.

CAUTION: The flooding beam must cover the entire viewing screen area, and writing beam current must be held within safe limits for the sweep speed used.

3.1 STORAGE DISPLAY SECTION

Viewing screen, Evs .... +11,000 volts
Viewing screen dissipation, Pvs .... 10 watts
Backing electrode, Ebe
  DC voltage .... +20 volts
  Erase pulse amplitude .... +15 volts
  DC voltage plus erase pulse .... +25 volts
Collector electrode, Ece .... +100 volts

3.2 FLOODING GUN

Grid no. 5, collimator, fEc5 .... +100 volts
Grid no. 4, collimator, fEc4 .... +100 volts
Grid no. 3, collimator, fEc3 .... +100 volts
Grid no. 2, anode, fEc2 .... +100 volts
Grid no. 1, control grid, fEc1
  Negative bias value .... −200 volts
  Positive bias value(see CAUTION above) . +10 volts
Heater, fEh .... 6.3 volts ±5 percent, DC

3.3 WRITING GUN

Grid no. 4 and 2, wEc4 and wEc2 (also fEc2) . . +100 volts
Grid no. 3, focus, wEc3 ▲ .... 0 volts
Grid no. 1, control grid, wEc1 ▲
  Negative bias value .... −150 volts
  Positive bias value (see CAUTION above) . . 0 volts
Cathode, wEk .... −3000 volts
Heater, wEh .... 6.3 volts ±5 percent, AC or DC

4.0 TYPICAL OPERATING CONDITIONS

All voltages are given with respect to the flooding gun cathode (fk), except those indicated by the symbol ▲, where values are referenced to the writing gun cathode (wk). Voltages indicated in TYPICAL OPERATING CONDITIONS are representative values for most common in-service uses. For specific applications, however, these voltages may deviate widely within the maximum ratings. Contact Applications Engineering regarding operating conditions to meet particular requirements.

4.1 STORAGE DISPLAY SECTION

Viewing screen, Evs .... +8,000 volts
Backing electrode, Ebe .... +7 volts
Collector electrode, Ece .... +30 volts

4.2 FLOODING GUN

Grid no. 5, collimator, fEc5 .... +5 to +20 volts
Grid no. 4, collimator, fEc4 .... 0 to +15 volts
Grid no. 3, collimator, fEc3 .... 0 to +15 volts
Grid no. 2, anode, fEc2 .... +25 volts
Grid no. 1, control grid, fEc1
  Operating bias for full coverage of the viewing screen .... +7 to −10 volts
  Cut-off bias, fE(co)c1 .... −15 to −35 volts
Cathode, fEk .... 0 volts
Heater, fEh .... 6.3 volts, DC
Heater current, fIh .... 1.8 amperes

4.0 TYPICAL OPERATING CONDITIONS (CONT.)

4.3 WRITING GUN

Grid no. 4 and 2, wEc4 and wEc2 (also fEc2) . . . +25 volts
Grid no. 3, focus, wEc3 ▲ . . . . +100 to +500 volts
Grid no. 1, control grid For undeflected spot cut off, wE(co)c1 ▲ . . . . −30 to −90 volts
Cathode, wEk . . . . −2500 volts
Heater, wEh . . . . 6.3 volts
Heater current, wIh . . . . 0.6 amperes

4.4 TYPICAL CURRENTS

Indicated DC currents are in microamperes for the following conditions: I_1 at equilibrium brightness, I_2 during dynamic (pulse train) erasure, and I_3 at cut-off.

Electrode	Voltage	I_1	I_2	I_3
Viewing screen, Ivs	+8 kV	450	100	75
Collector electrode, Ice	+30 V	650	700	700
Grid no. 5, fIc5	+8 V	60	60	60
Grid no. 4, fIc4	+5 V	35	90	95
Grid no. 3, fIc3	+4 V	10	25	25
Grid no. 2, fIc2	+25 V	950	1100	1100
Cathode, fIk	0 V	3000	3000	3000

4.5 CIRCUIT VALUES

Viewing screen circuit resistance . . . . . . 1 megohm, max.
0.1 megohm, min.
Backing electrode circuit resistance . . . 5000 ohms, max.
Collector electrode circuit resistance . . 5000 ohms, max.
1000 ohms, min.
Grid no. 1, control grid circuit resistance . 1 megohm, max.

4.6 TYPICAL INTER-ELECTRODE CAPACITANCES (APPROX.)

Viewing screen to all other electrodes . . . . 30 pf.
Backing electrode to all other electrodes . . . . 120 pf.
Collector electrode to all other electrodes . . . 110 pf.
fg1, control grid to all other electrodes . . . . 35 pf.
fk to all other electrodes . . . . 25 pf.
wg1, control grid to all other electrodes . . . . 7 pf.
wk to all other electrodes . . . . 4 pf.
Write gun heater to cathode (wh-k) . . . . 2 pf.

4.7 DEFLECTION SYSTEM

Deflection method . . . . Electromagnetic
Deflection angle (approximate)
Horizontal and vertical . . . . 60°

5.0 OPERATING PRINCIPLES

Illustrated in Fig. 1, Basic Storage Tube Structure, page 6, are the five components essential in producing a visible display: (1) the flooding gun, (2) collimating system, (3) writing gun, (4) deflection system, and (5) the storage display assembly.

The storage display assembly includes a viewing screen, a fine mesh backing electrode upon which the thin film dielectric storage surface has been deposited, and a collector electrode.

Operation of the tube is based primarily on the property of the storage surface to charge in a positive or a negative direction, depending upon the energy of the incident electron beam. This property is made possible by the secondary emission characteristic of the storage surface dielectric.

5.0 OPERATING PRINCIPLES (CONT.)

The flooding gun provides a continuous supply of electrons, which are collimated and approach the storage surface orthogonally and uniformly over its entire area. Whether these electrons pass through each of the many storage elements that comprise the storage surface, and accelerate toward the viewing screen, depends upon the potential present at each element. Since storage surface potentials in the half-tone range are negative with respect to the flooding gun cathode (see Fig. 5, Typical Storage Characteristics, back cover), each storage element acts as a virtual "control grid" for flood electrons approaching its area. Thus, if a varied charge pattern is present at the storage surface, flood electrons produce a corresponding pattern at the viewing screen.

The writing of stored information occurs when positive-going charges are induced at the storage surface by the incident electron beam. This is accomplished by the writing gun, whose beam energy levels lie within values required to produce storage surface secondary emission ratios greater than unity. When video signals and deflection signals are applied to the writing gun and deflection system, respectively, the intensity modulated writing beam scans the storage surface and establishes the charge pattern to be displayed.

The length of time after writing during which an acceptable output can be read is termed "storage retention time", and is limited chiefly by the presence of residual gas molecules within the tube. As these molecules collide with flood electrons, positive ions are formed and are accelerated toward the negatively charged storage surface. Upon landing of the ions, the storage surface is gradually charged in a positive direction, resulting in gradual brightening of the display background and corresponding loss of display contrast.

Erasure of stored information takes place when the storage surface charges in a negative direction. This is done with the flooding gun, whose relatively low beam energy results in a secondary emission ratio at the storage surface of less than unity.

To erase, a positive pulse of an amplitude equal to the value of storage surface cut-off potential is applied to the backing electrode. Due to capacitive coupling, the abrupt rise in backing electrode potential is accompanied by a similar rise in storage surface potential. Flood electrons, now attracted to the storage surface, charge it down to flood gun cathode potential.

When the pulse is removed, backing electrode potential drops by the same amount that it had been raised, and again the storage surface is carried capacitively with it. By this mechanism, the storage surface is brought to cut-off, erasure is complete, and the tube is ready for subsequent writing. Erasure may be accomplished with a single pulse, as described above, or, if persistence is to be controlled, with a train of very short pulses.

For a more detailed discussion of the operating principles of cathode ray charge storage display tubes, refer to "Operation of the Hughes Tonotron", Applications Engineering Publication 91-19A-5, which is available on request.

6.0 AVERAGE PERFORMANCE NOTES

6.1 VIEWING SCREEN BRIGHTNESS

With viewing screen potential at +10 kV, equilibrium brightness is 2000 foot-lamberts.

6.2 VIEWING TIME

Viewing time, considered as the interval between the end of single pulse erasure to just cut-off, and the rise of background light to 20 percent of equilibrium brightness, is 180 seconds for this tube type.

By employing flood gun pulse or erase pulse techniques, storage time may be extended in exchange for unneeded light output. Also, where continuous viewing is not essential, additional storage time may be gained by inclusion of a "push-to-view" feature, whereby the flooding beam is turned on only when it is required to make visual observations.

For data on extending storage time, refer to Applications Engineering Publication 91-19A-21, which is available on request.

6.3 WRITING SPEED

Writing speed is defined as the rate of lineal scanning, without overlap, of the writing beam across the storage surface. At 5 μA writing beam current, the tube will write to 80 percent of equilibrium brightness at 60,000 inches per second. With 30 volts of video drive, and writing to 30 percent of equilibrium brightness, speeds in the order of 250,000 inches per second are possible.

6.4 WRITTEN RESOLUTION

Written resolution, determined by the shrinking raster method at the 60,000 inch per second rate is 60 lines per inch when the brightness level is 80 percent of equilibrium value. At the same speed, resolution is 70 lines per inch when written to 50 percent of equilibrium brightness, and 80 lines per inch at 10 percent.

Writing speed and the degree of stored resolution may be "traded off". Where higher writing speeds are essential, they may be obtained at increased beam currents with some sacrifice in resolution; conversely, if greater resolution is of concern, lower beam currents may be used with resultant reduction in writing speed.

6.5 USABLE LEVELS

The tube is capable of displaying at least seven clearly discernible output levels including the extremes of "black" and "white".

6.6 ERASE TIME

To reduce display brightness from equilibrium value to cut-off, a single erase pulse whose amplitude is 120 percent of storage surface cut-off requires 160 milliseconds. With an erase pulse amplitude of 160 to 165 percent of storage surface cut-off, erase time is reduced to 50 milliseconds.

7.0 ELECTRICAL NOTES

7.1 SIGNAL CIRCUITS

Half-tone rendition of a stored display depends upon variations of video signal, but uniformity of the display over the entire viewing screen is maintained only if the writing speed and written line spacing, as well as the video reference level, remain constant. A change in any factor must be compensated for by changes in the others.

In writing a PPI or sector scan display, for example, the effective sweep speed is nonuniform, increasing from the point of sweep origin outward. Moreover, since the sweep lines are not parallel, but tend to overlap also near the sweep origin, the integrating property of the tube may cause the display in this area to build up toward equilibrium brightness. To compensate for these effects, a properly sloped ramp correcting voltage for video signal reference must be applied to the writing gun.

When retrace blanking is used in a display, care must be taken to ensure complete cut-off of the writing gun. Otherwise, integration of retrace lines may occur, causing them to progressively brighten toward equilibrium level.

7.2 ERASE CIRCUITS

Two types of erase circuits are used with this tube; one which permits the removal of stored information at once, and the other which provides for controlled display persistence.

For single pulse, or "static" erasure, only an arrangement for elevating backing electrode potential a brief time, 50 to 160 milliseconds, typically, is needed. The pulse may be initiated manually, with the pulse voltage supplied by a battery or other convenient means. Pulse amplitude should be adjustable, but must be limited to an ABSOLUTE MAXIMUM of +15 volts.

Where the degree of display persistence is to be controllable, pulse train, or "dynamic" erasure is employed, in which storage surface potentials are made to become progressively negative in discrete steps. Varying the width or the repetition rate of the erase pulses varies the erase pulse-train duty cycle, and thus governs the persistence, contrast, and integrating properties of the tube.

7.3 STATIC VOLTAGE SUPPLIES

Static voltages required are listed under TYPICAL OPERATING CONDITIONS, and may be readily furnished by conventional power supplies. There should be provision for convenient adjustment of several electrode voltages: (1) flooding gun grid 1 (fEc1) for full beam coverage of the storage surface area, (2) flooding gun grids 3, 4, and 5 (fEc3, fEc4 and fEc5) for collimation of the flooding beam, and (3) writing gun grid 3 (wEc3) for proper writing beam focus.

7.3 STATIC VOLTAGE SUPPLIES (CONT.)

Since the writing gun cathode does not operate at ground potential, voltages applied to writing gun grids 1 and 3 must be referenced to it; in addition, it is necessary that the ratio of focus to accelerating voltages be fixed in order to maintain a good spot size. The most simple yet entirely suitable means of meeting these conditions is by use of a single negative power supply with an appropriate voltage divider network. Separate power supplies may be used if desired, but they must incorporate excellent regulation.

7.4 PROTECTIVE CIRCUITS

Due to the high internal voltage gradient between the backing electrode and the viewing screen, it is advisable to provide protection against excessive surge currents. For the viewing screen, a limited energy type power supply with a 1 mA short circuit current is preferred. In any event, it is suggested that a high voltage protective resistor of approximately 0.5 megohms be connected in series with the viewing screen lead.

It is desirable to interlock both the writing gun control grid bias supply and the deflection driving source with the writing gun cathode power supply in such a way that, should either bias or deflection voltages fail, the cathode supply will be deenergized. This safety feature has the purpose of avoiding either excessive beam current or excessive dwell time, and so protects the storage surface from possible damage.

8.0 MECHANICAL NOTES

8.1 MOUNTING

The tube may be mounted in any position required for viewing. If the tube is to be used under conditions of severe shock or vibration, inclusion of appropriate snubbing or damping devices in the tube mount or cradle is recommended.

CAUTION: Do not support the tube by the writing gun neck, and do not rigidly mount the base connector socket.

8.2 MAGNETIC SHIELDING

Because stray magnetic fields in the vicinity of the tube in service operation are likely to seriously impair flooding beam collimation, the tube is furnished with an external magnetic shield.

8.3 POTTING

A dielectric compound is cast into the space between the tube and its magnetic shield in the area surrounding the lower bulb body and in the area adjacent to the viewing screen. By means of this potting, moisture accumulation in the vicinity of the bulb contacts is avoided and corona is minimized, so that the tube may be operated at full rated voltages to 70,000 feet.

9.0 COLLIMATION ADJUSTMENT

Collimation adjustments are made by varying the potentials of the electrostatic lens system until flood electrons approach the storage surface orthogonally and uniformly over the entire area. Correct collimation is essential when good half-tone presentation is required, and the effect is most evident at low brightness levels. For this reason, optimum collimation is obtained with the tube operating in the lowest clearly discernible half-tone state.

Flooding gun grid 1 (control grid) bias should initially be set beyond cut-off, and collimating electrode voltages at flooding gun grids 3, 4, and 5 should be set according to the data which accompanies each tube. Appropriate voltages may then be applied to the viewing screen, backing electrode, and collector electrode.

Flooding gun control grid bias should be decreased (made less negative) until just full coverage of the viewing screen is obtained, after which flooding gun grids 3 and 4 are adjusted for best uniform coverage within the 4-inch minimum diameter useful screen area.

While the tube is writing and erasing, final, fine adjustment is made with flooding gun grids 4 and 5 for optimum writing and erasing uniformity.

FIGURE 1
BASIC STORAGE TUBE STRUCTURE

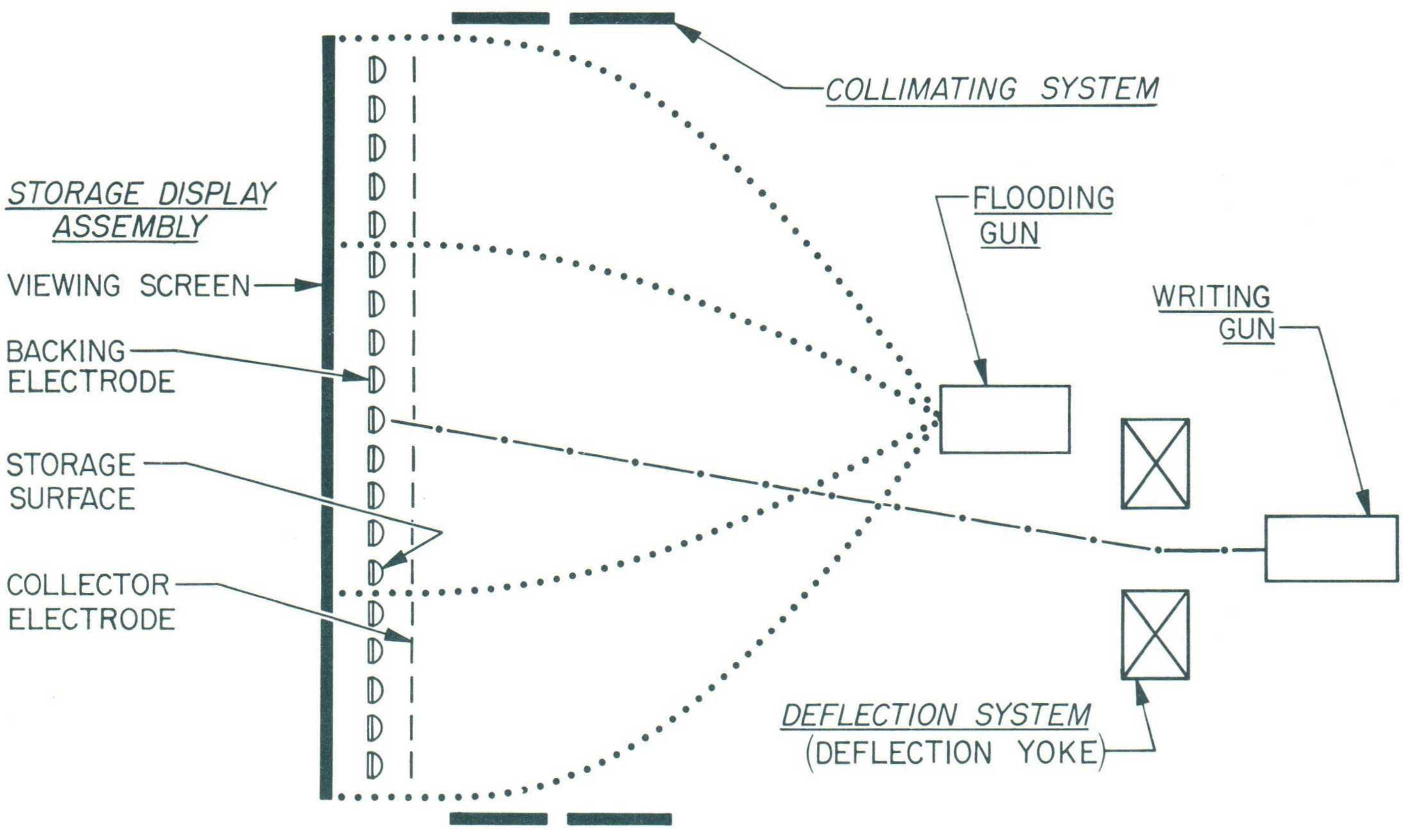


FIGURE 2
OUTLINE DRAWING
DIMENSIONS IN INCHES

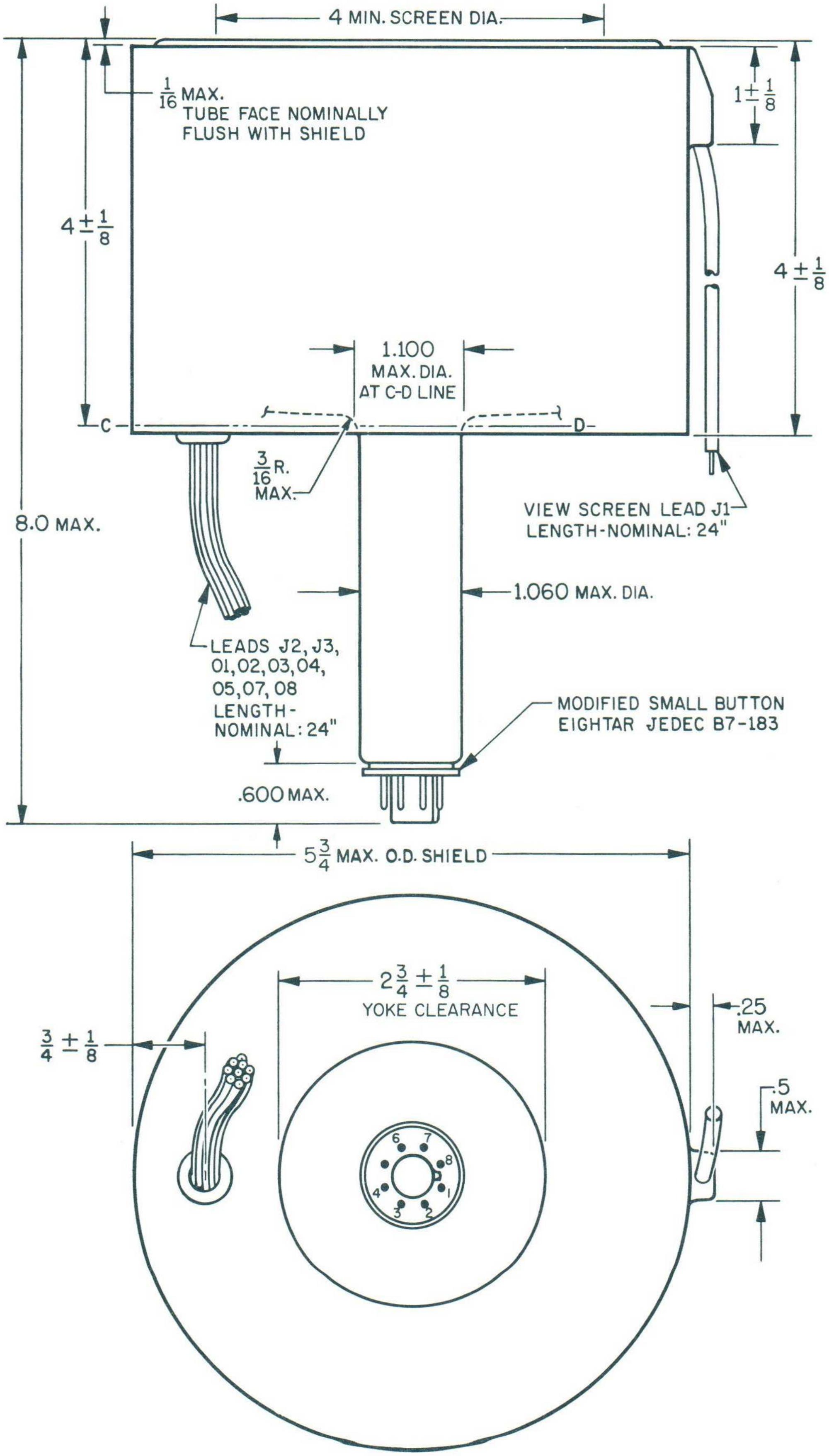
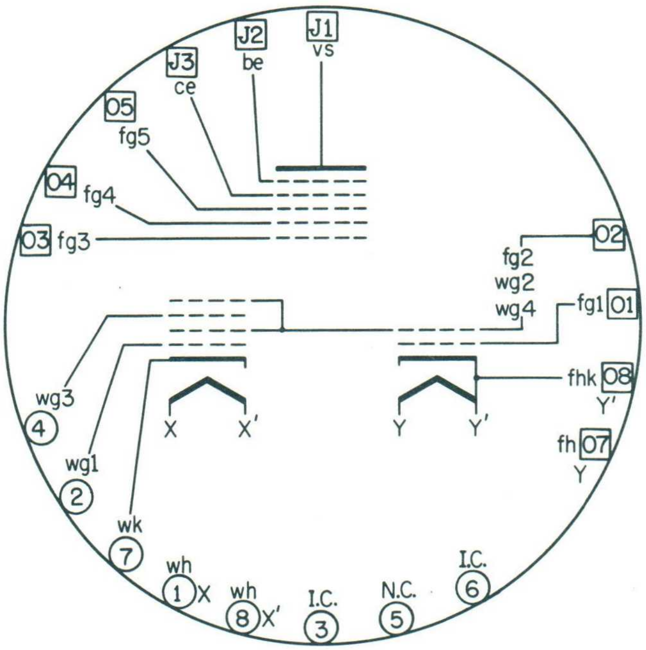


FIGURE 3
SCHEMATIC AND CONNECTION DIAGRAM

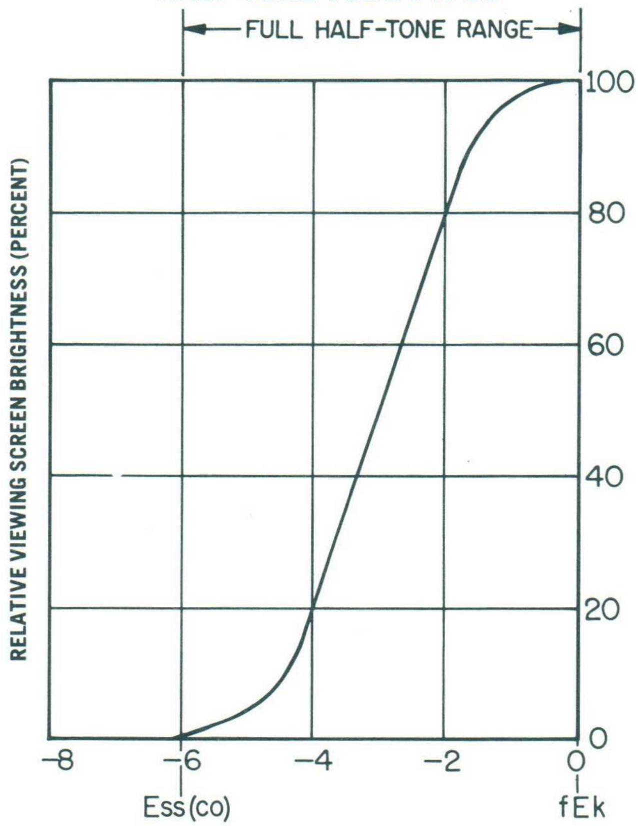


ELECTRODE CONNECTIONS

□ BULB LEAD NO.	CONNECTION	SYMBOL
J1	Viewing screen	vs
J2	Backing electrode	be
J3	Collector electrode	ce
05	Collimator	fg5
04	Collimator	fg4
03	Collimator	fg3
02	Flood gun grid 2, anode, and Write gun grids 2 and 4	fg2, wg2, wg4
01	Flood gun grid 1, control grid	fg1
08	Flood gun heater-cathode	fh-k
07	Flood gun heater	fh

◯ BASE PIN NO.		
1	Write gun heater	wh
2	Write gun grid 1, control grid	wg1
3	Internal connection, fg2, wg2,	wg4
4	Write gun grid 3, focus	wg3
5	Vacant pin	
6	Internal connection, wg1	
7	Write gun cathode	wk
8	Write gun heater	wh

FIGURE 4
TYPICAL STORAGE CHARACTERISTIC FOR HALF-TONE TUBE TYPES



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TYPE H-1059AP20*
MULTI - MODE TONOTRON**
10-inch direct display selective erase half tone storage tube with electrostatic focus and deflection

GENERAL DESCRIPTION

The Type H-1059AP20 multi-mode Tonotron tube is a 10-inch direct-view half-tone storage tube whose designation, "multi-mode," is descriptive of its capability to perform several functions unique in storage tube operation: (1) Simultaneous display of both stored and non-stored information plus simultaneous erasure, (2) Selective erasure, whereby any or all storage surface elements may be erased gradually or rapidly, or a combination of both simultaneously, and (3) Dark trace display, enabling presentation of a "negative" picture having an inherent resolution twice that of a normal display, accomplished by "erasing" information into a fully written storage pattern. These operating modes are possible because of the "dual-effects" property exhibited by the storage-surface dielectric.

Three electron guns are used, each operated at a different specific energy level. The low energy flood gun (f) and moderately high energy write gun (w) have functions essentially the same in this as in conventional half-tone storage tube types. The erase gun (r) is operated at the highest energy level, and is utilized for the selective erase, dark trace display, and non-stored write modes. Internal construction of the tube is illustrated in Fig. 2, Schematic Diagram.

Leads for all tube electrodes are encapsulated, allowing operation at full ratings over a wide range of environmental conditions, and the tube is supplied with a Netic-Co-Netic shield whose purpose is to minimize the adverse effects of stray magnetic fields.

OPERATING PRINCIPLES

DUAL-EFFECTS STORAGE SURFACE

The principles of operation of this tube are based on the ability of the storage surface dielectric to assume the property of secondary emission, and/or that of Bombardment - Induced - Conductivity, depending wholly upon the level of the incident-beam energy. At low beam energies, secondary emission is the predominant effect, charging the storage surface in a positive direction, resulting in stored writing. Conversely, at high beam energies, the bombardment-induced-conductivity effect takes precedence, discharging the storage surface and thus erasing. At some intermediate level the two effects cancel, permitting the display of non-stored information (a function sometimes referred to as "write-through") and stored information, simultaneously.

SELECTIVE ERASURE

The property of the storage-surface dielectric in the Type H-1059AP20 tube is such that the bombardment-induced-conductivity effect becomes substantial when the energy level of the erase gun is 6 kVdc. or greater.

SELECTIVE ERASURE (CONTINUED)

Storage action in this tube is the same as that observed in conventional half-tone storage tubes when writing with the moderately high energy write beam. A positive-going charge pattern is established on the dielectric surface by this gun because of the secondary emission ratio of the dielectric material.

When the higher energy erase gun bombards the storage surface with its electrons, the surface potential of the dielectric is conducted toward the backing electrode potential (negative) by the currents induced in the dielectric. This condition occurs ONLY in the bombarded areas. The degree of erasure is controllable by varying the beam current; therefore, half-tones are capable of being erased into a written area.

Erasure speed is determined by two operating parameters, beam energy and backing electrode potential; both have a threshold which must be reached before successful erasure can occur. The erase beam voltage must be at least 5.9 KV. to cause appreciable bombardment-induced-conductivity, and the negative backing electrode potential must be at least equal to the storage surface cut off potential. Erase speed increases when the beam voltage increases, or when the backing electrode is made more negative.

In practice, erase speeds in the order of 50,000 to 100,000 inches per second may be obtained at beam voltages between 6 and 6.2 KV. The backing electrode voltage can be varied between approximately −5 and −12 volts; its exact value is determined by the storage time desired, and will vary from tube to tube. Increasing backing electrode voltage in a positive direction results in increasing storage time.

NON-STORE DISPLAY (WRITE-THROUGH)

Since the secondary emission writing and bombardment-induced-conductivity erasure are examples of the addition and subtraction of charges, and their rates are finite and controllable, it is possible by adjusting the energy of the bombarding electrons to cause these opposing effects to become equal. In other words, as much charge is deposited on the surface by secondary emission as is conducted to the backing electrode by bombardment-induced currents. When this occurs, the beam is seen on the tube view screen in its unstored mode. Furthermore, practically no erasure takes place of the information already stored in that area.

The presentation of non-stored information is accomplished by pulsing the backing electrode negatively, and simultaneously applying the desired information to the high energy erase gun. The backing electrode pulses must have an amplitude sufficient to bring the total beam energy to the value necessary for the non-stored writing

** Type H-1059AP20 is a developmental tube. Data presented herein are accurate as of June 22, 1961, but are subject to change without notice. No obligation for future manufacture is assumed unless specifically arranged.*

*** Trademark of Hughes Aircraft Co.*

OPERATING PRINCIPLES

NON-STORE DISPLAY (WRITE-THROUGH) (CONT.)

operation. For example, if the erase gun is operating at −6000 volts and the backing electrode is at −10 volts, then the amplitude of the pulse applied to the backing electrode must be −1500 volts since the non-stored display occurs at approximately 4500 volts of beam energy.

DARK-TRACE DISPLAY (INCREASING RESOLUTION)

When operating in the normal manner, that is, writing and storing information with the moderately high-energy write-beam, the resolution of the Type H-1059AP20 multi-mode Tonotron tube is about 60 written lines per inch. However, if the customary write-gun is utilized as the "white erase gun" and the video information is applied to the high energy erase gun, so that a picture is erased into the storage surface pattern, resolution is approximately doubled; 100 to 120 written lines per inch are representative values. The greater resolution is primarily the result of the higher beam energy of the erase gun. If normal-aspect pictures are desired rather than the "negative" effect resulting from this method, the video information can be inverted before it is applied to the erase-gun.

GENERAL SPECIFICATIONS

OPTICAL DATA

Phosphor number .... P20 aluminized
Fluorescent color .... Green-yellow
Phosphorescent color .... Green-yellow
Face Plate .... Flat
  Transmission (visible range) .... 83 - 92 percent
  Useful screen diameter .... 8½ inches, min.

MECHANICAL DATA (SEE OUTLINE DRAWING)

MAXIMUM ELECTRICAL RATINGS

All voltages are given with respect to the flood gun cathode (fk) except those indicated by the symbol ▲, where values are given with respect to the particular high energy gun cathode -[write-gun cathode (wk) or erase-gun cathode (rk).] The figures represent MAXIMUM RATINGS, NOT OPERATING VOLTAGES and therefore should not be exceeded under any circumstances.

VIEWING SECTION

View screen (Evs) .... 9,000 volts
Backing electrode (Ebe) .... −25, +200 volts ✱
Collector electrode (Ece) .... 250 volts

FLOOD-GUN

Cathode (fEk) .... 0 volts
Grid no. 1, control grid (fEg1)
  Negative bias .... −200 volts
  Positive bias .... 0 volts
  Positive peak voltage .... 2 volts
Grid no. 2, anode (fEg2) .... 200 volts
Grid no. 3, collimating (fEg3) .... 200 volts
Grid no. 4, collimating (fEg4) .... 200 volts
Grid no. 5, collimating (fEg5) .... 400 volts
Heater (fEh) .... 6.93 volts, AC or DC
Heater-cathode voltage (fEhk) .... ±125 volts

WRITE-GUN

Cathode (wEk) .... −3000 volts
Grid no. 1, control gride (wEg1) ▲
  Negative bias .... −200 volts
  Positive bias .... 0 volts
  Positive peak voltage .... 2 volts
Grid no. 2, anode .... Internally connected to fg2
Grid no. 3, focus (wEg3) .... −3000 volts
Grid no. 4 .... Internally connected to fg2
Heater (wEh) .... 6.93 volts, AC or DC
Heater-cathode voltage (wEhk) .... ±125 volts
Heater-cathode peak AC volts .... 200 volts

✱ *Exception; refer to discussion in NON-STORE DISPLAY*

MAXIMUM ELECTRICAL RATINGS (CONT.)

ERASE-GUN

Cathode (rEk) .... −6500 volts
Grid no. 1, control grid (rEg1) ▲
  Negative bias .... −200 volts
  Positive bias .... 0 volts
  Positive peak voltage .... 2 volts
Grid no. 2, anode .... Internally connected to fg2
Grid no. 3, focus (rEg3) .... −5000 volts
Grid no. 4 .... Internally connected to fg2
Heater (rEh) .... 6.93 volts, AC or DC
Heater-cathode voltage (rEhk) .... ±125 volts
Heater-cathode peak AC volts .... 200 volts

TYPICAL OPERATING CONDITIONS

All voltages are given with respect to the flood gun cathode (fk) except those indicated by the symbol ▲, where values are given with respect to the particular high energy-cathode designated -[write-gun cathode (wk) or erase-gun cathode (rk).]

VIEWING SECTION

View-screen (Evs) .... 5,500 volts
View-screen current (Ivs)
  At equilibrium brightness .... 600 µa.
  Completely erased .... 150 µa.
Backing electrode (Ebe) .... −5 to −20 volts
Backing electrode current (Ibe)
  Writing and erasing .... −15 to +15 µa.
Collector electrode (Ece) .... 150 volts
Collector electrode current (Ice)
  At equilibrium brightness .... 750 µa.
  Completely erased .... 850 µa.

FLOOD-GUN

Cathode (fEk) .... 0 volts
Cathode current (fIk)
  At equilibrium brightness and completely erased/1.5 ma.
Grid no. 1, operating bias (fEg1),
  adjusted for full coverage of view screen/0 to −30 volts
Grid no. 2, anode (fEg2) .... 100 volts
Grid no. 2 current (fIg2)
  At equilibrium brightness .... 200 µa.
  Completely erased .... 250 µa.
Grid no. 3, collimating (fEg3) .... 0 to 60 volts
Grid no. 3, current (fIg3)
  At equilibrium brightness .... 15 µa.
  Completely erased .... 10 µa.
Grid no. 4, collimating (fEg4) .... 20 to 80 volts
Grid no. 4, current (fIg4)
  At equilibrium brightness .... 400 µa.
  Completely erased .... 450 µa.
Grid no. 5, collimating (fEg5) .... 40 to 100 volts
Grid no. 5, current (fIg5)
  At equilibrium brightness .... 10 µa.
  Completely erased .... 15 µa.
Heater, for unipotential
  cathodes (fEh) .... 6.3 volts, ±10 percent, AC or DC
Heater current (fIh) .... 0.6 amperes

WRITE-GUN

Cathode (wEk) .... −2,500 volts
Grid no. 1, control grid (wEg1),
  for undeflected focused spot cutoff ▲. −60 to −120 volts
Dynamic grid drive .... 90 volts, maximum
Grid no. 2, anode .... Internally connected to fg2
Grid no. 3, focus (wEg3) ▲ .... +300 to +800 volts
Grid no. 4 .... Internally connected to fg2
Heater, for unipotential
  cathodes (wEh) .... 6.3 volts, ±10 percent, AC or DC
Heater current (wIh) .... 0.6 amperes
Deflection factor
  (wEk to wEg2) .... 25 volts DC/in./KV., maximum

TYPICAL OPERATING CONDITIONS (CONT.)

ERASE-GUN

Cathode (rEk) .... −6,000 volts
Grid no. 1, control grid (rEg1),
for undeflected focused spot cutoff ▲ .. −60 to −120 volts
Dynamic grid drive .... 90 volts, maximum
Grid no. 2, anode .... Internally connected to fg2
Grid no. 3, focus (rEg3) ▲ .... +400 to +1000 volts
Grid no. 4 .... Internally connected to fg2
Heater, for unipotential
cathodes (rEh) .... 6.3 volts, ±10 percent, AC or DC
Heater current (rIH) .... 0.6 amperes
Deflection factor
(rEk to rEg2) .... 25 volts DC/in./KV., maximum

CIRCUIT VALUES

Control grid circuit resistance .... 1 megohm, maximum
Collimating electrode
circuit resistance .... 1,000 ohms, minimum
View screen circuit resistance .... 100,000 ohms, minimum

PERFORMANCE NOTES

VIEWING TIME (CONVENTIONAL HALF-TONE MODE)

Viewing time in the conventional half-tone mode is defined as that time during which the entire display background brightness rises from 0 to 20 percent of equilibrium (maximum) brightness, and is 30 seconds for this tube. By employing pulse-erase techniques, unneeded light output can be traded for extended storage time and, in applications where continuous viewing is not essential, inclusion of a "push-to-view" feature will result in considerable additional storage time. Data on extending storage time are available on request.

VIEWING TIME (DARK-TRACE DISPLAY MODE)

Viewing time in the dark trace display mode is defined as that time during which the entire display background brightness falls from 100 to 10 percent of equilibrium (maximum) brightness, and will range from 5 seconds to 5 minutes depending upon backing electrode potential. Maximum storage time occurs when backing electrode potential is at the most positive value (about −5 volts) within the prescribed operating range.

ERASE TIME (FLOOD-BEAM ERASURE)

To reduce display brightness from 100 down to 10 percent of equilibrium (maximum) value with a single pulse, a pulse duration of 300 milliseconds is required. Pulse amplitude should be about 120 percent of storage-surface cutoff value.

EQUILIBRIUM BRIGHTNESS

With 8000 volts applied to the view-screen, equilibrium brightness is not less than 400 foot/lamberts.

WRITING SPEED AND STORED RESOLUTION

Writing speed is taken as that speed at which the write-gun can increase brightness from 0 to 50 percent of equilibrium value, and is 20,000 inches/sec. Required grid drive is in the order of 50 volts. The stored resolution under these conditions is 450 lines/useful diameter.

The selective-erase speed is the speed at which the erase gun will decrease brightness from 100 percent of equilibrium value down to the point of visual extinction, and is 50,000 inches/sec. Grid drive in this case is about 25 volts. The stored resolution (dark-trace resolution) is 900 lines/useful diameter.

When resolution is of greater concern than writing speed, a decrease in write gun grid drive voltage can be effected to obtain resolution approaching 600 lines at 50 percent brightness, and 800 lines at lower levels of brightness.

WRITING SPEED AND STORED RESOLUTION (CONTINUED)

Conversely, when high resolution is not essential, an increase in write gun grid drive voltage (not to exceed maximum rating) can achieve writing speeds in excess of the 20,000 inches/second value specified.

In the selective erase mode, similar considerations apply to erase gun grid drive where erase speed and resolution trade-off is contemplated.

CIRCUITRY

The circuits required to operate the Type H-1059AP20 multi-mode Tonotron tube fall into three categories: signal (video and deflection) circuits, static voltage supplies, and protective circuits.

SIGNAL CIRCUITS

A video signal of approximately 90 volts is required to drive the erase gun at lineal speeds of 160,000 inches per second. As writing speed is decreased, the required video drive also decreases until, at 8,000 inches per second, it is reduced to about 15 volts. Similar considerations also apply for drive requirements of the write-gun.

Deflection circuitry for the high energy beams is conventional; however, since appreciable currents are drawn by the deflection plates, coupling to them with cathode followers is recommended.

STATIC VOLTAGE SUPPLIES

Static voltages required are listed under TYPICAL OPERATING CONDITIONS, and may be readily furnished by conventional power supplies. There should be provisions for convenient adjustment of several electrode voltages: (1) Collimator voltages (fEg3, fEg4 and fEg5), for collimation of the flood beam, (2) Flood gun grid no. 1 voltage (fEg1), to obtain full beam coverage of the storage area, (3) Backing electrode voltage (Ebe), for optimum storage over the range of operating conditions, and (4) Write and erase gun focus anode voltages (wEg3 and rEg3), for proper focus. The cathodes of the high energy guns do not operate at ground potential, therefore their associated control grids must either be referenced to them, or the cathode power supplies must incorporate exceptionally good regulation.

Since electrostatic focusing is proportional, care must be taken to preserve the focusing ratio in order to maintain a good spot. This implies either a proportional focus voltage, or well-regulated cathode and focus voltages.

Approximately equal deflecting electrode resistances is recommended.

PROTECTIVE CIRCUITS

Due to the high internal voltage gradient between the backing electrode and the view screen, it is advisable to provide protection against excessive surge currents. For the view screen, a limited-energy-type power supply with a 1 ma., maximum, short circuit current is preferred. In any event, it is suggested that a high voltage protective resistor of at least 0.1 megohm be connected in series with the view screen lead.

If it is necessary or desirable to operate either high energy gun with the flood beam cut off, considerable care should be exercised to avoid an excessive beam energy level. Such a condition may damage the storage surface, while there would be no increase in output light level to warn of the occurrence.

Application circuitry is available on request.

COLLIMATION ADJUSTMENT

When making collimation adjustments on the Type H-1059AP20 multi-mode Tonotron tube, the potentials of several electrostatic lenses are varied until flood gun electrons approach the storage surface orthogonally, and with uniform density, over its entire area. Correct collimation is essential when good half-tone presentation is required; the effect is more evident as progressively lower half-tone levels are displayed. Accordingly, best collimation adjustment is obtained with the tube operating in the lowest clearly-discernible half-tone state.

After appropriate potentials have been applied to the viewing section and to the electrodes of all guns, backing electrode voltage (Ebe) is brought to 0 volts and flood gun grid no. 1 bias (fEgl) is adjusted to just reach full screen coverage. Flood gun beam current should be kept low in order to avoid unwanted reflections and streaks across the view screen of the tube.

Backing electrode voltage (Ebe) is slowly increased in a negative direction until a low half-tone level is obtained. Collimator voltage at grid no. 5 (fEg5) is adjusted between the approximate limits of 40 and 100 volts, so as to obtain best uniformity over the usable screen area. The third and fourth grids (fg3 and fg4) are then adjusted for optimum uniform condition. Voltages should be kept at the lowest points within the range in which the desired effect occurs. Final, critical adjustments are best made while operating both the write and erase guns.

MECHANICAL NOTES

MOUNTING

The Type H-1059AP20 multi-mode Tonotron tube may be mounted in any position required for viewing. Where application of the tube under conditions of extreme shock and vibration is contemplated, the use of shock or vibration mounts, as applicable, is recommended to minimize the possibility of damage.

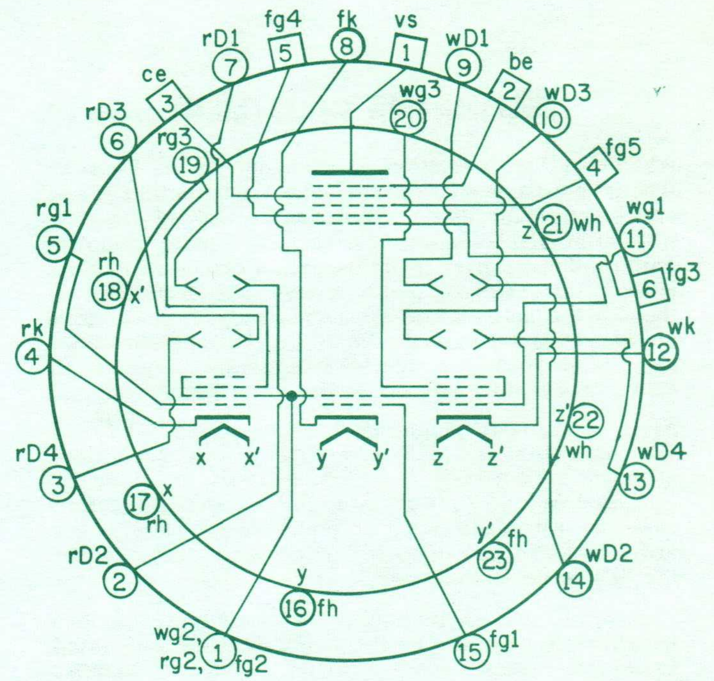
MAGNETIC SHIELD

Because of the relatively low energy level of the flood beam, any random magnetic field may seriously impair the collimating properties of the tube. For this reason, an external magnetic shield is furnished. Not only does this shield minimize the effects of undesirable fields during operation, but also affords protection during shipment and storage, when exposure to stray fields could cause permanent magnetization of certain tube parts. Additional protection during shipment is provided by a magnetic shield face plate cover.

OPERATING AND NON-OPERATING TEMPERATURES

It is recommended that under no circumstances should the tube be exposed to ambient temperatures beyond the limits of -40° and $+160^\circ$ F.

FIGURE 1 - BASING DIAGRAM



WIRE LIST

BULB LEADS □

Lead No.	Size AWG	Type	Electrode
1	20	SEHV (15)-1932A-(66)	View screen, vs
2	20	MIL-W-16878C, Type B-Nylon	Backing electrode, be
3	20	"	Collector electrode, ce
4	20	"	Collimator, fg5
5	20	"	Collimator, fg4
6	20	"	Collimator, fg3

BASE LEADS ○

Lead No.	Size AWG	Type	Electrode
1	24	MIL-W-16878C, Type B Nylon	Anode, fg2, wg2, rg2
2	24	"	Deflecting plate, rD2
3	24	"	Deflecting plate, rD4
4	22	SEHV (5)-730A-(45)	Cathode, rk
5	22	"	Control grid, rg1
6	24	MIL-W-16878C, Type B Nylon	Deflecting plate, rD3
7	24	"	Deflecting plate, rD1
8	24	"	Cathode, fk
9	24	"	Deflecting plate, wD1
10	24	"	Deflecting plate, wD3
11	22	SEHV (5)-730A-(45)	Control grid, wg1
12	22	"	Cathode, wk
13	24	MIL-W-16878C, Type B Nylon	Deflecting plate, wD4
14	24	"	Deflecting plate, wD2
15	24	"	Control grid, fg1
16	24	"	Heater, fh
17	22	SEHV (5)-730A-(45)	Heater, rh
18	22	"	Heater, rh
19	22	"	Focus electrode, rg3
20	22	"	Focus electrode, wg3
21	22	"	Heater, wh
22	22	"	Heater, wh
23	24	MIL-W-16878C, Type B Nylon	Heater, fh

minimum wire length 19 inches.

FIGURE 2 - SCHEMATIC DIAGRAM

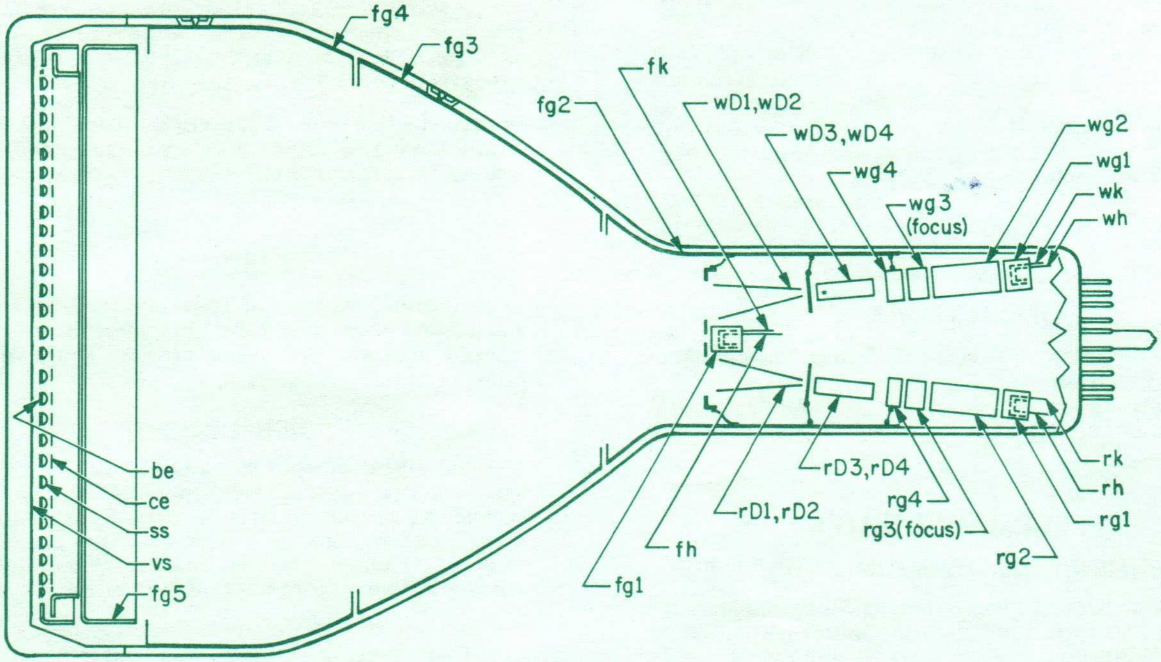
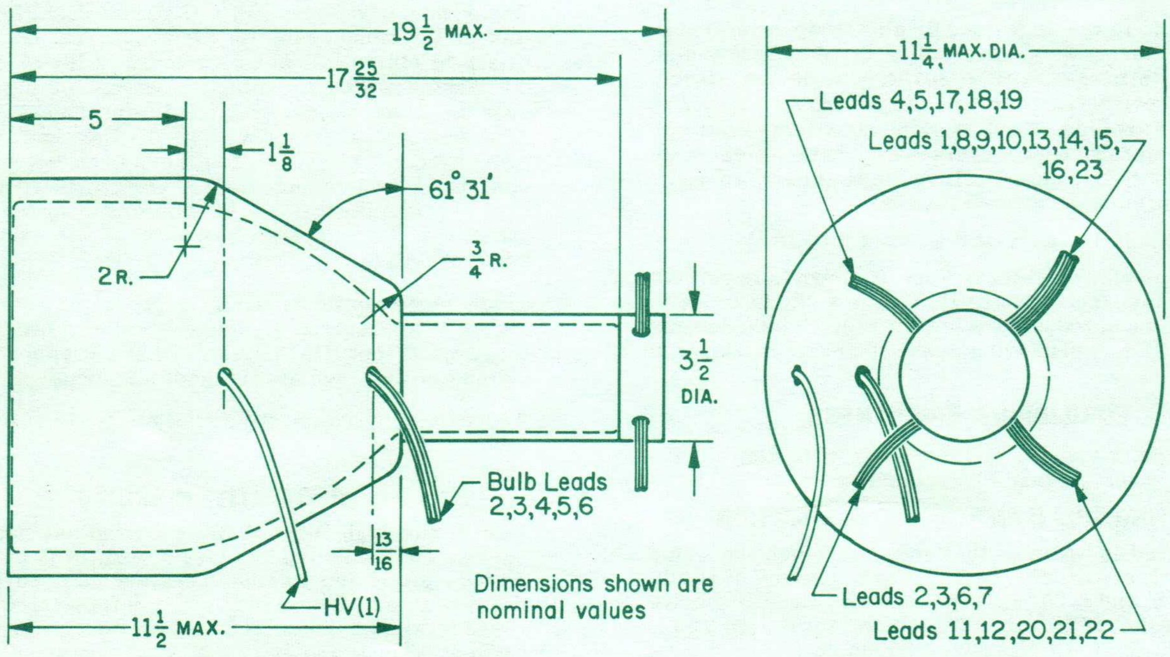


FIGURE 3 - OUTLINE DRAWING

DIMENSIONS IN INCHES



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VACUUM TUBE PRODUCTS DIVISION

TECHNICAL DATA

MULTI-MODE DIRECT VIEWING STORAGE TUBES

TYPE H-1038 *

TYPE H-1038 MULTI-MODE TONOTRON**

5-inch direct viewing, half tone display storage tube with electrostatic focus and deflection.

SELECTIVE ERASURE The selective erasure feature of multi-mode storage tubes is founded upon the principle of bombardment-induced conductivity. This is the property of some thin dielectric films to exhibit conductivity when they are bombarded by high energy beams of charged particles. In the H-1038 tube described in this data sheet, this effect becomes appreciable when the energy of write gun No. 2 (also referred to as the "erase" gun) is 6,000 volts or greater.

The storage target assembly operates as a conventional Tonotron tube target when written upon by the low energy writing gun. (For explanation of conventional storage tube operation, please refer to data published on Hughes earlier Tonotron tubes, type 7222, for example.) A charge pattern is established on the target's dielectric surface by this gun because of the secondary emission ratio of the dielectric material. When the high energy erase gun bombards the target with its electrons, the surface potential of the dielectric is conducted towards the backing electrode potential (negative) by current induced in the dielectric. This conduction occurs only in the bombarded areas. The amount of erasure is controllable by varying the beam current. Half-tones therefore are capable of being erased into a written area.

The erasure speed is determined by two operating parameters: the beam energy and the backing electrode potential. Both have a threshold which must be reached before successful erasure can occur. The beam voltage must be at least 5900 volts to cause bombardment-induced conductivity, and the negative backing electrode potential must be at least equal to the target cut off potential. Erase speed increases when the beam voltage increases or when the backing electrode is made more negative.

In practice erase speeds of the order of 50,000 to 100,000 inches per second have been achieved at beam voltages of 6000 to 6200 volts. The backing electrode voltage can be varied between approximately -5 and -12 volts. Its exact value is determined by the storage time desired and will vary from tube to tube. The larger the negative voltage, the shorter the storage time.

WRITE-THROUGH Since the secondary emission writing and bombardment-induced conductivity erasure are both examples of the addition and subtraction of charges and their rates are finite and controllable, it is possible, by adjusting the energy of the bombarding electrons, to cause both of these effects to become equal. In other words, as much charge is deposited on the surface by secondary emission as is conducted to the backing electrode by bombardment-induced currents. When this occurs, the beam is seen on the tube's view screen in its unstored mode. Furthermore, no erasure takes place of the information already stored in that area.

This presentation of non-stored information may be accomplished by utilizing a separate write-through gun as in the H-1061 multi-mode storage tube which is designed to operate at the necessary write-through voltage or by pulsing the back plate negatively and using the high energy writing (erase) gun for write-through in the H-1038 multi-mode storage tube.

The high energy writing (erase) gun operation must be synchronized with the back plate pulsing. The pulse amplitude must be large enough so that the total beam energy is equal to that necessary for write-through operation. If the high energy writing gun is operating at -6000 volts for example, and the backing electrode at -10 volts, then the pulse amplitude to apply to the backing electrode for write-through operation is -1500 volts since write-through occurs at 4500 volts of beam energy.

INCREASING RESOLUTION When operating in the normal manner of writing and storing information with the low energy writing beam, the resolution capabilities of multi-mode storage tubes are equivalent to that of conventional Tonotron tubes. However, if the low energy write gun is utilized as a "white erasing gun" and the video information is applied to the high energy erase gun grid, so that a dark trace picture is erased into the storage surface, resolution is approximately doubled. Values of 100 to 120 written lines per inch have been achieved. This greater resolution is produced by the higher beam energy of the erase gun. If normal pictures are desired rather than the "negative" effect produced above, the video information can be inverted before application to the erase gun grid.

* Type H-1038 and H-1038AP-20 also described are developmental tubes. Data presented herein are correct as of January 10, 1961, but are subject to change without notice. No obligation for future manufacture is assumed unless specifically arranged.

MECHANICAL

MOUNTING. The multi-mode storage tube may be mounted in any position required for viewing. Please refer to outline drawings attached for dimensional data. Where use under conditions of extreme shock or excessive vibration is contemplated, the use of shock mounting is recommended to prevent the possibility of damage.

When installing the multi-mode storage tube, support the tube with felt or rubber bumper strips placed inside the magnetic shield (see MAGNETIC SHIELDINGfor shield details). Install four of these bumper strips around the major diameter of the tube, between the face plate and the bulb cap terminals, and four more behind the bulb cap terminals, approximately one inch (1") in front of the "Reference Plane."

CAUTION: Do not support the tube by the neck and do not rigidly mount the base connection socket.

MAGNETIC SHIELDING. Magnetic shielding is required particularly for the flood gun. Low intensity magnetic fields (viz, the earth's magnetic field) can deflect the flood electrons enough to destroy collimation. (See COLLIMATION ADJUSTMENT on following page). Specific data on shielding is available on request.

CIRCUITRY

The circuits required to operate the multi-mode storage tube fall into three catagories: video and deflection circuits, static-voltage supplies, and protective circuits.

VIDEO AND DEFLECTION CIRCUITS. A video signal of approximately 90 volts (ac/dc) is required to drive the high energy erase gun at lineal speeds of 160,000 inches per second. As writing speed is decreased, the video drive required also decreases so that at 8,000 inches per second the required drive has dropped to about 15 volts. The "write" guns are similar to a standard cathode ray gun with electrostatic focus and deflection. Drive requirements for the low energy write gun are similar.

Deflection circuitry for the writing beams is conventional, but since the deflection plates draw appreciable current, coupling to the plates should utilize cathode followers.

STATIC VOLTAGE SUPPLIES. Static voltages should be supplied as listed in "TYPICAL OPERATING CONDITIONS." This may be done by use of conventional power supplies. Provision must be made for easy adjustment of: (a) Collimator voltage, to collimate the flood beam, (b) the flood gun control-grid voltage, to adjust for full coverage of the beam, (c) the write gun focus anode voltage (both write guns), and (d) the backing electrode voltage for optimum storage over a range of conditions. Since the write gun cathodes are not operated at ground, either the control-grid driving circuits must be referenced to the cathodes, or else the cathode potentials must be well regulated. The electrostatic focusing is proportional, and care must be taken to preserve the focusing ratio to maintain a good spot. This implies either a proportional focus voltage, or well-regulated cathode and focus voltages. It is recommended that the resistances of the deflecting electrode circuits be approximately equal.

CIRCUITRY (CONT.)

PROTECTIVE CIRCUITS. Due to high internal voltage gradient between the backing electrode and the view screen, it is advisable to provide protection against excessive surge currents. For the view screen use of a limited-energy type power supply with 1 ma maximum short circuit current is preferred. In any event, a high voltage protective resistor of at least one megohm should be used in series with the view screen lead. Damage to the storage surface may result from operation of the writing beam on any part of the screen not covered by the flood beam. If it is necessary or desirable to operate any write gun with the flood beam cut off, the collector electrode voltage must be lowered to backing electrode potential.

GENERAL SPECIFICATIONS

OPTICAL DATA

Phosphor number .... P20* Aluminized
Fluorescent color .... Green-Yellow
Phosphorescent color .... Green-Yellow
Face plate
 Transmission (visible range) 83-92%
 Radius of curvature .... Flat

MECHANICAL DATA (SEE FIGURE 1)

MAXIMUM ELECTRICAL RATINGS **

Values presented here should not be exceeded under any circumstances.
THESE ARE NOT OPERATING VOLTAGES. All voltages are given with respect to the flood gun cathode except those identified by the symbol △, which are given with respect to the write gun cathode.

Cathode, flood gun (fk) .... 0 max. volts
Cathode, write gun 1 (wlk) ....−3,000 max. volts
Cathode, write gun 2(w2k) ....−6,500 max. volts
Grid No. 1, flood gun (fg1)
 Negative bias value .... 200 max. volts
 Positive bias value .... 0 max. volts
 Positive peak value .... 2 max. volts
Grid No. 1, write guns 1&2 (w1g1, w2g1)△
 Negative bias value .... 200 max. volts
 Positive bias value .... 0 max. volts
 Positive peak value .... 2 max. volts
Grid No. 2, flood gun (fg2), write guns
 1&2, (w1g2, w2g2) .... 200 max. volts
Grid No. 3 focus anode, write gun 1,(w1g3)...−3000 max volts
Grid No. 3, focus anode, write gun 2
 (w2g3) ....−6500 max. volts
Grid No. 4, (Internal connection to Grid No. 2)

Peak heater-cathode voltage
(both write guns) 200 max. volts

Heater negative with respect to cathode...... 125 max. volts
Heater positive with respect to cathode ...... 125 max. volts

* Other phosphors available on request

** Application circuitry is available on request

MAXIMUM ELECTRICAL RATINGS (CONT.)

Peak heater-cathode voltage (flood gun)

Heater negative with respect to cathode ...... 125 max. volts
Heater positive with respect to cathode ...... 125 max. volts
View screen (scn) .... 7,500 max. volts
Backing electrode (be) .... −25 volts to +200 max. volts *
Collector electrode (ce) .... 250 max. volts
Collimator (fg4) .... 200 max. volts
Third anode (fg3) .... 200 max. volts

MAXIMUM CIRCUIT VALUES

Control grid circuit resistance (each gun) ...... 1 megohm
Backing electrode (be) .... 5,000 ohms

MINIMUM CIRCUIT VALUES

Collimator (fg4) .... 1,000 ohms
View screen (scn) .... 1 megohm
Collector electrode (ce) .... 1,000 ohms

TYPICAL OPERATING CONDITIONS

All voltages are given with respect to the flood gun cathode except those indicated by the symbol △, which are given with respect to the write gun cathode.

VIEWING SECTION

View screen voltage .... +5,500 volts
Backing electrode .... −5 to −12 volts
Collector electrode .... +120 volts
Collimator
adjust for optimum collimation .... +30 to +80 volts
Fourth anode .... +20 to +50 volts
View screen current .... 0 to 500 µa
Backing electrode .... −15 to +75 µa
Collector electrode, second anode,
third anode, fourth anode currents ... each less than 2 ma.

FLOOD GUN

Cathode voltage .... 0 volts
Cathode current .... 0 to 2 ma
Control grid operating bias (adjust for
full coverage of view screen .... 0 to −30 volts
Control grid cutoff .... −60 to −120 volts
Anode (fg2) .... 100 volts
Heater voltage .... 6.3V. AC or DC
Heater Current .... 0.6 amps.

* Exception - - see discussion under "WRITE THROUGH"

TYPICAL OPERATING CONDITIONS (CONT.)

	WRITE GUN NO. 1	WRITE GUN NO. 2
Cathode Voltage	−2500 volts	−6000 volts
Cathode Current	0 to 2000 µa	0 to 2000 µa
Control Grid Voltage for cutoff of undeflected focused spot △	−70 to −120 volts	−70 to −120 volts
First Anode Voltage for Focus △	+350 to +750 volts	+850 to 1800 volts
Second Anode Voltage (fg2)	+100 volts	+100 volts
Heater Voltage	6.3 V AC/DC	6.3V AC/DC
Heater Current	0.6 amps	0.6 amps
Deflection Plates-Average Voltage	+100 volts	+100 volts
Deflection Factor (horizontal & vertical matched)	50 volts/inch	170 volts/inch
Plate Pairs	(w1D1, w1D2), (w1D3, w1D4)	(w2D1, w2D2), (w2D3, w2D4)

Deflection Direction

Positive voltage on w1D1 or w2D1 deflects beam toward bulb contact No. 1 (view screen connector).

Positive voltage on w1D4 or w2D4 deflects beam toward bulb contact No. 3 (collector electrode connector).

Relative Plate Locations

w1D1, w1D2, w2D1, w2D2 are nearer view screen
w1D3, w1D4, and w2D3, w2D4 are nearer cathode

Orientation (with view screen lead to left of tube, looking at tube face)

w1D3, w1D4 and w2D3, w2D4 cause vertical deflection.
w1D1, w1D2 and w2D1, w2D2 cause horizontal deflection.

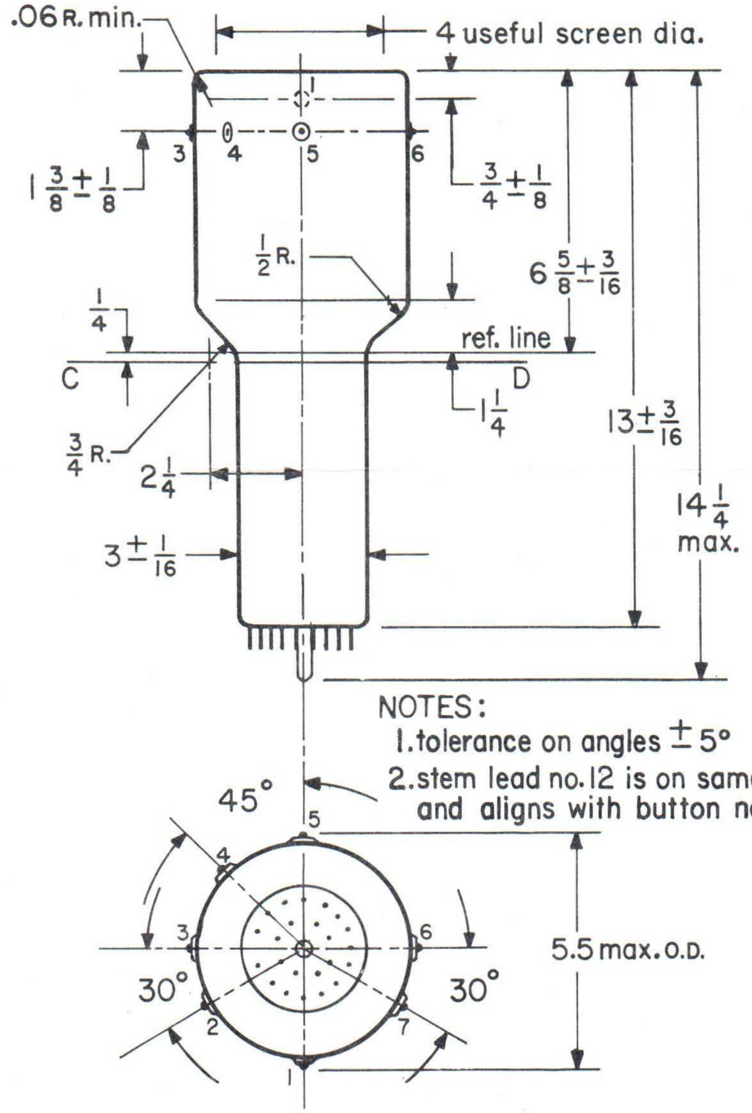
COLLIMATION ADJUSTMENT

In making the collimation adjustment, the potential in an electrostatic lens gap is varied until the viewing electrons approach the storage surface orthogonally over the entire area. The collimation is critical only for half-tones, and is most critical in the vicinity of the cut-off point. Therefore, the most precise collimation adjustment can be obtained when the entire screen is in a half-tone state near cutoff. After view screen, backing electrode, collector electrode, and flood gun voltages are applied to the tube, the flood gun bias should be reduced until full coverage of the screen is just obtained with zero volts on the backing electrode. Then the backing electrode voltage should be slowly increased negatively until the screen brightness has acquired a low half-tone level. At this time the collimator, fg4 ,potential is adjusted (in the vicinity of +40v) to obtain best uniformity over a four-inch diameter circle. In some cases it is possible to improve the collimation somewhat by simultaneously adjusting the third-anode, fg3, (in the vicinity of 40v) along with the collimator, fg4.

TYPE H-1038

FIG. 1 OUTLINE DRAWING

DIMENSIONS IN INCHES



NOTES:
1. tolerance on angles $\pm 5°$
2. stem lead no. 12 is on same side as and aligns with button no. $1 \pm 5°$

TYPE H-1038

FIG. 2 STEM DETAIL

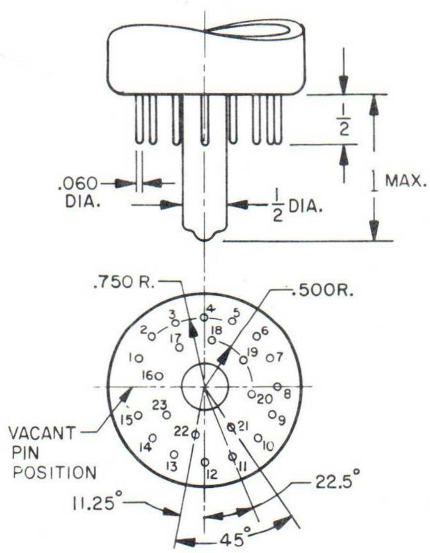
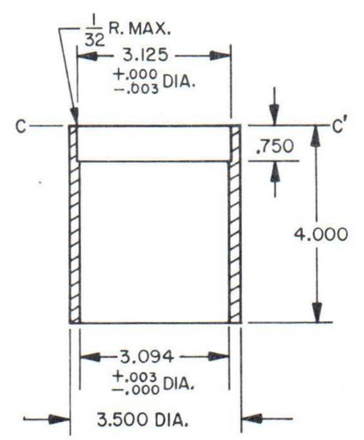


FIG. 3 REFERENCE LINE GAUGE



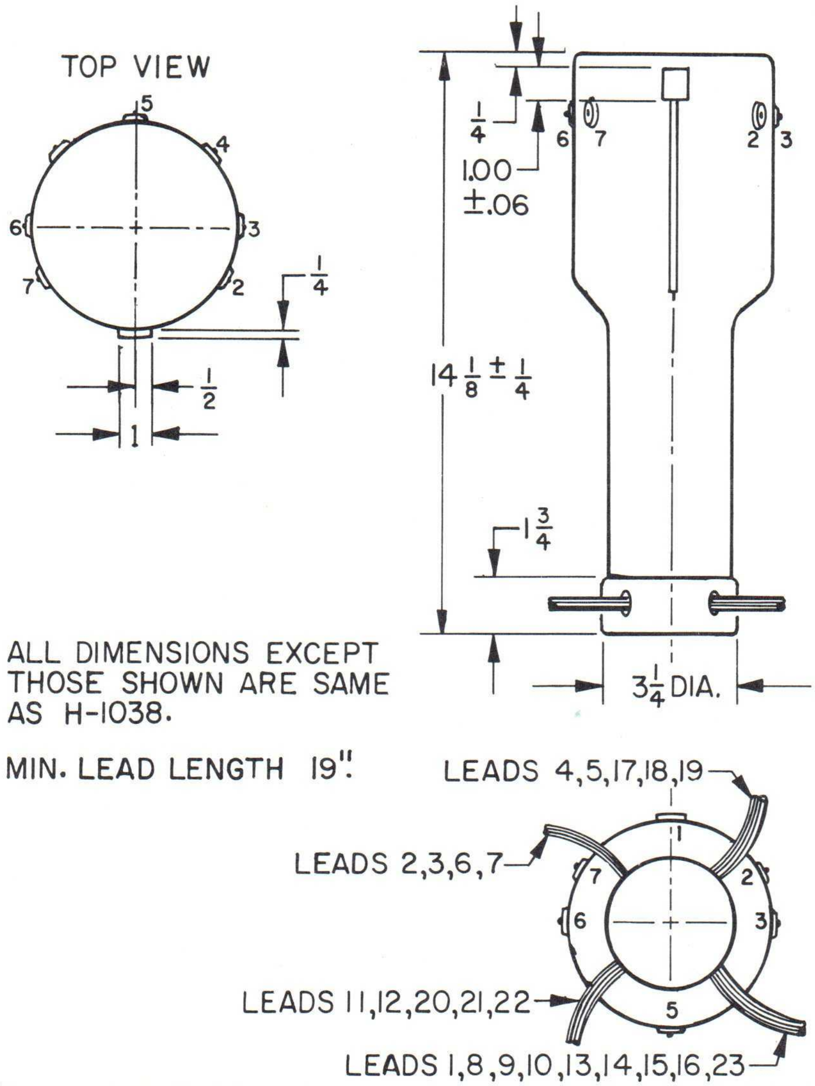
WHEN TUBE NECK IS INSERTED THROUGH GAUGE; REFERENCE LINE WILL BE DETERMINED BY PLANE C-C' WHEN GAUGE IS RESTING ON FUNNEL.

TYPE H-1038AP20

This type is the same as the H-1038 except that the base and view screen connections are potted to permit operation at altitudes to 70,000 feet.

FIG. 6 OUTLINE DRAWNG TYPE H-1038AP20

DIMENSIONS IN INCHES



WIRE LIST H-1038AP20

WIRE NO.	LENGTH MIN. INCHES	SIZE AWG	TYPE	ELECTRODE
1	19	24	MIL-W-16878,Type B	Second Anode,w1g1,w2g2,fg2
2	19	24	"	Deflecting Plate,w2D2
3	19	24	"	Deflecting Plate,w2D4
4	19	22	SEHV (5)-732A-(45)	Cathode, Write Gun 2, w2k
5	19	22	"	Control Grid, Write Gun 2, w2g1
6	19	24	MIL-W-16878,Type B	Deflecting Plate, w2D3
7	19	24	"	Deflecting Plate, w2D1
8	19	24	"	Cathode, Flood Gun, fk
9	19	24	"	Deflecting Plate, w1D1
10	19	24	"	Deflecting Plate, w1D3
11	19	22	SEHV(5)-732A-(45)	Control Grid, Write Gun 1, w1g1
12	19	22	"	Cathode , Write Gun 1, w1k
13	19	24	MIL-W-16878,Type B	Deflecting Plate, w1D4
14	19	24	"	Deflecting Plate, w1D2
15	19	24	"	Control Grid, Flood Gun, fg1
16	19	24	"	Heater, Flood Gun, fh
17	19	22	SEHV (5)-732A-(45)	Heater, Write Gun 2, w2h
18	19	22	"	Heater, Write Gun 2, w2h
19	19	22	"	Focus Electrode, Write Gun 2, w2g3
20	19	22	"	Focus Electrode, Write Gun 1, w1g3
21	19	22	"	Heater, Write Gun 1, w1h
22	19	22	"	Heater, Write Gun 1, w1h
23	19	24	MIL-W-16878,Type B	Heater, Flood Gun, fh

View screen lead, unnumbered, 20 gauge, SEHV (15)1932A-(66). Min. length nineteen inches.

FIG. 4 SCHEMATIC DIAGRAM TYPE H-1038

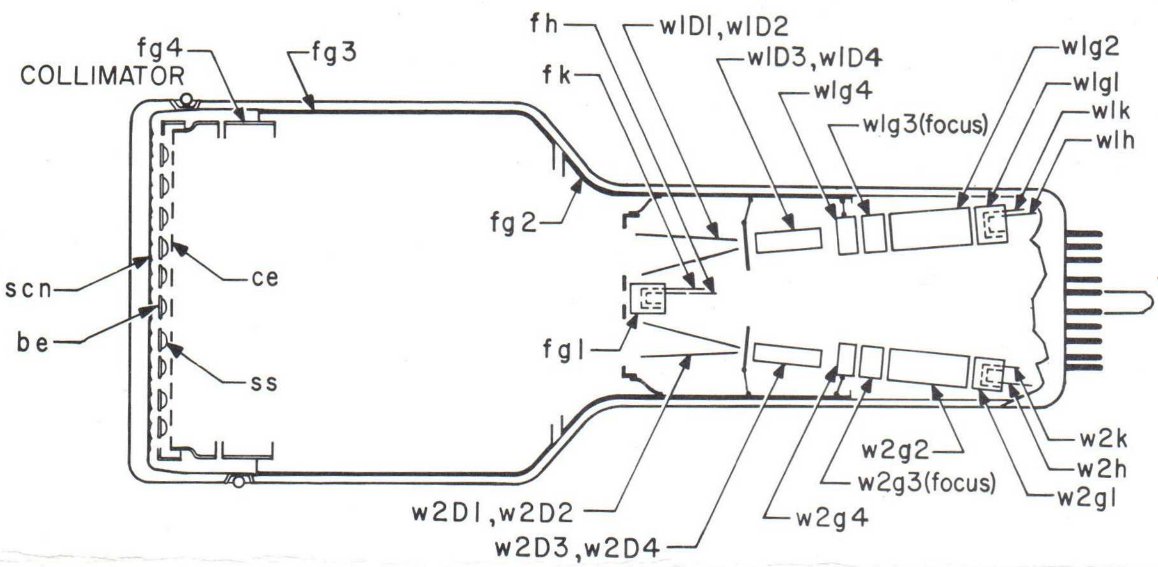
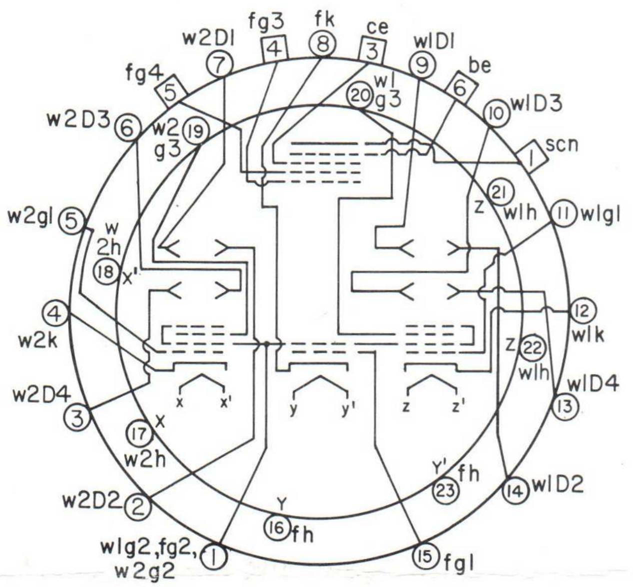


FIG. 5 BASING DIAGRAM TYPE H-1038



BULB CONTACT □		CONNECTION
1	JETEC J1-22	VIEW SCREEN (scn)
2		INTERNAL CONNECTION TO fg4
3	JETEC J1-22	COLLECTOR ELECTRODE (ce)
4	JETEC J1-22	THIRD ANODE (fg3)
5	JETEC J1-22	COLLIMATOR (fg4)
6	JETEC J1-22	BACKING ELECTRODE (be)
7		INTERNAL CONNECTION TO fg4

PIN NO. ○	CONNECTION
1	SECOND ANODE (w1g2, w2g2, fg2)
2	DEFLECTING PLATE (w2D2)
3	DEFLECTING PLATE (w2D4)
4	CATHODE (w2k)
5	CONTROL GRID (w2g1)
6	DEFLECTING PLATE (w2D3)
7	DEFLECTING PLATE (w2D1)
8	CATHODE, FLOOD GUN (fk)
9	DEFLECTING PLATE (w1D1)
10	DEFLECTING PLATE (w1D3)
11	CONTROL GRID (w1g1)
12	CATHODE (w1k)
13	DEFLECTING PLATE (w1D4)
14	DEFLECTING PLATE (w1D2)
15	CONTROL GRID FLOOD GUN (fg1)
16	HEATER, FLOOD GUN (fh)
17	HEATER (w2h)
18	HEATER (w2h)
19	FOCUS ELECTRODE (w2g3)
20	FOCUS ELECTRODE (w1g3)
21	HEATER (w1h)
22	HEATER (w1h)
23	HEATER, FLOOD GUN (fh)

JETEC J1-22 = RECESSED SMALL BALL CAP
w1 = ... WRITING GUN NO. 1
w2 = ... WRITING GUN NO. 2

CRST-8/1.5M/SL/2-61

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For additional information, please write:

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VACUUM TUBE PRODUCTS DIVISION
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2020 SHORT STREET, OCEANSIDE, CALIFORNIA
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HUGHES / 21" TONOTRON*
DIRECT-VIEW CATHODE-RAY STORAGE TUBE
TYPE H1020

DESCRIPTION

Hughes 21" Tonotron, Type H1020, is a direct-view storage tube which features storage of half tones plus a large area for displayed stored information, together with controllable persistence and sufficient brightness for use with high ambient illumination.

High light output has been achieved by providing a multiple-cathode viewing gun and by utilizing an efficient, aluminized phospher view screen operated at high potential. When high light output is unnecessary, the viewing time can be extended with some sacrifice of brightness through the use of pulsing techniques.

TENTATIVE SPECIFICATIONS

Bulb (approx.)

- Diameter .... 20 13/16 inches ± 1/8
- Over-all length .... 25 inches ± 1/2
- Usable screen diameter .... 17 5/8 inches
- Mounting position .... Any, except face down
- Phosphor .... P20 aluminized

Writing-Gun

- Writing gun axis offset** .... 2 inches (approx.)
- Focusing method .... Magnetic
- Deflection method .... Magnetic
- Heater .... 6.3 v at 0.6 amp
- Cathode supply*** .... -5 kv at 1 ma

Flood-Gun

- Heater .... 6.3 v at 1.8 amp
- Anode supply*** .... +100 v at 20 ma

AVERAGE PERFORMANCE FOR SPECIFIED CONDITIONS

- Viewing time from 0% to 20% of saturated brightness .... 60 seconds
- Erasing time, length of single pulse to reduce brightness from 100% to 10% .... 300 msec
- Writing speed for 40 μa beam current from 0% to 80% of saturated brightness .. 40,000 inches/sec
- Grid drive for 80% of saturation and 40,000 inches/second .... 16 volts
- Saturated brightness for 10,000 volts on viewing screen .... 200 ft. lamberts
- Resolution (stored) for 40 μa beam current and 80% of saturated brightness .... 475 lines/min. useful diameter
- Shortest controlled persistence for 20:1 contrast ratio .... 6 seconds max.
- Longest controlled persistence for 20:1 contrast ratio .... 60 seconds min.

Notes: **Writing gun is tilted to point toward center of screen.
***All voltages are referenced to the flood-gun cathode as zero volts.

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ELECTRON TUBE DIVISION
INTERNATIONAL AIRPORT STATION
LOS ANGELES 45, CALIFORNIA

21-INCH DIRECT VIEW DISPLAY HALF-TONE, CHARACTER WRITING AND SPOT WRITING STORAGE TUBE WITH ELECTROSTATIC FOCUS & CONVERGENCE, AND ELECTROMAGNETIC DEFLECTION

VTP

TYPE H-1019*
TYPOTRON®

AVERAGE PERFORMANCE SUMMARY

Specified conditions for the values below are given in paragraph 6.0, page 4 and 5.

Viewing Screen Brightness, 150 Foot-Lamberts (P20 Phosphor)
120 Foot-Lamberts (P4 Phosphor)
Viewing Time .... 120 Seconds
Character Writing Time .... 25 Microseconds
Character Registration 1.33
Spot Writing Speed .... 40,000 Inches Per Second
Stored Resolution .... 425 Lines
Half-Tone Levels .... 5, Between Extremes of Black & White
Erase Time .... 400 Milliseconds

1.0 GENERAL DESCRIPTION

The Type H-1019 Typotron tube is a 21-inch charge-storage cathode ray tube which presents, for direct viewing, a bright visual display of stored CHARACTER-WRITTEN data and SPOT-WRITTEN situation information. By virtue of its dual-mode writing capability, the tube is especially suited to *air surveillance, identification,* and *traffic control service,* and for *computer and high speed communication read out* applications – particularly where system outputs include coordinate information for curve plotting or facsimile reproduction.

A display with sufficient brilliance to be plainly visible in high ambient light is produced by operating the efficient aluminized-phosphor viewing screen at a high potential and by exciting the phosphor with a dense flooding beam from a multiple cathode source. At least five readily distinguishable half-tone levels between "black" and "white" may be presented.

Two methods of erasure may be used, one of which effects the removal of stored information at once, and the other which provides for controlled persistence of the display. Electrostatic focus, selection, convergence and compensation, and electromagnetic deflection, are employed.

2.0 GENERAL SPECIFICATIONS

2.1 ELECTRICAL DATA

Storage mode .... Half-tone
Erasing method .... Flooding gun
Writing gun data
- Focusing method .... Electrostatic
- Converging method .... Electrostatic
- Imaging method .... Electrostatic
- Selecting method .... Electrostatic
- Compensating method .... Electrostatic
- Deflecting method .... Electromagnetic
- Deflection angle .... 60°, approx.

Matrix alignment .... Matrix image is erect on the viewing screen when the tube is positioned with the writing gun neck on the top side. Positive voltage on sD1 and cD1 displays the left hand characters of the matrix (Observer's left, facing the viewing screen.) Positive voltage on sD3 and cD3 displays the lower characters on the matrix. (Refer to Matrix Configuration, Fig. 2, page 6).

* *Type H-1019 is a developmental tube. Data presented herein are accurate as of February 5, 1963, but are subject to change without notice. No obligation for future manufacture is assumed unless specifically arranged.*

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OCEANSIDE, CALIFORNIA

TABLE OF CONTENTS

DRAWINGS AND CURVES

2.0 GENERAL SPECIFICATIONS (CONT.)

2.2 OPTICAL DATA

Phosphor number * . . P4 (aluminized) P20 (aluminized)
Fluorescent color . . . . . . Blue-white . . Yellow-green
Phosphorescent color . . . . . White . . Yellow-green
Face plate data
- Radius of curvature . . . . 28 inches
- Useful screen diameter . . . . 18 inches, minimum
- Transmission (visible range) . . . 90 percent, approx.

2.3 MECHANICAL DATA

(Refer Outline Drawing, Fig. 3, page 7)

Overall length . . . . 36 1/2 ±1/2 inches
Bulb diameter . . . . 20 13/16 ±1/8 inches
Bulb connections
- Collimating electrode (fg4) recessed cavity . . . . JEDEC J1-21
- All others . . . . . . Potted, with 30", minimum, leads

Base connections
- Neck base (writing gun) . . . . 23-pin socket, Cinch Mfg. Co. no. 47 A-22025 or equivalent
- Body base (flooding gun) . . . . Small shell 7-pin socket

Bulb connection alignment . . . Refer to Outline Drawing
Base alignment
- Neck base (writing gun) . . . . Pin 14 aligns with a plane through the center of the bases ±10°
- Body base (flooding gun) . . . . Pin 4 aligns with a plane through the center of the bases ±20°

Deflection yoke . . . . . Syntronic Instruments, Inc. type no. C2706-3 Y3924 or equivalent
Operating position . . . . Any, except with face plate downward
Weight . . . . 40 pounds, approximately

3.0 MAXIMUM ELECTRICAL RATINGS

All voltages are given with respect to the flooding gun cathode (fk), except those indicated by the symbol ▲, where values are referenced to the writing gun cathode (wk). MAXIMUM ELECTRICAL RATINGS define those voltages which may be applied to the tube without damage, but which may not give required performance.

CAUTION: The flooding beam must cover the entire viewing screen area, and writing beam current must be held within safe limits for the character writing time or spot sweep speed used.

3.1 STORAGE DISPLAY SECTION

Viewing screen, Evs . . . . +10,000 volts
Backing electrode, Ebe
- D. C. voltage . . . . −25, +17 volts
- Erase pulse amplitude . . . . +17 volts
- D. C. voltage plus erase pulse . . . . +30 volts

Collector electrode, Ece . . . . +250 volts

3.2 FLOODING GUN

Grid no. 4, collimator, fEc4 . . . . +300 volts
Grid no. 3, fEc3** . . . . +300 volts
Grid no. 2, fEc2 . . . . +150 volts
Grid no. 1, control grid, fEc1
- Negative bias value . . . . −500 volts

Cathode, fEk . . . . 0 volts
Heater, fEh . . . . 6.93 volts, AC or DC
Peak voltage, heater with respect to cathode, fEh-k.
- During warmup period not to exceed 15 seconds . . . . −410, +180 volts
- After warmup . . . . ±180 volts

* *Other phosphors available on request.*

** *Flooding gun grid no. 3 is internally connected to writing gun grid nos. 2, 4, 5, 7, and 9.*

3.3 WRITING GUN

Grid no. 8, imaging electrode, wEc8 . . . . −5000 volts
Grid no. 6, matrix, wEc6 . . . . +3500 volts
Grid no. 3, focus, wEc3 . . . . −5000 volts
Grid no. 1, control grid, wEc1 ▲
 Negative bias value . . . . −300 volts
Cathode, wEk . . . . −5000 volts
Heater, wEh . . . . 6.93 volts, AC or DC
Peak voltage, heater with respect to cathode, wEh-k ▲
 During warmup period not to exceed
 15 seconds . . . . −410, +180 volts
 After warmup . . . . ±180 volts

4.0 TYPICAL OPERATING CONDITIONS

All voltages are given with respect to the flooding gun cathode (fk), except those indicated by the symbol ▲, where values are referenced to the writing gun cathode (wk). Voltages indicated in TYPICAL OPERATING CONDITIONS are representative values for most common in-service uses. For specific applications, however, these voltages may deviate widely within the maximum ratings. Contact Applications Engineering regarding operating conditions to meet particular requirements.

4.1 STORAGE DISPLAY SECTION

Viewing screen, Evs . . . . +8,000 volts
Backing electrode, Ebe . . . . +5 volts
Collector electrode, Ece . . . . +150 volts

4.2 FLOODING GUN

Grid no. 4, collimator, fEc4 . . . . +30 to +50 volts
Grid no. 3, fEc3* . . . . +50 volts
Grid no. 2, fEc2 . . . . +100 volts
Grid no. 1, control grid, fEc1 Adjusted for full coverage
 of the viewing screen . . . . −10 to −50 volts
 Cut-off value, fE(co)c1 . . . . −200 to −300 volts
Cathode, fEk . . . . 0 volts
Heater, fEh . . . . 6.3 volts
Heater current, fIh . . . . 1.8 amperes

4.3 WRITING GUN

Grid no. 8, imaging electrode,
 wEc8 . . . . −2,075 to −2,875 volts
Grid no. 6, matrix, wEc6 . . . . +2500 to +3000 volts
Grid no. 3, focus, wEc3 . . . . −2750 to −3150 volts
Grid no. 1, control grid, for undeflected spot cut-off,
 wE(co)c1 ▲ . . . . −60 to −130 volts
Cathode, wEk . . . . −3250 volts
Heater, wEh . . . . 6.3 volts
Heater current, wIh . . . . 0.6 ampere

4.4 TYPICAL CURRENTS

Electrode	Voltage	I_1 **	I_2 **	I_3 **
View-screen, Ivs	+8 kV	1200μA	400μA	0
Collector electrode Ice	+150 V	3600μA	4000μA	4400μA
Grid no. 4, fIc4	+44 V	900μA	900μA	900μA
Grid no. 3, fIc3	+50 V	800μA	1050μA	1050μA
Grid no. 2, fIc2	+100 V	100μA	250μA	250μA

4.5 CIRCUIT VALUES

Viewing screen circuit resistance . . 1 megohm, maximum
 0.1 megohm, minimum
Backing electrode circuit resistance . . 5000 ohms, max.
Collector electrode circuit resistance . . 1000 ohms, min.
Control grid circuit resistance,
 each gun . . . . 1 megohm, max.
Flooding gun grids 2, 3, and 4, anode and collimator
 circuit resistances
 . . . . . 25,000 ohms, maximum, 1000 ohms, minimum

4.6 SELECTION AND COMPENSATION FACTORS

sD1 and sD2 . . . . 24 to 30 volts per character
sD3 and sD4 . . . . 24 to 30 volts per character
cD1 and cD2 . . . . 27 to 33 volts per character
cD3 and cD4 . . . . 27 to 33 volts per character
Maximum centering voltage . . . . 50 volts
Average reference level of selection and compensation
 plates . . . . Same as writing gun grid no. 2
Undeflected spot position . . . . Within a 25 millimeter
 radius circle whose center is at the center of the
 viewing screen

4.7 INTERELECTRODE CAPACITANCES (Approx.)

Measurement	Capacity (picofarads)
Viewing screen to all other electrodes	409
Backing electrode to all other electrodes	1032
Collector electrode to all other electrodes	732
fg4, collimator, to all other electrodes	192
fg3, wg2, wg4, wg5, wg7 and wg9 to all other electrodes	185
fg2 to all other electrodes	17
fg1 to all other electrodes	15
fk to all other electrodes	20
fh to all other electrodes	27
wg8, imaging electrode, to all other electrodes	20
wg6, matrix, to all other electrodes	20
wg3, focus electrode, to all other electrodes	18
wg1, control grid, to all other electrodes	15
wk to all other electrodes	10
wh to all other electrodes	15
sD1 to all other electrodes	13
sD2 to all other electrodes	15
sD3 to all other electrodes	10
sD4 to all other electrodes	10
sD1 to sD2	1
sD3 to sD4	3
cD1 to all other electrodes	20
cD2 to all other electrodes	20
cD3 to all other electrodes	20
cD4 to all other electrodes	20
cD1 to cD2	1
cD3 to cD4	2

5.0 OPERATING PRINCIPLES

The principal components incident to the operation of Type H-1019 Typotron tube are shown in Fig. 1, Simplified Cut-away Diagram. These are: (1) the storage display assembly, (2) flooding gun, (3) collimating system, (4) writing gun, including the character selection and beam shaping elements, and (5) the externally mounted deflection yoke.

The storage display assembly consists of an aluminized viewing screen, a fine mesh backing electrode upon which a thin-film dielectric storage surface has been deposited, and a collector electrode.

Operation of the tube is based upon the ability of the storage surface to charge in a positive or negative direction depending on the energy level of the incident electron beam. This property is made possible by the secondary emission characteristics of the storage surface dielectric.

The flooding gun supplies a continuous stream of electrons, which are collimated and approach the storage surface orthogonally and uniformly over its entire area. Whether these electrons penetrate each of the many storage elements that comprise the storage surface, and are accelerated to the viewing screen, depends on

* *Flooding gun grid no. 3 is internally connected to writing gun grid nos. 2, 4, 5, 7, and 9.*

** *I_1 at equilibrium brightness, I_2 during dynamic erasure, I_3 at cut-off.*

5.0 OPERATING PRINCIPLES (CONT.)

the potential present at each element. Since storage surface potentials in the half-tone range are negative with respect to the flooding gun cathode (Refer to Fig. 5, page 8), every element of the storage surface is a virtual "control grid" for flood electrons approaching its area. If, therefore, a charge pattern is present at the storage surface, the display pattern produced at the viewing screen by flood electrons will be identical.

The writing of stored information occurs when positive-going charges are induced at the storage surface by the incident electron beam. This is accomplished by the writing gun, whose beam energy levels lie within the values required to produce storage surface secondary-emission ratios greater than unity.

The unique feature of Type H-1019 Typotron tube is the ability to establish storage surface charge patterns by character writing or spot writing, the choice of mode being determined chiefly by the values of focus voltage and selection plate potentials.

When the writing beam is directed by the selection plates to any of the 8X8 array of characters on the stencil-like character matrix (See Fig. 2), character writing results. In this operation, the writing beam is focused to cover a single character without overlap and, upon passing through the matrix, is shaped according to the character selected. By means of an electrostatic convergence field and the compensation plates, the shaped beam is reoriented along the longitudinal axis of the writing gun. The deflection yoke then positions the shaped beam to any desired location on the storage surface.

Spot writing is accomplished by essentially the same mechanism, except that the writing beam is directed by the selection plates through the spot writing aperture, and is re-focused to spot rather than character size at the storage surface.

The length of time after writing during which an acceptable output can be read is termed "retention time" (or "storage time"), and is limited primarily by the presence of residual gas molecules within the tube. As these molecules collide with flood electrons, positive ions are formed and are accelerated toward the negatively-charged storage surface. Upon landing of the ions, the storage surface is gradually charged in a positive direction, resulting in gradual brightening of the display background and corresponding loss of display contrast. At the limit of acceptable output, the storage surface may be erased and a new cycle begun.

Erasure of stored information takes place when the storage surface charges in a negative direction. This is accomplished by the flooding gun, whose relatively low beam energy level results in a secondary emission ratio at the storage surface of less than unity.

To erase, a positive pulse having amplitude equal to the value of storage surface cut-off potential is applied to the backing electrode. Due to capacitive coupling, the abrupt rise in backing electrode potential is accompanied by a similar rise in storage surface potential. Flood beam electrons, now attracted to the storage surface, charge it back down to flooding gun cathode potential.

When the pulse is removed, backing electrode potential drops by the same amount that it had been raised, and again the storage surface is carried with it. By this mechanism, the storage surface is driven to cut-off, erasure is complete, and the tube is ready for a subsequent writing operation.

Erasure may be accomplished with a single pulse as described above, or, if persistence is to be controlled, with a train of very short pulses.

For a more detailed discussion of the operating principles of half-tone charge-storage display tubes, please refer to "Operation of the Hughes Tonotron Tube", Application Engineering Publication 91-19A-5, which is available on request.

6.0 AVERAGE PERFORMANCE NOTES

6.1 EQUILIBRIUM BRIGHTNESS

With viewing screen potential at +8 kV, equilibrium brightness is approximately 150 foot lamberts with P20 phosphor, and 120 foot lamberts with P4 phosphor. Refer to Fig. 6, page 8.

6.2 VIEWING TIME

Viewing time, considered as the interval between the end of single pulse erasure to just cut-off, and the rise of background light to 20 percent of equilibrium brightness, is 120 seconds for this tube type.

By employing flood gun pulse or erase pulse techniques, storage time may be extended in exchange for unneeded light output. Also, where continuous viewing is not essential, additional storage time may be gained by inclusion of a "push-to-view" feature, whereby the flooding beam is turned on only when it is required to make visual observations. For data on extending storage time, refer to Applications Engineering Publication 91-19A-21, which is available on request.

6.3 ERASE TIME

To reduce display brightness from equilibrium value to cut-off, a single erase pulse whose amplitude is 120 percent of storage surface cut-off requires 400 milliseconds. If erase pulse amplitude is increased to the value of storage surface cut-off plus 5 volts, erase time is reduced to 60 milliseconds.

When display persistence is to be controlled, dynamic erasure is used, where a train of short positive-going pulses, rather than a relatively long single pulse, is continuously applied to the backing electrode. Persistence of written information in this mode of operation varies inversely with the pulse-train duty cycle, but the maximum duration of controlled persistence is limited by the same factor which governs the length of viewing time after single pulse erasure — the rate of storage surface decay due to ion charging. Refer to "OPERATING PRINCIPLES", pages 3 and 4.

6.4 CONTRAST RATIO

Shortest controlled persistence
for 20:1 contrast ratio . . . . 6 seconds, maximum
Longest controlled persistence
for 20:1 contrast ratio . . . . 120 seconds, minimum

The positive-going erase pulses applied to the backing electrode in the controlled persistence mode cause the viewing screen to assume full brightness for the duration of each pulse. This phenomenon causes the contrast ratio to deteriorate gradually as controlled persistence is decreased, thus constituting a limitation on the shortest usable persistence time.

However, by pulsing the viewing screen to a level below approximately +2 kV for the duration of each erase pulse, deterioration of the contrast ratio can be substantially reduced, and persistence times even shorter than the average performance value given above may be achieved.

6.5 CHARACTER WRITING

Character writing time; the time in which brightness is increased from cut-off to 80 percent of equilibrium value with 100 μA matrix current . . . . 25 μsec

Registration figure (ratio of superimposed character height to character height) 1.33

Character height (for letters and numbers) . . . . 0.140 inches ±10 percent

Character width . . . . Average approximately 75 percent of character height

Matrix* . . . . 64 characters; refer Fig. 2, page 6

6.6 SPOT WRITING

Writing speed; lineal speed at which brightness is increased from cut-off to 80 percent of equilibrium value . . . . 40,000 inches per second

Stored resolution at limiting writing speed, with writing gun grid 3 and 8 adjusted for minimum spot size . . . 425 lines per minimum useful diameter

Writing speed and the degree of stored resolution may be "traded off". At a typical writing gun cathode operating potential of 3250 volts, writing speeds well in excess of 40,000 inches per second can be attained at higher writing beam currents with some sacrifice in resolution. Conversely, resolution approaching 550 lines at 80 percent of equilibrium brightness can be obtained at lower beam current, but with a resultant reduction in writing speed.

If writing gun cathode potential is increased to −4875 volts, resolution can be increased by about 30 percent of the values cited above, without sacrificing writing speed. In general, imaging, focusing, and matrix voltages will require readjustment, within maximum ratings, and selection and compensation factors, as well as writing gun cut-off voltage, will increase in proportion to the increase in cathode potential.

7.0 ELECTRICAL NOTES

7.1 STATIC VOLTAGE SUPPLIES

Static voltages required are listed under TYPICAL OPERATING CONDITIONS, and may be readily furnished by conventional power supplies. There should be provisions for convenient adjustment of several electrode voltages: collimating voltage (fEc4) for proper collimation of the flooding beam, flooding gun control-grid voltage (fEc1) for full beam coverage of the storage area, focus anode voltage (wEc3) for correct cross section of the writing beam at the matrix, and image electrode voltage (wEc8) for adjustment of character sharpness or of spot resolution at the storage surface.

Since the writing gun cathode does not operate at ground potential, the imaging electrode and focus anode potentials must be referenced to it; in addition, it is necessary that the ratio of imaging and focus to accelerating voltages be fixed in order to maintain a specific character or spot size. A suitable means of meeting these conditions is by use of a single negative power supply with an appropriate voltage divider network. Separate power supplies may be used if desired, but they must incorporate excellent regulation.

7.2 PROTECTIVE CIRCUITS

Due to the high internal voltage gradient between the backing electrode and the viewing screen, it is advisable to provide protection against excessive surge currents. For the viewing screen, a limited-energy-type power supply with a 3 mA short circuit current is preferred. In any event, it is suggested that a high voltage protective resistor of approximately 0.5 megohms be connected in series with the viewing screen lead.

8.0 MECHANICAL NOTES

8.1 MOUNTING

The Type H-1019 Typotron tube may be mounted in any position for viewing, except with the face plate downward.

If the tube is to be used under conditions of shock or vibration, inclusion of appropriate snubbing or damping devices in the tube mount or cradle is recommended.

IMPORTANT: Under no circumstances should the writing gun neck be used to support any portion of the tube weight.

8.2 MAGNETIC SHIELDING

External magnetic fields present in the vicinity of a direct view display storage tube in service operation are likely to seriously impair flood beam collimation. For this reason, the tube must be installed within a suitable magnetic shield. If such fields are severe, a shield extending several inches beyond the face-plate may be necessary. It may also be necessary to shield the tube neck to minimize writing beam modulation.

Hughes Drawing C91-4A-72, which describes a magnetic shield for the Type H-1019 TYPOTRON tube, is available on request.

9.0 COLLIMATION ADJUSTMENT

When making collimation adjustments on the tube, the potentials of an electrostatic lens system are varied until flood electrons approach the storage surface orthogonally, and uniformly, over the entire area. Correct collimation is essential when good half-tone presentation is required; the effect is most evident at low brightness levels. Adjustments for optimum collimation should therefore be made with the tube operating in the lowest clearly discernible half-tone state.

After appropriate potentials have been applied to the viewing screen, backing electrode, collector electrode, and the flooding gun, flooding gun control grid, grid no. 1, bias (initially in cut-off) should be decreased until full coverage of the screen is just obtained.

Flooding gun grid no. 3 and no. 4 voltages should be set in accordance with the data which accompanies each tube. Then grid no. 4 voltage is adjusted for optimum uniform coverage of the viewing screen area.

* *Other matrix configurations can be developed by special arrangement.*

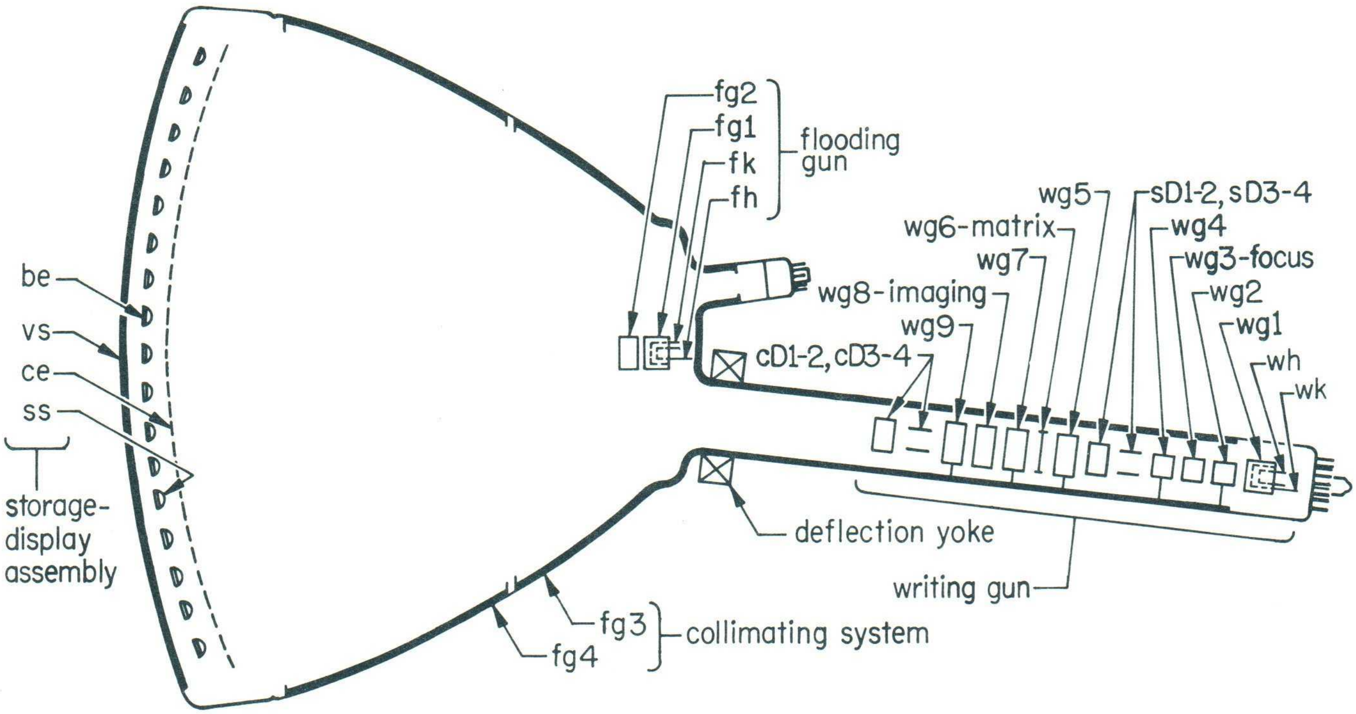
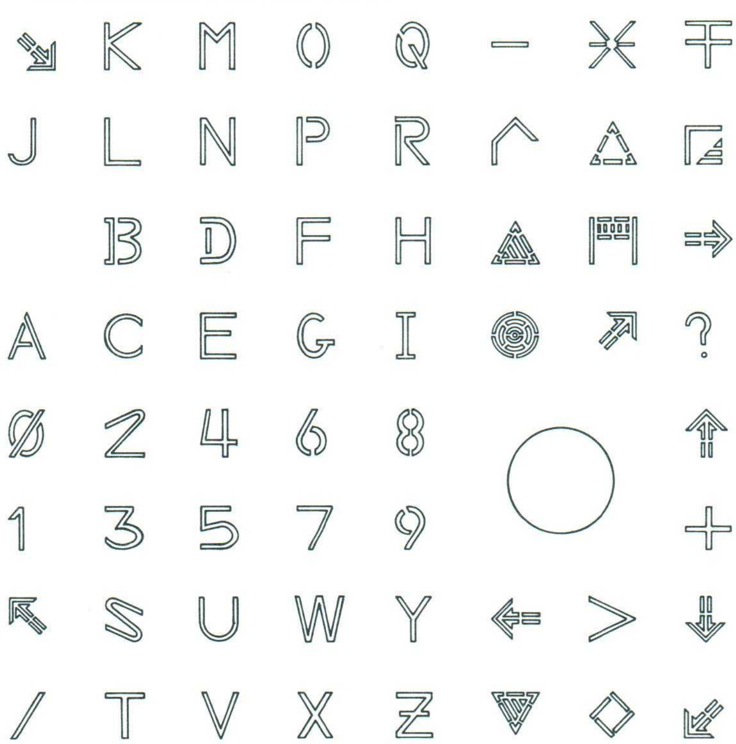


FIGURE 1
SIMPLIFIED CUT-AWAY DIAGRAM

FIGURE 2
MATRIX CONFIGURATION

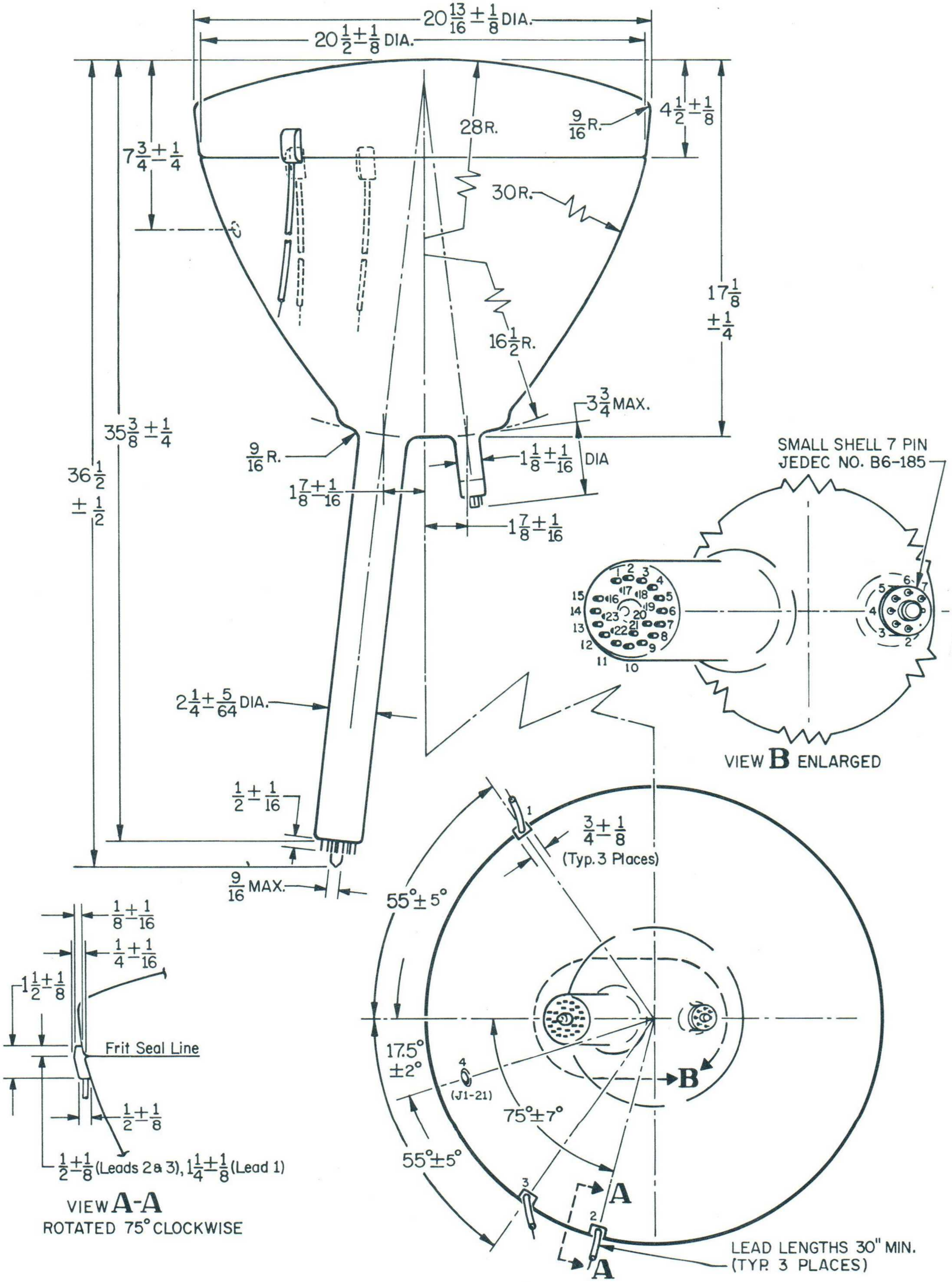


10.0 SET UP PROCEDURE FOR THE WRITE GUN

1. Adjust flood gun control grid bias to −300 volts.
2. Connect the view screen, backing electrode, and collimator (fg4) to the collector electrode at +150 volts.
3. Adjust write gun control grid bias to −150 volts.
4. A. Set cathode voltage at −3,250 volts, referenced to ground.
   B. Set imaging voltage at −2,500 volts, referenced to ground.
   C. Set matrix voltage at +2,500 volts, referenced to ground.
   D. Set focus voltage at +300 volts, referenced to the write gun cathode.
5. Connect the compensation plates to reference voltage, +50 volts.
6. Reduce write gun grid bias until matrix current is approximately 25μA.
7. Adjust selection centering voltages to present a single character near the center of the matrix. Vary the horizontal selection voltage to move the beam back and forth across the character while adjusting imaging voltage to minimize movement of the character. Repeat in the vertical direction.
8. Adjust the focus voltage to the more positive of the two values for which the size of the beam is equal to the center-to-center spacing of the four central characters. This will be approximately +400 volts.
9. Adjust both vertical and horizontal selection amplitude to display the entire matrix.
10. Reduce write gun grid bias to provide 100μA matrix current. Focus voltage may require readjustment.
11. Adjust the matrix voltage for the straightest rows and columns on the outer edges of the matrix format.
12. Remove the compensation plates from reference voltage and reconnect them to the normal compensation voltage source.
13. Bias the write gun off and return the view screen, backing electrode and collimator (fg4) to their normal operating voltages.

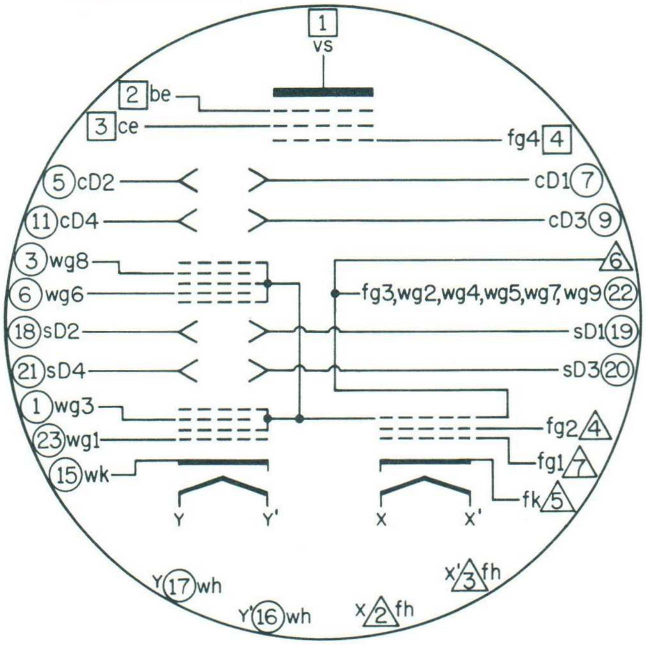
FIGURE 3 - OUTLINE DRAWING

DIMENSIONS IN INCHES



NOTE: ALL RADII DIMENSIONS ARE DESIGN CENTERS

FIGURE 4
SCHEMATIC AND BASING DIAGRAM



ELECTRODE CONNECTIONS

□ BULB TERMINAL CONNECTIONS

1 .... Viewing screen lead* .... vs
2 .... Backing electrode lead** .... be
3 .... Collector electrode lead** .... ce
4 .... Flooding gun grid 4 contact fg4

○ NECK BASE CONNECTIONS

1 .... Writing gun grid 3, focus anode wg3
2 .... No connection ....
3 .... Writing gun grid 8, imaging electrode wg8
4 .... No connection ....
5 .... Horizontal compensation plate cD2
6 .... Writing gun grid 6, matrix wg6
7 .... Horizontal compensation plate cD1
8 .... No connection ....
9 .... Vertical compensation plate cD3
10 .... No connection ....
11 .... Vertical compensation plate cD4
12, 13, 14 .... No connection ....
15 .... Writing gun cathode .... wk
16 .... Writing gun heater .... wh
17 .... Writing gun heater .... wh
18 .... Horizontal selection plate sD2
19 .... Horizontal selection plate sD1
20 .... Vertical selection plate sD3
21 .... Vertical selection plate sD4
22 .... Writing gun grids 2, 4, 5, 7, and 9; flooding gun grid 3 . wg2, wg4, wg5, wg7, wg9, fg3
23 .... Writing gun grid 1, control grid wg1

△ BODY BASE CONNECTIONS

1 .... Blank ....
2 .... Flooding gun heater .... fh
3 .... Flooding gun heater .... fh
4 .... Flooding gun grid 2 .... fg2
5 .... Flooding gun cathode .... fk
6 .... Internally connected to neck base connection 22
7 .... Flooding gun grid 1, control grid fg1

**SEHV(30) 19/32A silicone rubber wire*

***MIL-W-16878/2A Type B wire*

FIGURE 5
TYPICAL STORAGE CHARACTERISTICS

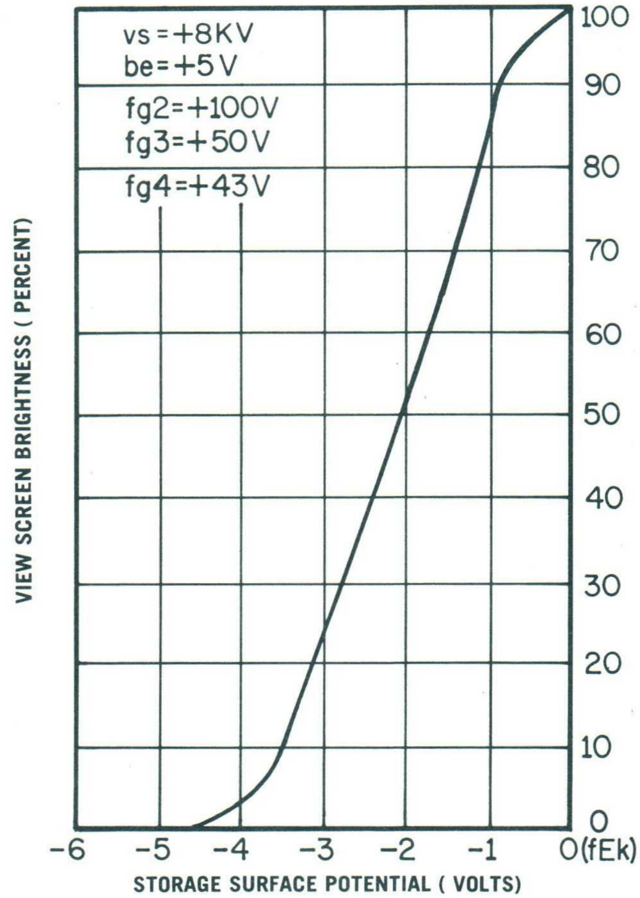
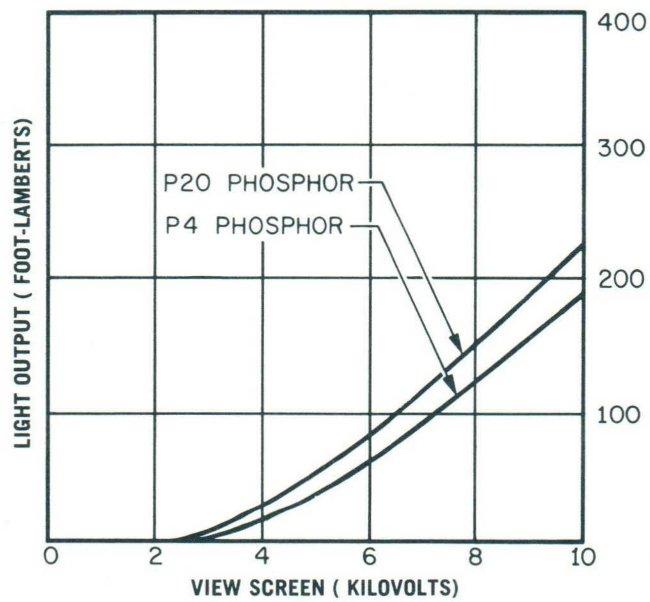


FIGURE 6
AVERAGE LIGHT OUTPUT



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TWX: 714-278-7106

Tentative Technical Information

Hughes Products
Hughes Aircraft Company

TONOTRON* (ELECTROSTATIC) H-1010

5-inch Direct-Display Half-tone Storage Tube

A. DESCRIPTION

The Tonotron is a direct-display, cathode-ray storage tube featuring: (1) storage of half-tones, (2) sufficient brightness for use in high ambient-light levels, (3) controllable persistence, (4) minimum over-all length. Black**, white, and intermediate shades of grey can be stored for periods of the order of a minute.*** Erasure can be either "instantaneous" or a gradual fading. The physical dimensions of the electrostatic Tonotron are given in the accompanying outline drawing.

There are two guns, a writing gun and a flood gun. The flood gun sprays the entire storage surface with a uniform spray of well-collimated, low-energy, electrons. The relative brightness at the viewing screen depends upon the surface potentials of the insulating storage layer on the gun side of the metal storage mesh. Starting with a uniform potential about 5 volts negative with respect to the flood-gun cathode, the storage surface is unwritten, or black. The writing gun can then apply a charge pattern on the screen, raising this potential through the half-tone scale towards the flood-gun cathode potential (full brightness). Since the storage surface is always negative, it can control the flood-electron transmission, but no flood electrons can strike it. Except for ion currents, then, the stored pattern could exist indefinitely. Under good vacuum conditions, ion currents limit the storage time to the order of a minute. Instantaneous erasure can be effected by application of a single positive voltage pulse to the storage grid. This pulse carries the potentials of the storage area positive with respect to the flood-gun cathode, and the flood electrons landing on the insulator surface restore its potential to the flood-gun cathode potential. When the pulse is removed, the insulator surface potential becomes so negative with respect to the flood-gun cathode potential that flood electrons are everywhere prevented from reaching the viewing screen. For gradual erasure, the single pulse is replaced by a train of very much shorter pulses; the time of erasure (persistence time) is controlled by adjusting the duty cycle of this pulse train. Additional discussion of erase performance will be found under "contrast" in Section "B".

*Trademark of the Hughes Aircraft Company

** The use of "black" and "white" refer to the unwritten and the fully written states.

*** See Section "H" for method of extending the storage time beyond one minute.

B. PERFORMANCE (typical values)

Full-tone writing speed Speed given for max. beam current.	40,000 in/sec.
Written resolution Measured by shrinking-raster method, at full brightness speed. Half-tones can be written with up to 60 lines/in. resolution.	45 lines/in. min.
Brightness (at 10 KV)	1500 foot-lamberts min.
Contrast Ratio The contrast ratio is roughly proportional to the persistence time for short persistences. The relatively long "instantaneous" erase pulse causes the entire screen to assume full highlight brightness (unless the viewing-screen voltage is simultaneously dropped). Similarly, with gradual erasure, each individual pulse of the erase train causes the entire screen to assume full highlight brightness for its duration so that the average "unwritten" brightness is increased. Thus, the contrast is proportional to the persistence time for short values of persistence, although the effect is negligible for long persistence.	3-Second persistence about 100:1
Erase time (single-pulse erasure)	250 milliseconds max.
Number of Half-tones	at least 5

C. GENERAL SPECIFICATIONS

Heaters, (two), for unipotential Cathodes	
Voltage	6.3±10 per cent ac or dc volts
Current (each heater)	0.6 amp
Phosphor	P20* Aluminized
Focusing Method	Electrostatic
Deflection Method	Electrostatic
Over-all length	15" max.
Greatest Diameter of Bulb	5-1/4±1/16"
Useful Screen Diameter	4" nominal
Mounting Position	Any

*Other Phosphors available on special order.

fl 6/58

Base	Small-Shell Diheptal 14-Pin	(JETEC No. B14-45)
Pin 1	Heater, Writing Gun	
Pin 2	Cathode, Writing Gun	
Pin 3	Control Grid, Writing Gun	
Pin 4	Deflection Plate D_1	
Pin 5	Deflection Plate D_3	
Pin 6	Control Grid, Flood Gun	
Pin 7	Heater, Flood Gun	
Pin 8	Heater, Flood Gun	
Pin 9	Cathode, Flood Gun	
Pin 10	A_2	
Pin 11	Deflection Plate D_4	
Pin 12	Deflection Plate D_2	
Pin 13	Focus (A_1), Writing Gun	
Pin 14	Heater, Writing Gun	

D_1 and D_2 are nearer the base. D_3 and D_4 are nearer the screen.

Bulb Terminal Connections (See Drawing on Page 6)

D. MAXIMUM RATINGS*

Viewing Screen voltage	10,000 volts
Storage-mesh voltage	-25 volts, +200 volts
Collector-mesh voltage	250 volts
Fourth-anode voltage	200 volts
Third-anode voltage	200 volts
Second-anode voltage	200 volts
Cathode (Writing Gun) voltage	-3000 volts
First-anode (Writing Gun) voltage	-3000 volts

E. TYPICAL OPERATING CONDITIONS*

1. Voltages and Currents

Viewing Screen Voltage	4000-8000 volts
Storage Mesh Voltage	5 volts
Collector Mesh Voltage	120 volts
Third Anode Voltage (adjust for optimum collimation)	30 to 50 volts
Fourth Anode Voltage	0 volts
Second Anode Voltage	100 volts
Control-Grid (Flood Gun), operating bias (adjust for full coverage of viewing screen; cut-off value is approximately -100 volts)	0 to -10 volts
Cathode (Flood Gun) Voltage	0 volts
Cathode (Writing Gun) Voltage	-2500 volts
Control Grid (Writing Gun) Voltage for visual extinction of focused spot*	-30 to -80 volts
First Anode (Writing Gun) Voltage for focus*	350 to 750 volts

*All voltages are given with respect to the flood gun cathode, except those starred, which are given with respect to the writing gun cathode.

Viewing-screen current	0 to 500 μa
Storage-mesh current	-15 to +75 μa
Collector-mesh, fourth-anode, third-anode, second-anode currents, each less than	2 ma
Cathode (flood gun) current	0 to 2 ma
Cathode (writing gun) current	0 to 1000 μa

2. Magnetic Shielding
   Magnetic shielding is required, particularly for the flood gun. Low intensity magnetic fields (viz, the earth's magnetic field) can deflect the flood electrons enough to destroy collimation (see Sec. "G").

F. CIRCUITRY

The circuits required to operate the Tonotron are simple. They fall into four categories: erase circuits, video and deflection circuits, static-voltage supplies, and protective circuits.

1. Erase Circuits. Two types of erase-pulse circuits are commonly used with the Tonotron tube. One is merely a battery, potentiometer, and micro-switch arrangement to manually elevate the storage mesh potential for "instantaneous" erasure; the other is a pulse-train generator, with variable amplitude and duty cycle. The amplitude is 0 to 10 volts; duty cycle is adjustable between 0.5 per cent and 20 per cent.

2. Video and Deflection Circuits. A video signal is required to drive the writing gun, which is a standard cathode-ray gun with electrostatic focus and deflection. Deflection circuitry, for the 2.5 KV beam is conventional.

3. Static Voltage Supplies. Static voltages must be supplied as listed in Part E: Typical Operating Conditions. This may be done by use of conventional power supplies. Provision must be made for easy adjustment of: (a) the third-anode voltage, to collimate the flood beam, (b) the flood-gun control-grid voltage, to adjust the size of the flood beam, (c) the writing-gun first-anode voltage, for focus and (d) the storage-mesh voltage, for evaluation of storage for a range of slightly different conditions. Since the writing-gun cathode voltage is not operated at ground, it is clear that either the control-grid driving circuits must be referenced to the cathode, or else the cathode potential must be well regulated. The electrostatic focusing is proportional, and care must be taken to preserve the focusing ratio to maintain a good spot. This implies either a proportional focus voltage, or well-regulated cathode and focus voltages.

4. Protective Circuits. Due to the high internal voltage gradient between the storage mesh and the viewing screen, it is advisable to provide protection against excessive surge currents. For the viewing screen, use of a limited-energy type power supply with 1 ma maximum short circuit current is preferred. In any event, a high voltage protective resistor of at least one megohm should be used in series with the viewing-screen lead. Damage

to the storage surface may result from operation of the writing beam on any part of the screen not covered by the flood beam. If it is necessary or desirable to operate the writing gun with the flood beam cut off, the collector-mesh voltage must be lowered to storage-mesh potential to prevent runaway charges from breaking down the dielectric coating on the storage mesh.

G. COLLIMATION ADJUSTMENT

In making the collimation adjustment, the potential in an electrostatic lens gap is varied until the flood electrons approach the storage mesh orthogonally over the entire area. The collimation is critical only for half-tones, it is most critical in the vicinity of the cut-off point. Therefore, the most precise collimation adjustment can be obtained when the entire screen is in a half-tone state near cutoff. After viewing-screen, storage-mesh, collector, and flood gun voltages are applied to the tube, the flood-gun bias should be reduced until just full coverage of the target is obtained. Then the target should be erased (using either a single long pulse, or a pulse train), by slowly increasing the pulse amplitude until, in the absence of the pulse, the screen brightness has acquired a low half-tone level. There will then be a period of the order of 30 seconds, before ion effects become important, in which to adjust the collimation. This is done by adjusting the third-anode potential (in the vicinity of 40 v) to obtain best uniformity over the largest obtainable circle. After a reasonable value seems to have been obtained, it is wise to re-erase the target and check the result again. In some cases it is possible to improve the collimation somewhat by simultaneously adjusting the fourth anode (in the vicinity of 0 v) along with the third anode.

H. EXTENDING STORAGE TIME

By means of a pulsing technique it is possible to increase the storage time from about one minute to more than five minutes. Image deterioration in a Tonotron is caused by positive ions (produced by the collision of flood electrons with gas molecules) landing on the storage surface where they neutralize some of the negative charge. If the flood gun is cut off half the time, approximately half the ions are produced and thus storage time is doubled. A sacrifice in brightness proportional to the increase in storage time is implicit in this technique. Because of certain technical complications, further information should be obtained before this mode of operation is employed.

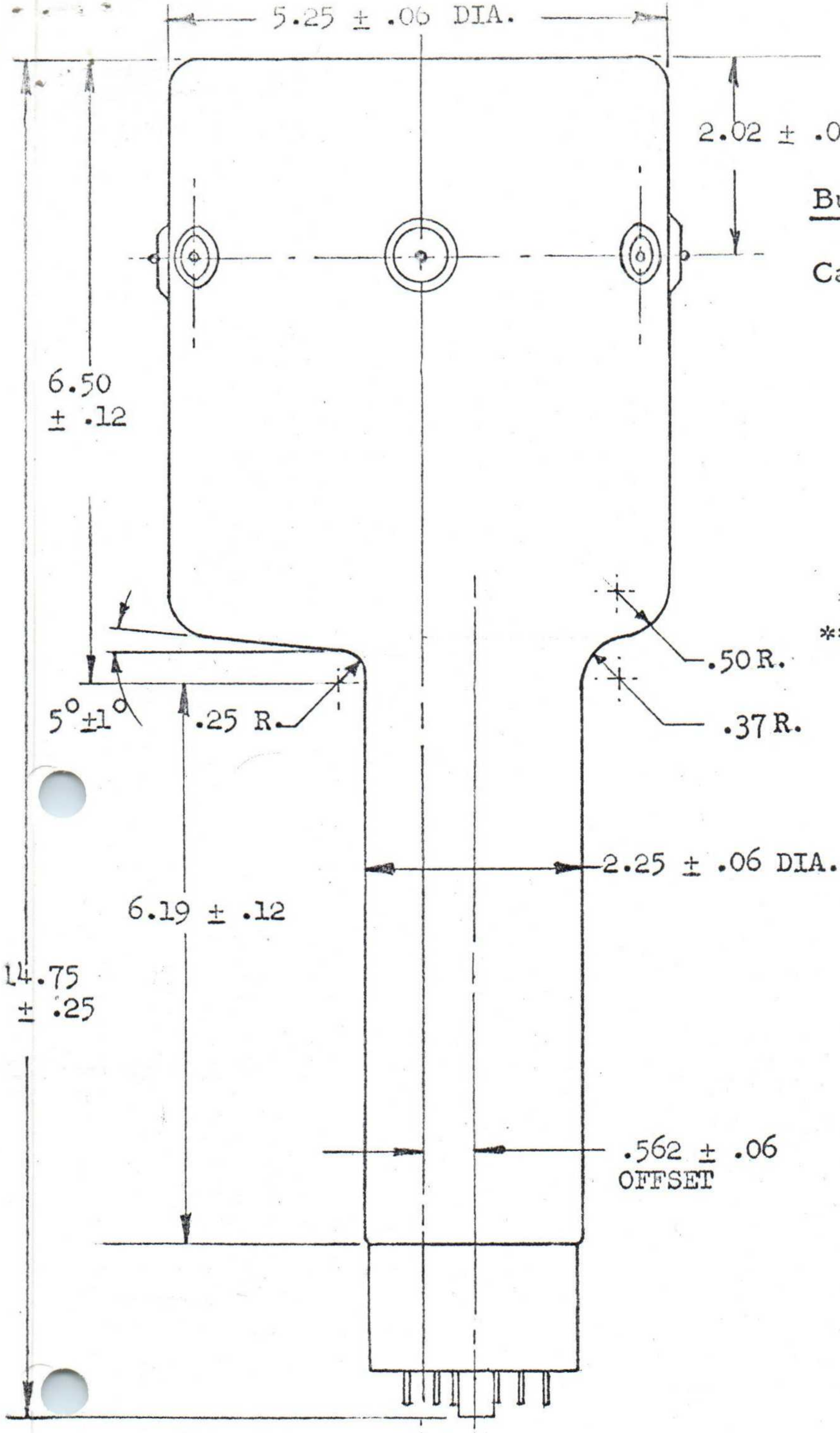
I. OUTLINE DRAWING

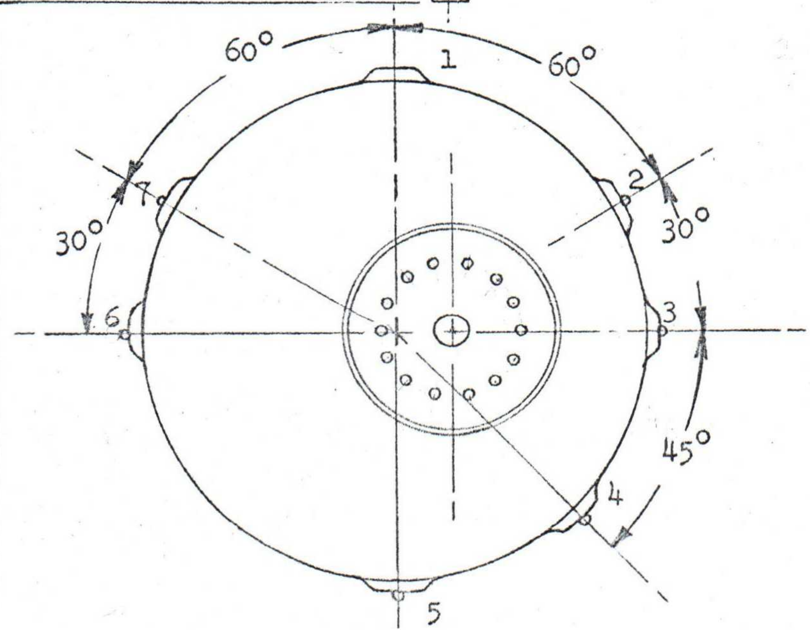
(Drawing on Page 6)

Please address any inquiries for further technical information to:

Hughes Products
Electron Tube Division
Attention: Commercial Engineering
International Airport Station
Los Angeles 45, California

HUGHES H-1010
5-Inch Electrostatic Tonotron





Bulb Contacts

Cap No. 1: JETEC J1-22**-Viewing Screen
2: JETEC J1-22**-Internal connection
3: JETEC J1-22 - Collector mesh
4: JETEC J1-22 Front Dag A_4
5: JETEC J1-22 Collimator, A_3
6: JETEC J1-22 Storage Mesh
7: JETEC J1-22 Internal Connection

**JETEC J1-22 - recessed small ball cap

14-Pin Stem

Pin 1 - Heater, Writing Gun
2 - Cathode, Writing Gun
3 - Control Grid, Writing Gun
4 - Deflection Plate D_1
5 - Deflection Plate D_3
6 - Control Grid, Flood Gun
7 - Heater, Flood Gun
8 - Heater, Flood Gun
9 - Cathode, Flood Gun
10 - A2
11 - Deflection Plate D_4
12 - Deflection Plate D_2
13 - Focus (A_1), Writing Gun
14 - Heater, Writing Gun

(10) (5) T.P.D.

TENTATIVE TECHNICAL INFORMATION

Hughes Products

TONOTRON* (ELECTROSTATIC)

Hughes Type No. H1009

3-inch Direct-Display Half-tone Storage Tube

A. DESCRIPTION

The Tonotron, direct-display, cathode-ray storage tube features: (1) storage of half-tones, (2) sufficient brightness for use in high ambient-light levels, (3) controllable persistence, (4) minimum over-all length. Black**, white, and intermediate shades of grey can be stored for periods of the order of a minute.*** Erasure can be either "instantaneous" or a gradual fading. The physical dimensions of the Electrostatic Tonotron electron tube are given in the accompanying outline drawing.

There are two guns, a writing gun and a flood gun. The flood gun sprays the entire storage surface with a uniform spray of well-collimated, low-energy, electrons. The relative brightness at the viewing screen depends upon the surface potentials of the insulating storage layer on the gun side of the metal storage mesh. Starting with a uniform potential about 5 volts negative with respect to the flood-gun cathode, the storage surface is unwritten, or black. The writing gun can then apply a charge pattern on the screen, raising this potential through the half-tone scale towards the flood-gun cathode potential (full brightness). Since the storage surface is always negative, it can control the flood electron transmission, but no flood electrons can strike it. Except for ion currents, then, the stored pattern could exist indefinitely. Under good vacuum conditions, ion currents limit the storage time to the order of a minute. Instantaneous erasure can be effected by application of a single positive voltage pulse to the storage grid. This pulse carries the potentials of the storage area positive with respect to the flood gun cathode, and the flood electrons landing on the insulator surface restore its potential to the flood gun cathode potential. When the pulse is removed, the insulator surface potential becomes so negative with respect to the flood gun cathode potential that flood electrons are everywhere prevented from reaching the viewing screen. For gradual erasure, the single pulse is replaced by a train of very much shorter

* Trade Mark Hughes Aircraft Company

** The use of "black" and "white" refer to the unwritten and the fully written states.

*** See Section I for a method of extending the storage time beyond one minute.

pulses; the time of erasure (persistence time) is controlled by adjusting the duty cycle of this pulse train. Additional discussion of erase performance will be found under "contrast" in Section "B".

B. PERFORMANCE (typical values)

Full-tone writing speed Speed given for 500 μa cathode current. Higher values are available at higher currents, with sacrifice in resolution.	10,000 inches/sec.
Written resolution Measured by shrinking-raster method, at full brightness speed. Half-tones can be written with up to 60 lines/in. resolution.	45 lines/in. (min.)
Brightness at 7.5 KV (E_{A3}, E_{A4} and E_{G1} (flood gun) adjusted for brightest, most uniform display)	500 foot-lamberts (min.)
Contrast Ratio The contrast ratio is roughly proportional to the persistence time for short persistences. The relatively long "instantaneous" erase pulse causes the entire screen to assume full highlight brightness (unless the viewing screen voltage is simultaneously dropped). Similarly, with gradual erasure, each individual pulse of the erase train causes the entire screen to assume full highlight brightness for its duration so that the average "unwritten" brightness is increased. Thus, the contrast is proportional to the persistence time for short values of persistence, although the effect is negligible for long persistence.	3-Second persistence about 100:1
Erase time (single-pulse erasure, pulse amplitude equal to target cutoff)	250 milliseconds (max.)
Number of Half-tones	3

C. GENERAL

Heaters (2)	6.3 volts
Phosphor	aluminized P1
Focusing method	electrostatic
Deflection method	electrostatic
Persistence	5 sec. minimum

Dimensions

Overall length (max.)	9-1/4"
Greatest diam. of bulb	3-1/16"
Neck diam.	1-3/8"
Useful screen diam.	2" min.

Terminals -	1. Viewing Screen)	recessed
	2. Storage Mesh)	cavity
	3. Collector Mesh)	cap
	4. Third Anode)	JETEC
	5. Fourth Anode)	No. J1-21

Neck Base	16 pin

D. MAXIMUM RATINGS

	Writing Gun	Flood gun
Cathode	-2500 max volts	0 Max. volts
Grid No. 1		
Negative Bias Value	200*max volts	100 max volts
Positive Bias Value	0*max volts	0 max volts
Positive Peak Value	2*max volts	0 max volts
Grid No. 2	150 max volts	150 max volts
Grid No. 3	-2500 max volts	-
Grid No. 4	150 max volts	-
Peak Heater-Cathode Voltage:		
Heater negative with respect to cathode	125*max volts	-
Heater positive with respect to cathode	125*max volts	
Screen Voltage	9,000 max volts	
Storage Mesh	200 max volts	
Collector Mesh	300 max volts	
A3	300 max volts	
A4	300 max volts	

E. TYPICAL OPERATING CONDITIONS (Approx.)

Viewing Screen Voltage	4 - 8 KV
Storage Mesh	5 volts
Collector Mesh	120 volts

* With respect to cathode of Writing Gun.

A3	30 - 50 volts
A4	50 volts
A2	100 volts

(All voltages with respect to Flood Gun Cathode)

Flood Gun

A1	100 volts
G1 (Voltage required for cut off)	-50 to -125 volts

Writing Gun (All voltages with respect to writing gun cathode)

G1 (Voltage for cutoff of undeflected focused spot)	-45 to -90 volts
G3 (focus electrode)	300 - 800 volts

Cathode of writing gun at -2000 volts with respect to flood gun cathode.

Deflection sensitivity - horizontal and vertical matched - 150 volts/inch

F. CIRCUITRY

The circuits required to operate the Tonotron electron tube are simple. They fall into four categories: erase circuits, video and deflection circuits, Static-voltage supplies, and protective circuits. Figure "F" is a diagram of typical circuits for Erase Pulse Generator and Static-Voltage Supply.

1. Erase Circuits. Two types of erase-pulse circuits are commonly used with the Tonotron tube. One is merely a battery, potentiometer, and micro-switch arrangement to manually elevate the storage mesh potential for "instantaneous" erasure; the other is a pulse-train generator, with variable amplitude and duty cycle. The amplitude is 0 to 10 volts; duty cycle is adjustable between 0.5 per cent and 20 per cent. Some shaping of the pulse by delaying the rise of the leading edge may be desirable for greatest ease of erasure.

2. Video and Deflection Circuits. A video signal of about 4 volts is required to drive the writing gun, which is a standard cathode-ray gun with electrostatic focus and deflection. Deflection circuitry, for the 2.0 kv beam, is conventional.

3. Static Voltage Supplies. Static voltages must be supplied as listed in Part E: Typical Operating Conditions. This may be done by use of conventional power supplies. Provision must be made for easy adjustment of: (a) the third-anode voltage, to collimate the flood beam, (b) the flood-gun control-grid voltage, to adjust the size of the flood beam, (c) the writing-gun first-anode voltage, for focus and (d) the storage-mesh voltage, for evaluation of storage for a range of slightly different conditions. Since the writing-gun cathode voltage is not operated at ground, it is clear that either the control-grid driving circuits must be referenced to the cathode, or else the

cathode potential must be well regulated. The electrostatic focusing is proportional, and care must be taken to preserve the focusing ratio to maintain a good spot. This implies either a proportional focus voltage, or well-regulated cathode and focus voltages. It is recommended that the resistances of the deflecting electrode circuits be approximately equal.

4. Protective Circuits. Due to the high internal voltage gradient between the storage mesh and the viewing screen, it is advisable to provide protection against excessive surge currents. For the viewing screen, use of a limited-energy type power supply with 1 ma maximum short circuit current is preferred. In any event, a protective resistor of at least one megohm should be used in series with the viewing-screen lead. Damage to the storage surface may result from operation of the writing beam on any part of the screen not covered by the flood beam. If it is necessary or desirable to operate the writing gun with the flood beam cut off, the collector mesh voltage must be lowered to storage mesh potential to prevent runaway charges from breaking down the dielectric coating on the storage mesh.

G. COLLIMATION ADJUSTMENT

In making the collimation adjustment, the potential in an electrostatic lens gap is varied until the flood electrons approach the storage mesh orthogonally over the entire area. The collimation is critical only for half-tones; it is most critical in the vicinity of the cut-off point. Therefore, the most precise collimation adjustment can be obtained when the entire screen is in a half-tone state near cutoff. Collimating voltages should be regulated to 1% for satisfactory half-tone reproduction. After viewing-screen, storage-mesh, collector, and flood gun voltages are applied to the tube, the flood-gun bias should be reduced until just full coverage of the target is obtained. Then the target should be erased (using either a single long pulse, or a pulse train), by slowly increasing the pulse amplitude until, in the absence of the pulse, the screen brightness has acquired a low half-tone level. There will then be a period of the order of 30 seconds, before ion effects become important, in which to adjust the collimation. This is done by adjusting the third-anode potential to obtain best uniformity over the largest obtainable circle. After a reasonable value seems to have been obtained, it is wise to re-erase the target and check the result again. Further improvement in collimation may be possible by slight adjustment of the fourth anode (in the vicinity of 0 volts). Average deflection plate potential must be close to the A1-A2 potential for optimum tube operation.

H. OUTLINE DRAWING (Drawing on Page 7)

I. EXTENDING STORAGE TIME

By means of a pulsing technique it is possible to increase the storage time from about one minute to more than five minutes. Image deterioration in a Tonotron tube is caused by positive ions (produced by the collision of flood electrons with gas molecules) landing on the storage surface where they neutralize some of the negative charge. If the flood gun is cut off half the time, approximately half the ions are produced and thus storage time is doubled. A sacrifice in brightness proportional to the increase in storage time is implicit in this technique.

A multivibrator of variable duty cycle can be used to pulse the flood gun grid on-and-off. The repetition rate of this multivibrator should be such as to avoid visual "beating" effects between the intensity modulation of the erasing pulse and that of the flood gun grid pulse. Pulsing deflects the writing beam approximately 0.030" and therefore corrective compensation is required in the sweep circuits to maintain spot size.

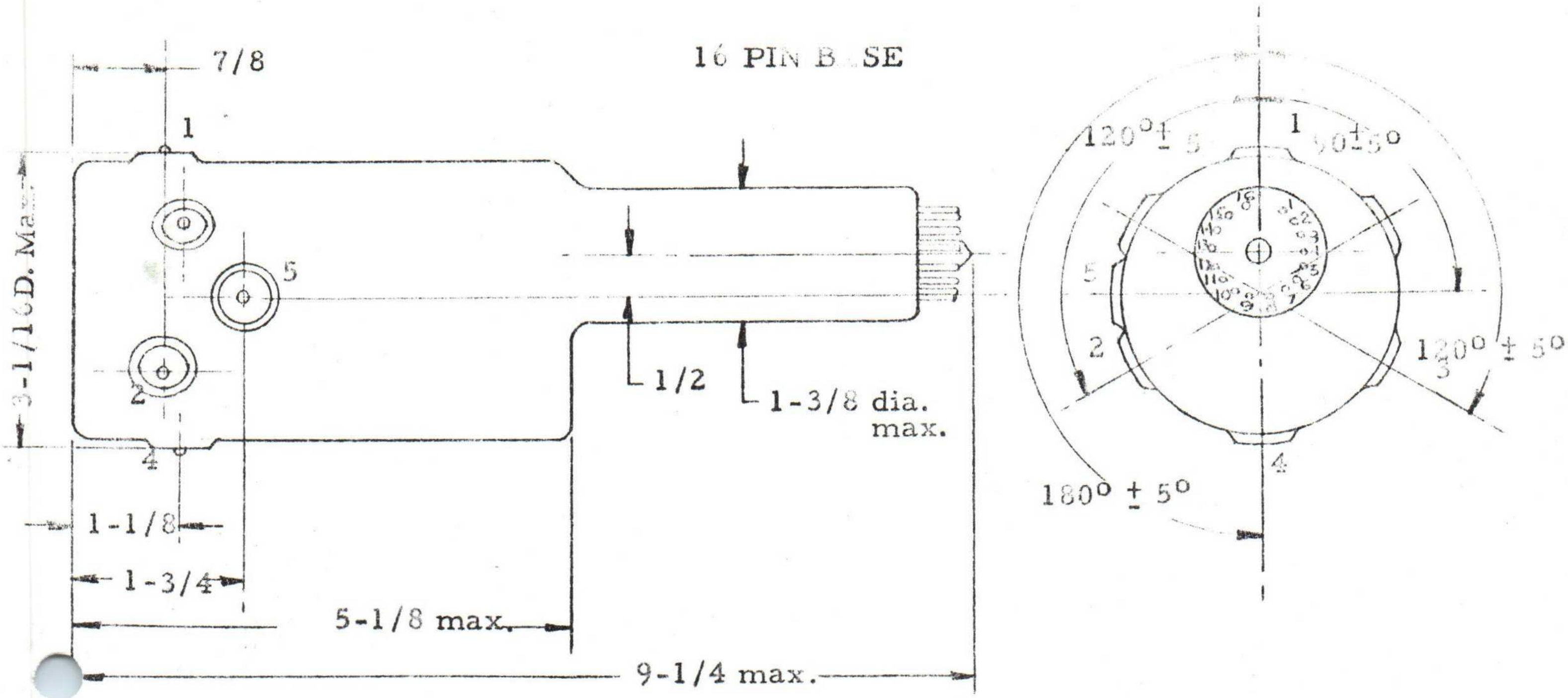
J. MAGNETIC SHIELDING

Magnetic shielding is required particularly for the flood gun. Low intensity Magnetic fields (e.g., the earths magnetic field) can deflect the flood electrons enough to destroy collimation. It is recommended that the entire tube, with the exception of the face, and the last 2 inches of the neck be enclosed in close fitting mu metal or equivalent shield.

Please address any inquiries for further technical information to:

Hughes Products
Electron Tube Subdivision
Attention: Commercial Engineering
International Airport Station
Los Angeles 45, California

H. OUTLINE DRAWING



Bulb Contacts - recessed small cavity cap, JETEC J1-21

Cap No. 1 - viewing screen
2 - storage mesh
3 - collector mesh
4 - Collimator, A3
4 - A4

<u>16-Pin Stem</u>

1 - Heater, writing gun
2 - Heater, writing gun
3 - Cathode, writing gun
4 - Control Grid, writing gun
5 - Focus Anode, writing gun
6 - A1, Flood gun
7 - Heater, cathode, flood gun
8 - Heater, flood gun
9 - Control grid flood gun
10 - Internal Connection - Do Not Use
11 - A2
12 - Vertical deflection plate
13 - Vertical deflection plate
14 - Internal Connection - Do Not Use
15 - Horizontal deflection plate
16 - Horizontal deflection plate

T.P.D.

(4) (4)

Tentative Technical Information 1-2-57

Hughes Aircraft Company

TONOTRON (MAGNETIC)

Hughes Type No. H1004

5-inch Direct-Display Half-tone Storage Tube

A. DESCRIPTION

The Tonotron is a direct-display, cathode-ray storage tube featuring: (1) storage of half-tones, (2) sufficient brightness for use in high ambient-light levels, (3) controllable persistence, (4) minimum over-all length. Black*, white, and intermediate shades of grey can be stored for periods of the order of a minute.**Erasure can be either "instantaneous" or a gradual fading. The physical dimensions of the magnetic Tonotron are given in the accompanying outline drawing. The envelope is of pressed glass construction for dimensional uniformity and strength.

There are two guns, a writing gun and a flood gun. The flood gun sprays the entire storage surface with a uniform spray of well-collimated, low-energy, electrons. The relative brightness at the viewing screen depends upon the surface potentials of the insulating storage layer on the gun side of the metal storage mesh. Starting with a uniform potential about 5 volts negative with respect to the flood-gun cathode, the storage surface is unwritten, or black. The writing gun can then apply a charge pattern on the screen, raising this potential through the half-tone scale towards the flood-gun cathode potential (full brightness). Since the storage surface is always negative, it can control the flood electron transmission, but no flood electrons can strike it. Except for ion currents, then, the stored pattern could exist indefinitely. Under good vacuum conditions, ion currents limit the storage time to the order of a minute. Instantaneous erasure can be effected by application of a single positive voltage pulse to the storage grid. This pulse carries the potentials of the storage area positive with respect to the flood gun cathode, and the flood electrons landing on the insulator surface restore its potential to the flood gun cathode potential. When the pulse is removed, the insulator surface potential becomes so negative with respect to the flood gun cathode potential that flood electrons are everywhere prevented from reaching the viewing screen. For gradual erasure, the single pulse is replaced by a train of very much shorter pulses; the time of erasure (persistence time) is controlled by adjusting the duty cycle of this pulse train. Additional discussion of erase performance will be found under "contrast" in Section "B".

* The use of "black" and "white" refer to the unwritten and the fully written states.
** See Section I for a method of extending the storage time beyond one minute.

B. PERFORMANCE (typical values)

Full-tone writing speed Speed given for 60 μa beam current. Slightly higher values are available at higher beam currents, with sacrifice in resolution.	150,000/sec
Written resolution Measured by shrinking-raster method, at full brightness speed. Half-tones can be written with up to 80 lines/in. resolution.	60 lines/in.
Brightness (at 10 kv)	1000 foot-lamberts
Contrast Ratio The contrast ratio is roughly proportional to the persistence time for short persistences. The relatively long "instantaneous" erase pulse causes the entire screen to assume full highlight brightness (unless the viewing screen voltage is simultaneously dropped). Similarly, with gradual erasure, each individual pulse of the erase train causes the entire screen to assume full highlight brightness for its duration so that the average "unwritten" brightness is increased. Thus, the contrast is proportional to the persistence time for short values of persistence, although the effect is negligible for long persistence.	3-Second persistence about 100:1
Erase time (single-pulse erasure)	50 milliseconds
Number of Half-tones	at least 5

C. GENERAL SPECIFICATIONS

Heaters (two), for Unipotential Cathodes	
Voltage	6.3±10 per cent ac or dc volts
Current (each heater)	0.6 amp
Phosphor	P20* Aluminized
Focusing Method	Electrostatic
Deflection Method	Magnetic
Over-all length	11½" nominal
Greatest Diameter of Bulb	5-¼ ± 1/8"
Useful Screen Diameter	4" nominal
Mounting Position	Any

Bulb Terminal Connections

Cap No. 1	Viewing Screen	(Recessed small cavity cap, JETEC No. J1-21)
Cap No. 2	Collector Mesh	(Recessed small ball cap, JETEC No. J1-22)
Cap No. 3	Third Anode	(Recessed small ball cap, JETEC No. J1-22)
Cap No. 4	Storage Mesh	(Recessed small ball cap, JETEC No. J1-22)

* Other phosphors available on special order.

Body Base Connections (7-pin miniature JETEC E7-1)

- Pin No. 1 First Anode (Flood Gun)
- Pin No. 2 Control Grid (Flood gun)
- Pin No. 3 Heater, (Flood gun)
- Pin No. 4 Heater, (Flood gun)
- Pin No. 5 Internal Connection - Do not use
- Pin No. 6 Second Anode (Writing and Flood guns)
- Pin No. 7 Cathode (Flood gun)

Neck Base Connections (Small Button ditetrar 8-pin JETEC E8-11)

- Pin No. 1 Control Grid (Writing gun)
- Pin No. 2 Heater (Writing gun)
- Pin No. 3 Heater (Writing gun)
- Pin No. 4 Internal Connection - Do not use
- Pin No. 5 Cathode (Writing gun)
- Pin No. 6 Internal Connection _ Do not use
- Pin No. 7 No connection
- Pin No. 8 First Anode (Writing gun)

D. MAXIMUM RATINGS**

Viewing-screen voltage	10,000 volts
Storage-mesh voltage	-25 volts, +75 volts
Collector-mesh voltage	250 volts
Third-anode voltage	100 volts
Second-anode voltage	75 volts
First-anode (Flood gun) voltage	150 volts
Cathode (Writing gun) voltage	-3000 volts
First-anode (Writing gun) voltage	-3000 volts

E. TYPICAL OPERATING CONDITIONS**

1. Voltages and Currents

Viewing-screen voltage	4000 to 8000 volts
Storage-mesh voltage	0 to 5 volts
Collector-mesh voltage	120 volts
Third-anode voltage (Adjust for optimum collimation)	20 to 40 volts
Second-anode voltage	6 volts
First-anode (Flood gun) voltage	80 volts
Control-grid (Flood gun) operating bias (Adjust for full coverage of viewing screen; cut-off value is approximately 100 volts)	0 to -30 volts
Cathode (Flood gun) voltage	0 volts
Cathode (Writing gun) voltages	-2500 volts
Control-grid (Writing gun) (Voltage for visual extinction of focused spot)**	-75 volts
First-anode (Writing gun) voltage for focus**	350 to 750 volts

**All voltages are given with respect to the flood-gun cathode, except those starred, which are given with respect to the writing-gun cathode.

Viewing-screen current	0 to 250 μa
Storage-mesh current	-15 to +75 μa
Collector-mesh, third-anode, second-anode currents, each less than	2 ma
Cathode (Flood gun) current	0 to 2 ma
Cathode (Writing gun) current	0 to 1000 μa

2. Magnetic Shielding

   Magnetic shielding is required for both the writing gun and the flood gun. Low intensity magnetic fields (viz, the earth's magnetic field) can deflect the flood electrons enough to destroy collimation (see Sec "G"). Stray magnetic fields from the deflection yoke can divert the writing beam within the gun, so as to modulate the beam current as it passes through the limiting aperture. It is suggested that the magnetic shield over the writing gun be brought to within 1½ inches of the reference plane shown on the attached outline drawing.

F. CIRCUITRY

The circuits required to operate the Tonotron are simple. They fall into four categories: erase circuits, video and deflection circuits, static-voltage supplies, and protective circuits. Figure "F" is a diagram of typical circuits for Erase Pulse Generator and Static-Voltage Supply.

1. Erase Circuits. Two types of erase-pulse circuits are commonly used with the Tonotron tube. One is merely a battery, potentiometer, and micro-switch arrangement to manually elevate the storage mesh potential for "instantaneous" erasure; the other is a pulse-train generator, with variable amplitude and duty cycle. The amplitude is 0 to 10 volts; duty cycle is adjustable between 0.5 per cent and 20 per cent. Some shaping of the pulse by delaying the rise of the leading edge may be desirable for greatest ease of erasure.

2. Video and Deflection Circuits. A video signal is required to drive the writing gun, which is a standard cathode-ray gun with electrostatic focus and magnetic deflection. Deflection circuitry, for the 2.5 kv beam, is conventional. In the design of the deflection yoke, the centering device, and the writing gun magnetic shield, careful consideration should be given to deflection field uniformity and to the prevention of the deflection field from affecting the writing beam inside the gun.

3. Static Voltage Supplies. Static voltages must be supplied as listed in Part E: Typical Operating Conditions. This may be done by use of conventional power supplies. Provision must be made for easy adjustment of: (a) the third-anode voltage, to collimate the flood beam, (b) the flood-gun control-grid voltage, to adjust the size of the flood beam, (c) the writing-gun first-anode voltage, for focus and (d) the storage-mesh voltage, for evaluation of storage for a range of slightly different conditions. Since the writing-gun cathode voltage is not operated at ground, it is clear that either the control-grid driving circuits must be referenced to the cathode, or else the cathode potential must be well regulated. The electrostatic focusing is proportional, and care must be taken to preserve the focusing ratio to maintain a good spot. This implies either a proportional focus voltage, or well-regulated cathode and focus voltages.

4. <u>Protective Circuits.</u> Due to the high internal voltage gradient between the storage mesh and the viewing screen, it is advisable to provide protection against excessive surge currents. For the viewing screen, use of a limited-energy type power supply with 1 ma maximum short circuit current is preferred. In any event, a protective resistor of at least one megohm should be used in series with the viewing-screen lead. Damage to the storage surface may result from operation of the writing beam on any part of the screen not covered by the flood beam. If it is necessary or desirable to operate the writing gun with the flood beam cut off, the collector mesh voltage must be lowered to storage mesh potential to prevent runaway charges from breaking down the dielectric coating on the storage mesh.

G. COLLIMATION ADJUSTMENT

In making the collimation adjustment, the potential in an electrostatic lens gap is varied until the flood electrons approach the storage mesh orthogonally over the entire area. The collimation is critical only for half-tones; it is most critical in the vicinity of the cut-off point. Therefore, the most precise collimation adjustment can be obtained when the entire screen is in a half-tone state near cutoff. After viewing-screen, storage-mesh, collector, and flood-gun voltages are applied to the tube, the flood-gun bias should be reduced until just full coverage of the target is obtained. Then the target should be erased (using either a single long pulse, or a pulse train), by slowly increasing the pulse amplitude until, in the absence of the pulse, the screen brightness has acquired a low half-tone level. There will then be a period of the order of 30 seconds, before ion effects become important, in which to adjust the collimation. This is done by adjusting the third-anode potential (in the vicinity of 30 v) to obtain best uniformity over the largest obtainable circle. After a reasonable value seems to have been obtained, it is wise to re-erase the target and check the result again.

H. OUTLINE DRAWING

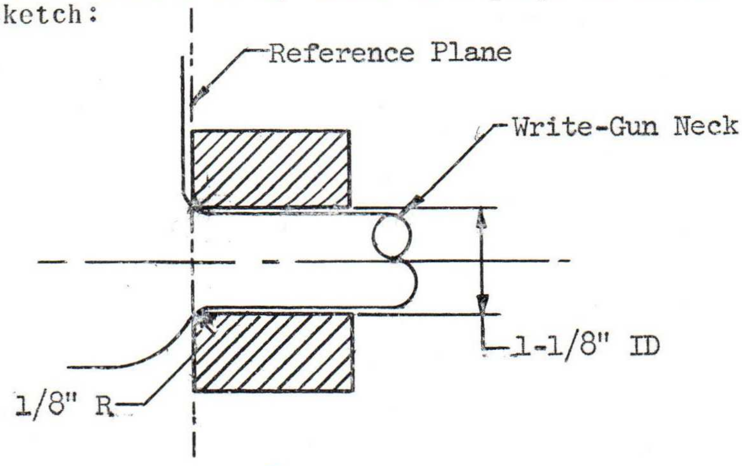
(Drawing on Page 6)

Notes:

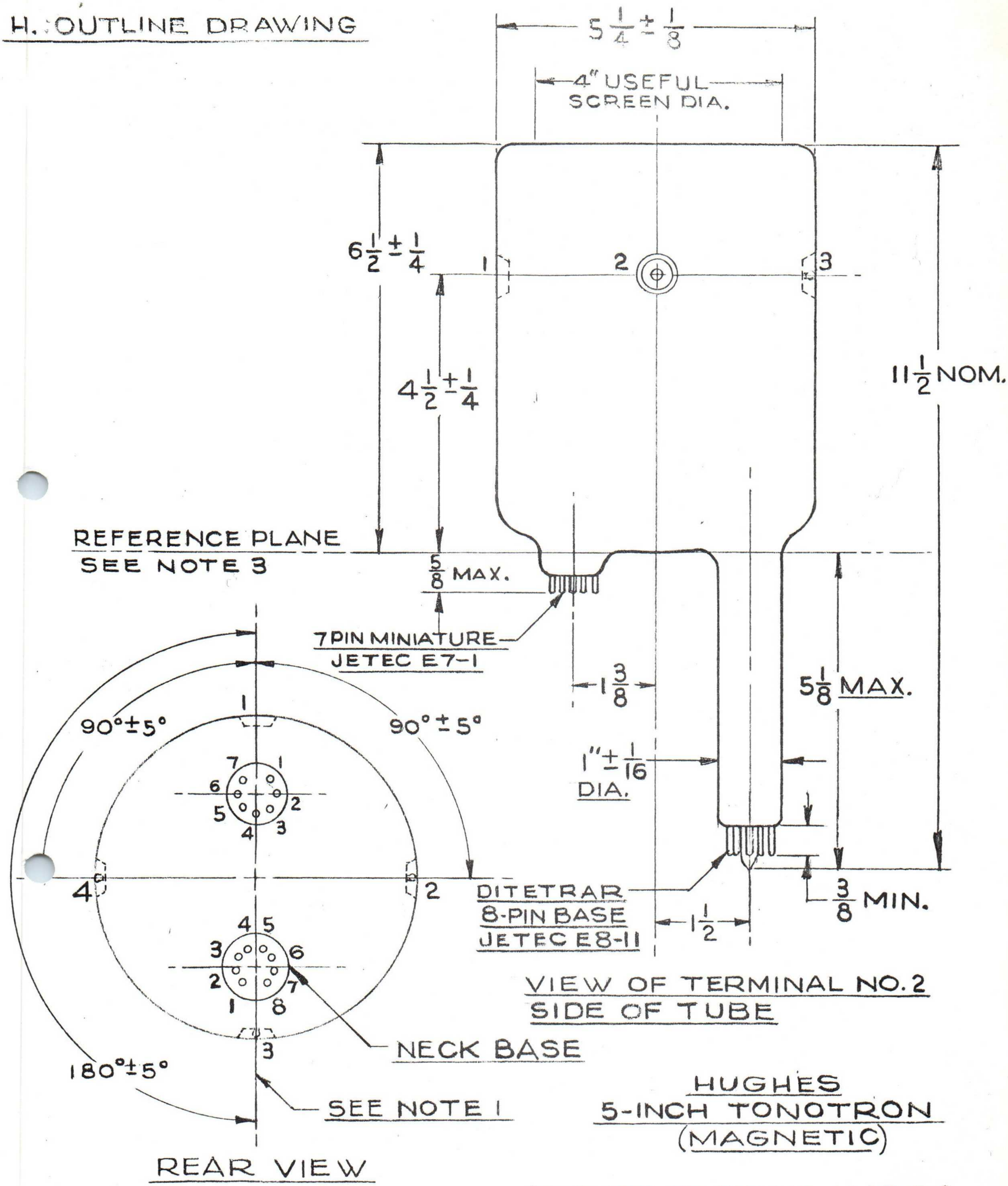
1. Plane through centers of neck and flood gun base coincides with plane through tube axis and bulb terminal 1 and 3 within $\pm 10^{o}$.

2. Dimensions without tolerances are design centers.

3. The reference plane is determined by means of a gauge as shown in the following sketch:



H. OUTLINE DRAWING



HUGHES
5-INCH TONOTRON
(MAGNETIC)

HUGHES TYPE NO. H-1004

I. EXTENDING STORAGE TIME

By means of a pulsing technique it is possible to increase the storage time from about one minute to more than five minutes. Image deterioration in a Tonotron is caused by positive ions (produced by the collision of flood electrons with gas molecules) landing on the storage surface where they neutralize some of the negative charge. If the flood gun is cut off half the time, approximately half the ions are produced and thus storage time is doubled. A sacrifice in brightness proportional to the increase in storage time is implicit in this technique.

A multivibrator of variable duty cycle can be used to pulse the flood gun grid on-and-off. The repetition rate of this multivibrator should be such as to avoid visual "beating" effects between the intensity modulation of the erasing pulse and that of the flood gun grid pulse.

Please address any inquiries for further technical information to:

Hughes Products
Electron Tube Subdivision
Attention: Commercial Engineering
International Airport Station
Los Angeles 45, California

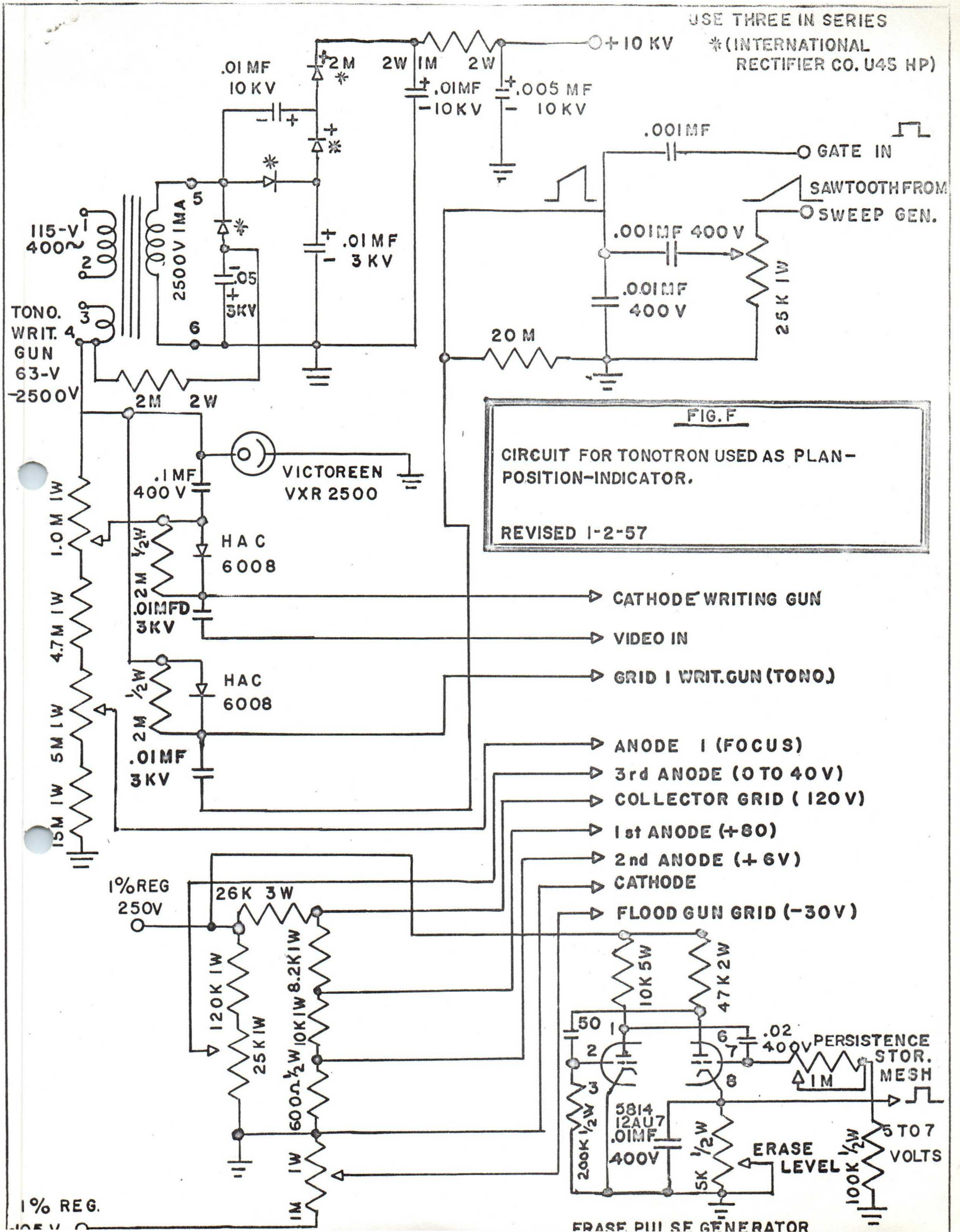


FIG. F

CIRCUIT FOR TONOTRON USED AS PLAN-POSITION-INDICATOR.

REVISED 1-2-57

February 16, 1955

Technical Data

TYPOTRON*

6577

5-Inch Character-Writing Cathode-Ray-Type Storage Tube

GENERAL:

Heaters (two) for Unipotential Cathodes	
Voltage	6.3 ± 10% ac or dc volts
Current (each heater)	0.6 amp
Phosphor	
Fluorescence and Phosphorescence	Green P1
Persistence of Phosphorescence	Medium
Focusing Method	Electrostatic
Deflection Method, Including Character Selection and Compensation	Electrostatic
Convergence of Characters	Magnetic
Over-all Length	31" Maximum
Seated Height	28-1/4" ± 1/2"
Greatest Diameter of Bulb	5-5/8" Maximum
Neck Diameter	2-1/4" + 3/32"
Minimum Usable Screen Diameter	4"
Mounting Position	Any**
Base	23-Pin Glass Stem

Pin 1 Anode No. 1 (Writing Gun)
Pin 2 Heater (Flood Gun)
Pin 3 Heater, Cathode (Flood Gun)
Pin 4 Control Grid (Flood Gun)
Pin 5 Matrix Assembly***
Pin 6 Compensating Electrode C_3
Pin 7 Compensating Electrode C_4
Pin 8 Compensating Electrode C_1
Pin 9 Matrix Assembly****
Pin 10 Deflecting Electrode D_2
Pin 11 Deflecting Electrode D_1
Pin 12 Compensating Electrode C_2
Pin 13 Deflecting Electrode D_3
Pin 14 Deflecting Electrode D_4
Pin 15 Matrix Assembly****

*Hughes Aircraft Company registered trademark for direct-reading bright-display character-writing storage tube.

**The characters can be made to appear right-side-up on the viewing screen when the tube is mounted with the viewing screen terminal at either the top or the bottom of the face. The subscripts given above for the compensating electrodes and deflecting electrodes apply when the viewing screen terminatl (HV Contact) is at the top. To use the other position, the polarities of the voltages applied to these electrodes must be reversed, and the direction of the convergence coil current must also be reversed.

***The matrix assembly is connected internally to the conductive coating in the neck.

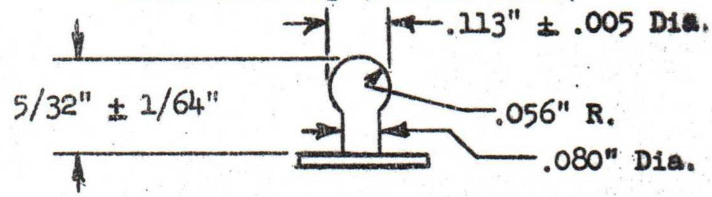
****Use Pin 5 for socket connection.

Pin 16 Heater (Writing Gun)
Pin 17 Heater, Cathode (Writing Gun)
Pin 18 Selecting Electrode S_1
Pin 19 Selecting Electrode S_2
Pin 20 Selecting Electrode S_4
Pin 21 Selecting Electrode S_3
Pin 22 Anode No. 2 (Both Guns)
Pin 23 Control Grid (Writing Gun)

Terminals on Bulb

Cap No. 1 Viewing Screen
Cap No. 3 Anode No. 3
Cap No. 4 Ion Repeller Mesh
Cap No. 5 Collector Mesh
Cap No. 6 Storage Mesh

Small Ball Cap (Sketch below)



Cap No. 1 is not recessed.
Caps No. 3, 4, 5 and 6 are partially recessed.

NOTE: For all deflecting plates, subscripts 1 and 2 are nearer the stem, subscripts 3 and 4 are nearer the screen. With S_1 positive with respect to S_2, the beam is deflected toward the left of the matrix. With S_3 positive with respect to S_4, the beam is deflected toward the top of the matrix.

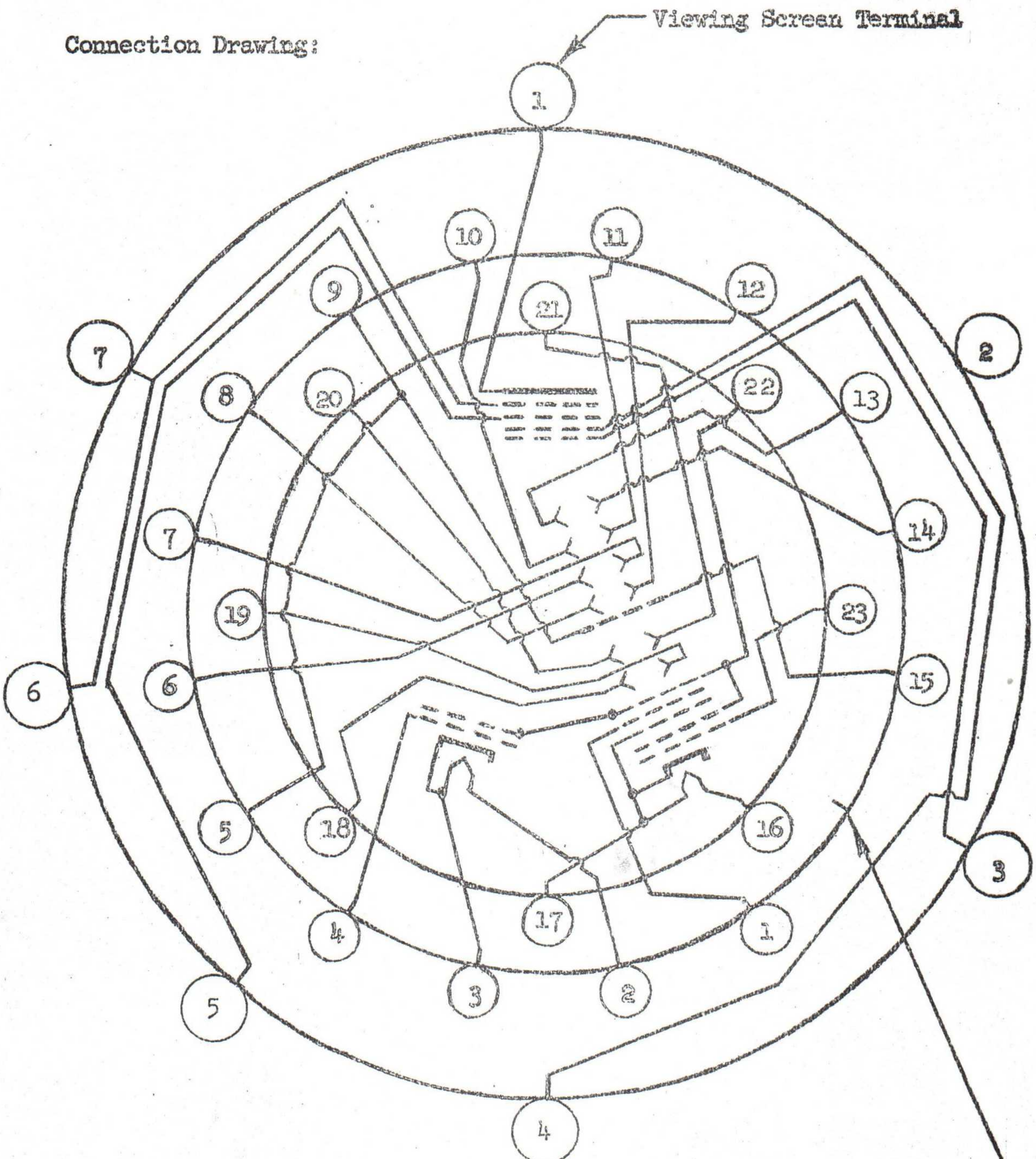
With D_1 positive with respect to D_2, the beam is deflected toward the left of the screen. With D_3 positive with respect to D_4, the beam is deflected toward the top of the screen.

The polarity of the voltage required for a given compensation plate is the same as the polarity of the selection plate having the same subscript.

MATRIX CONFIGURATION:

u	f	X	N	T	Y	t	v
i	D	P	I	U	A	E	r
G	L	0	1	2	3	C	J
V	R	4	5	6	7	S	W
Q	M	8	●	9	H	B	Ƶ
b	K	a	p	h	g	F	d
c	m	o	w	e	s	z	n
■	▲	▼	▬	↑	↓	x	

Connection Drawing:

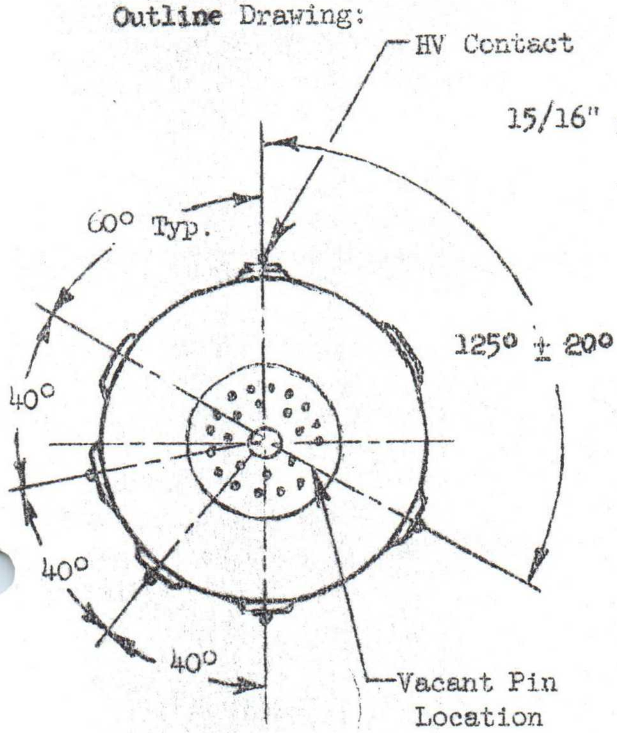


BOTTOM VIEW

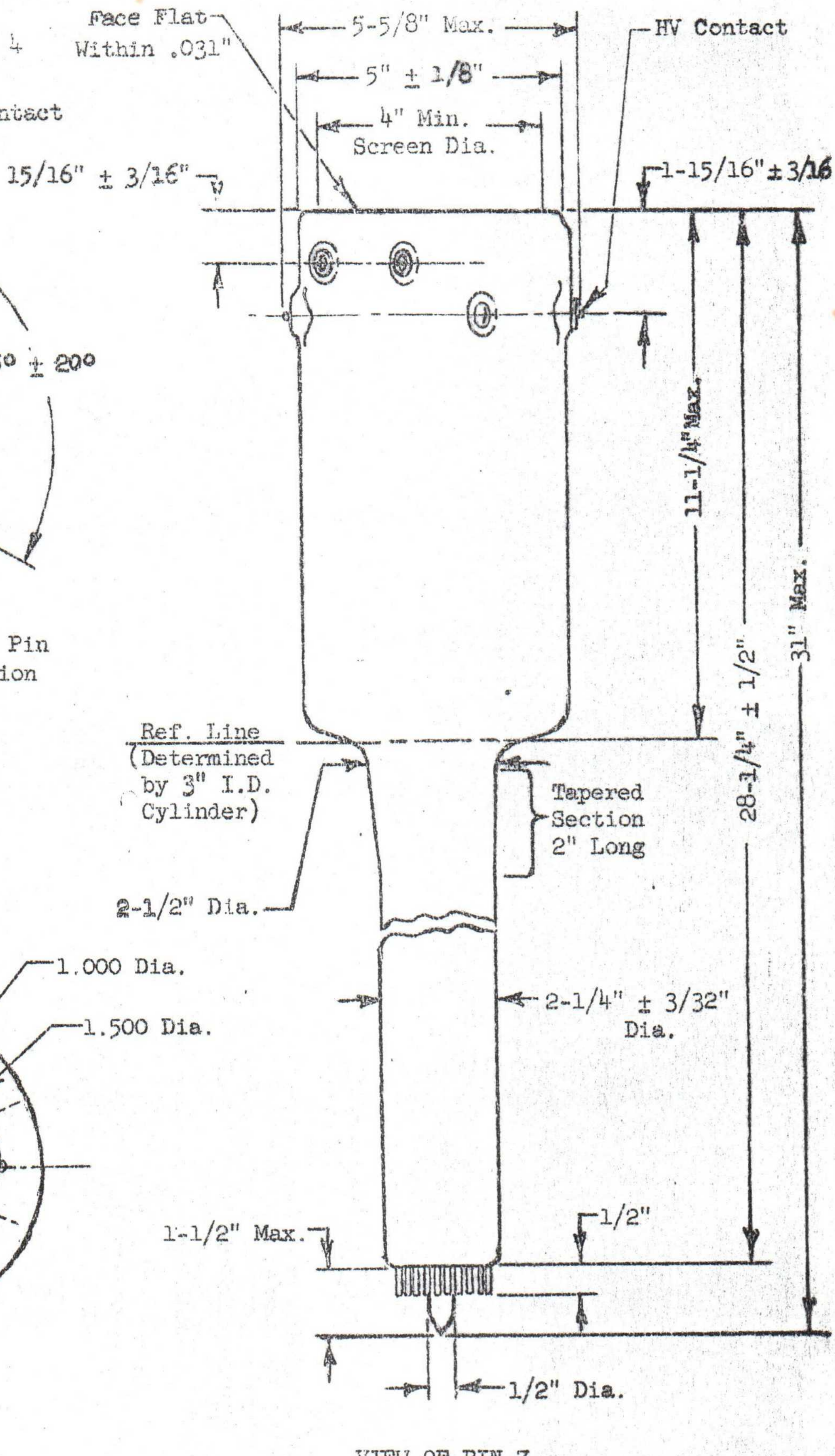
LSY/rh/z

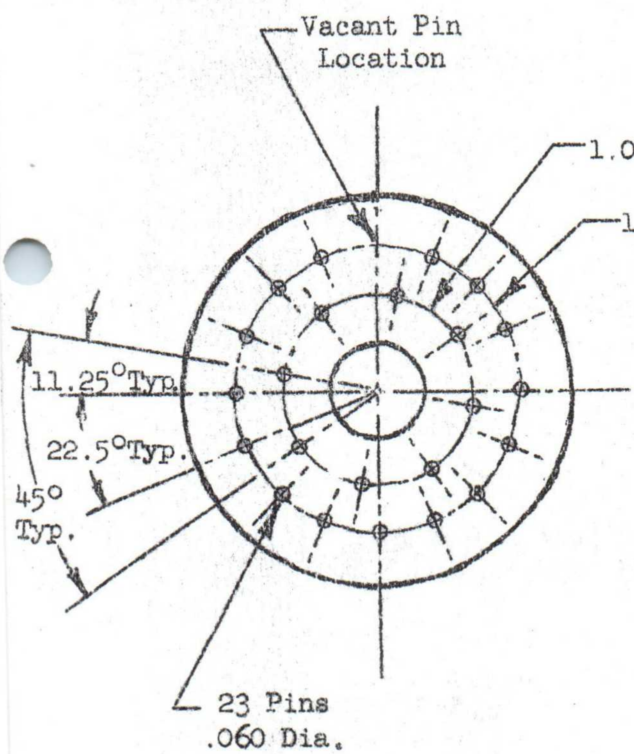
Technical Data - TYPOTRON - 4

Outline Drawing:



BOTTOM VIEW





PIN LOCATION
(Bottom View)
(Scale: Full)

VIEW OF PIN 7
SIDE OF TUBE

February 16, 1955

LSY/rh

MAXIMUM RATINGS:*

Viewing Screen	4000 volts
Ion Repeller Mesh	350 volts
Second Anode	300 volts
Matrix	300 volts
Selection Plates, Average Potential	300 volts
Compensation Plates, Average Potential	300 volts
Deflection Plates, Average Potential	300 volts
Collector Mesh	250 volts
Third Anode	250 volts
Storage Mesh	-50 volts
First Anode	-3400 volts
Cathode Writing Gun	-3400 volts

TYPICAL OPERATING VOLTAGES AND CURRENTS:

Viewing Screen Voltage	3000 volts
Ion Repeller Mesh Voltage	250 volts
Second Anode Voltage	200 volts
Matrix Voltage	200 volts
Selection Plates, Average Potential	200 volts
Compensation Plates, Average Potential	200 volts
Deflection Plates, Average Potential	200 volts
Collector Mesh Voltage, Operating Level**	150 to 200 volts
Third Anode Voltage	150 volts
Storage Mesh Voltage	0 volts
Control Grid (Flood Gun) Voltage, Operating Level***	-50 to -200 volts
First Anode (Writing Gun) Voltage, for Focus****	300 to 800 volts
Cathode (Writing Gun) Voltage	-3100 volts
Control Grid (Writing Gun) Voltage, for Cutoff****	-40 to -70 volts

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* All maximum voltages are given with respect to the flood gun cathode potential and represent the absolute maximum departure from this potential.

** The collector mesh operating level, by definition, is 15 volts above the lowest voltage at which written information remains visible indefinitely on all parts of the viewing screen. This latter voltage has been named the retention threshold.

*** Adjusted for complete coverage of the storage surface.

**** All typical operating voltages are given with respect to the flood gun cathode potential except the control grid (writing gun) voltage and the first anode (writing gun) voltage, which are given with respect to the writing gun cathode potential.

Viewing Screen Current	0 to 300 μa
Ion Repeller Mesh Current	0 to 4 ma
Second Anode Current	0 to 3 ma
Matrix Current	0 to 3 ma
Collector Mesh Current	-0.5 to +4 ma
Third Anode Current	-0.5 to +2 ma
Storage Mesh Current	-15 to +15 μa
First Anode (Writing Gun) Current	-5 to +5 μa
Cathode (Writing Gun), Peak	300 μa
Convergence Coil Current (Main Coil)	45 to 55 ma*

PROTECTIVE CIRCUITRY:

Power supplies should be of the limited-energy type with inherent regulation to limit the continuous short-circuit currents to the values tabulated below. If the effective output capacitance is capable of storing more than 10 microcoulombs, a resistance not less than the value given below should be provided between the electrode and the output of the power supply. The 100,000 ohms resistance in series with the storage mesh should be provided regardless of output capacitance.

Electrode	Maximum Short Circuit Current	Minimum Resistance
Storage Mesh	3 ma	100,000 ohms
Collector Mesh	6 ma	200 ohms
Viewing Screen	1 ma	100,000 ohms
Writing Gun Cathode	3 ma	10,000 ohms

STANDARD COMPONENTS:

Convergence Coil	Drawing No. 415504
Socket	Drawing No. 60626

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* For convergence coil listed under standard components located on the neck at 18-3/16" from the front of the face to the center of the coil. The coil has bucking fields at each end which require not more than 95% of the main coil current. An adjustment of ±3/4" should be provided from the 18-3/16" position on the neck. The convergence coil is designed for use with a magnetic shield having an inside diameter of 5-1/2" to shield the tube from stray magnetic fields.

PERFORMANCE CHARACTERISTICS:

Character Height	.125 ± .015 inches

The above character height applies to upper case letters, and other so-called normal size characters in the matrix, projected on the screen.

Registration	±30% of character height

With all adjustments optimized, the composite character produced by superimposing all characters of the matrix has a height and width no greater than 160% of the height of a normal size character.

Selection Factor, at 3.3 KV Cathode-to-Second Anode Voltage

S_1 and S_2	28 to 34 volts/character
S_3 and S_4	28 to 34 volts/character

Compensation Factor, at 3.3 KV Cathode-to-Second Anode Voltage

C_1 and C_2	28 to 34 volts/character
C_3 and C_4	28 to 34 volts/character

Deflection Factor, at 3.3 KV Cathode-to-Second Anode Voltage

D_1 and D_2	110 to 134 volts/inch
D_3 and D_4	101 to 123 volts/inch

Writing Time	40 microseconds maximum

A character can be written on the storage surface by driving the writing gun control grid from beyond cutoff to a voltage at which the instantaneous beam current is 100 microamperes by a rectangular pulse of the above duration.

Erase Time	200 milliseconds maximum

Written information is erased by momentarily lowering the collector mesh voltage below the retention threshold. This is best accomplished by means of a triangular pulse having a slow ascent occupying most of the pulse width.

Brightness of Written Information with 4 KV on Viewing Screen, 0 volts on Storage Mesh, and Collector at Operating Level.	10 Foot-Lamberts minimum

Contrast Ratio 3:1 minimum
with 4 KV on Viewing Screen,
0 volts on Storage Mesh, and
Collector at Operating Level.

The ratio of brightness of written information to that of the background can be increased by lowering the storage mesh voltage below zero volts, however, this improvement is made with some sacrifice of resolution and brightness of the written information. Contrast can be enhanced without sacrifice of brightness and resolution by applying a positive pulse to both the storage mesh and collector mesh having a 10 to 30-volt amplitude, 1000-cycle repetition rate, and 1% duty cycle.

LSY/z

OPERATION OF THE HUGHES TONOTRON*

DIRECT VIEW DISPLAY HALF TONE STORAGE TUBE

Applications Engineering
Publication No. 91-19A-5
January, 1962

HUGHES

HUGHES AIRCRAFT COMPANY
VACUUM TUBE PRODUCTS DIVISION
OCEANSIDE, CALIFORNIA

TABLE OF CONTENTS

DISPLAY STORAGE TUBE NOMENCLATURE

(From JEDEC Publication No. 33, August 1961)

The nomenclature and symbols listed below refer to a generalized tube of the display storage type.

NOMENCLATURE	SYMBOL
Writing gun (write gun)	w
Writing gun (write gun) heater	wh
Writing gun (write gun) cathode	wk
Writing gun (write gun) grids, numbered serially after cathode	wg1, wg2
Writing gun (write gun) deflecting electrodes	wD1, 2 - wD3, 4
Flooding gun (flood gun)	f
Flooding gun (flood gun) heater	fh
Flooding gun (flood gun) cathode	fk
Flooding gun (flood gun) grids, numbered serially after cathode	fg1, fg2
Ion repeller (if used)	ir
Collector electrode	ce
Storage surface	ss
Backing electrode	be
Screen (viewing screen)	vs

NOTES

1. *Where more than one gun serves a similar function, use w1 for the first writing gun, w2 for the second writing gun, f1 for the first flooding gun, etc.*
2. *Where a gun is designed specifically for either selective erasure or non-store writing, use "r" or "n", respectively, in place of "w" for writing or "f" for flooding.*
3. *Any mesh or mesh-like structure lying in a plane perpendicular to the axis of the tube is named by its function and is not included in the grid numbering system.*
4. *Voltages on specific electrodes are expressed in the following manner:*
   a. *Cut-off voltage on grid no. 1 (w2g1) of writing gun no. 2: w2E(co)c1.*
   b. *RMS voltage on grid no. 1 (w2g1) of writing gun no. 2: w2Eg1.*
   c. *DC voltage on grid no. 4 (fg4) of flooding gun: fEc4.*
   d. *Voltage on the screen: Evs.*

GLOSSARY OF STORAGE TUBE TERMS

CATHODE RAY STORAGE TUBE
A storage tube in which the information is written by means of a cathode ray beam.

CHARGE STORAGE TUBE
A storage tube in which the information is retained on a storage surface in the form of a pattern of electric charges.

COLLIMATE
To modify the paths of electrons in a flooding beam so that they become more nearly parallel as they approach the storage assembly.

CROSS OVER VOLTAGE
The voltage of a secondary emitting surface, with respect to cathode voltage, at which the secondary emission ratio is unity.

DECAY
A change in magnitude or configuration of stored information for any reason other than writing or erasing.

DISPLAY STORAGE TUBE
A storage tube into which the information is introduced as an electrical signal, and read at a later time as a visible output corresponding to the stored information.

EQUILIBRIUM BRIGHTNESS
The viewing screen brightness occurring when the tube is in a fully written stored condition.

ERASE
To reduce by a controlled operation the amount of stored information.

HALF-TONES
Output levels, each related to a different input, that can be distinguished from one another regardless of location on the storage surface.

ION CHARGING
Spurious charging or discharging caused by ions striking the storage surface.

READ
To observe the stored information at the viewing screen.

VIEWING TIME
The time during which the storage tube is presenting a visible output corresponding to the stored information.

WRITE
To establish stored information corresponding to the input signal.

WRITING SPEED
Lineal scanning rate of the beam across the storage surface in writing.

GENERAL

A direct-view display storage tube is an electron tube into which information is introduced as an electrical signal, and read out at a later time as a visible output corresponding to the stored information.

The "half-tone" storage tube, represented by the Hughes Tonotron tube, accepts and stores intensity-modulated information and presents at the viewing screen a visible output whose relative brightness levels are proportional to modulation amplitude.

In the performance of its intended function, the storage tube exhibits two inherent characteristics of significant importance; these are (1) the capability of delivering a brilliant, non-flickering, uniform display, and (2) an ability to control display persistence.

Display brightness is high . . . several thousand foot-lamberts for some types . . . resulting from the use of a constant source of electrons to illuminate the viewing screen phosphor during the viewing operation. Thus the intermittent character of the writing gun beam has no direct effect on the finite levels of display brightness.

Persistence of the display is controllable because it is primarily dependent upon quantities of electric charge established at a storage surface, and is not perceptibly affected by the characteristic of the viewing screen phosphor. Typical display times for half-tone storage tubes range from several seconds to several minutes, depending on tube type and viewing screen diameter, but these times may be considerably extended by the use of special techniques.

Direct-view display storage tubes are available in several viewing screen diameters from three inches to twenty one inches. They may use electrostatic or electromagnetic focus and deflection, or combinations of the two. For the purpose of this presentation, a representative 5-inch size electrostatic type is assumed, the internal construction of which is shown in Fig. 1, Simplified Schematic Diagram.

DESCRIPTION OF THE TUBE

The essential components of the tube illustrated in Fig. 1 are: (1) the WRITING GUN, INCLUDING THE DEFLECTION SYSTEM, (2) the FLOODING GUN, (3) the COLLIMATING SYSTEM, and (4) the STORAGE ASSEMBLY.

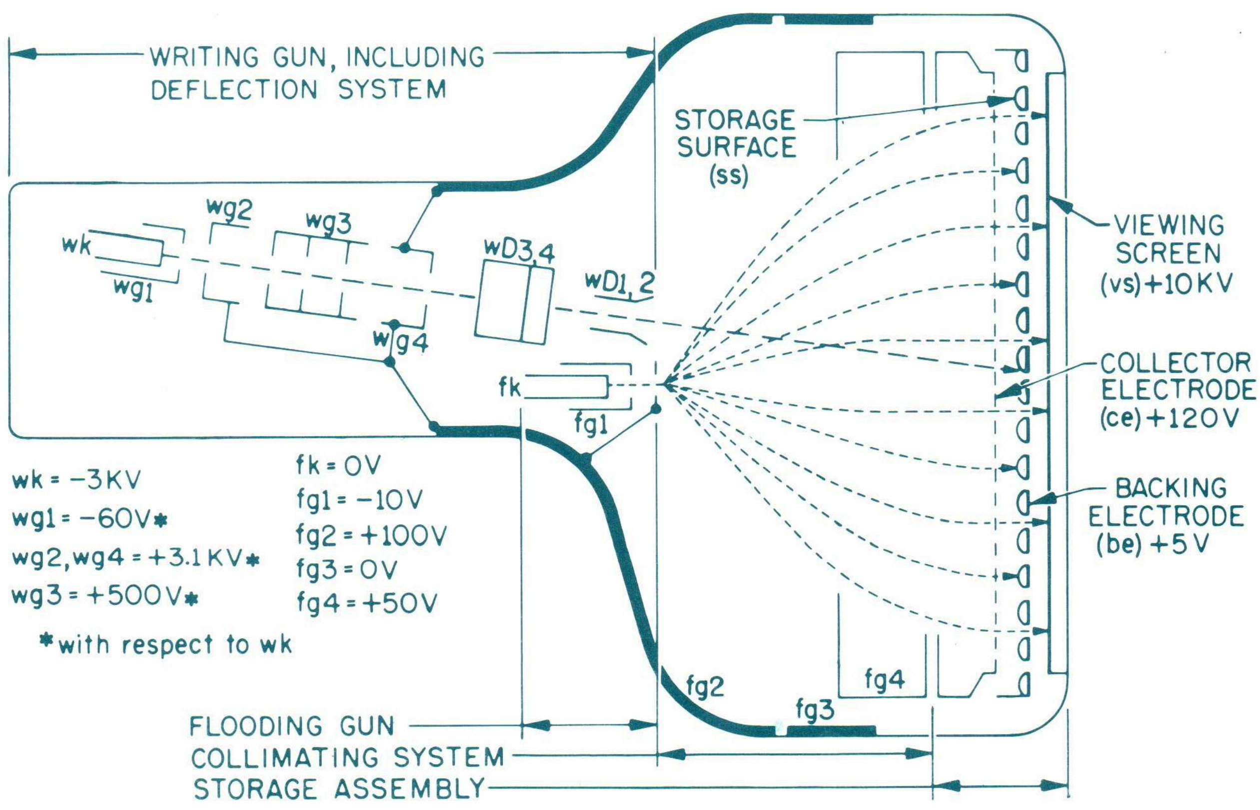
The writing gun and deflection system serve to generate a sharply focused high energy beam and position it at the proper place on the storage surface.

The flooding gun provides a constant flow of low energy electrons, which is referred to as the "flooding beam". Due to the electron lens action of the collimating system, flooding beam electrons are caused to approach the storage surface orthogonally, and uniformly over its entire area. In Fig. 1, the electrons shown penetrating to the viewing screen represent those which excite the viewing screen phosphor to produce the visible display. Flooding beam electrons are also used to erase the storage surface.

The elements comprising the storage assembly are, from left to right in Fig. 1, the collector electrode, the storage surface which is a thin film dielectric that stores written information, the fine mesh backing electrode supporting the storage surface and the aluminized viewing screen.

Tube element symbols follow the generally accepted nomenclature for storage tubes. Electron gun elements are identified by letters "w" or "f" for the writing and flooding functions respectively. Gun elements from the cathode outward toward the storage assembly (except the deflecting electrodes) are designated "grids" and numbered serially from the cathode end. The storage assembly elements are designated according to the function they perform.

FIGURE 1
DIRECT VIEW DISPLAY STORAGE TUBE; SIMPLIFIED SCHEMATIC DIAGRAM

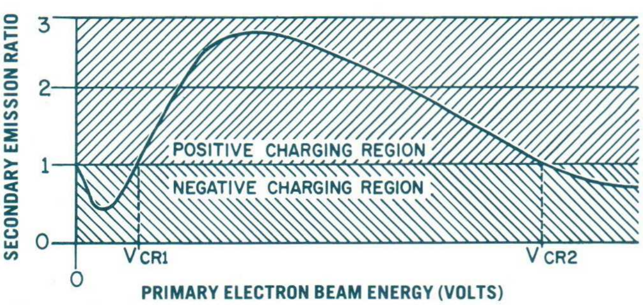


NATURE OF THE STORAGE SURFACE

A charge storage tube is an electron tube in which information is retained on a storage surface in the form of a pattern of electric charges. This definition is applicable to the direct view display half-tone storage tube.

The operation of the charge storage tube is based upon the property of the storage surface to charge in a positive or negative direction, depending wholly upon the energy of the incident electron beam. Such a property is made possible by the secondary emission characteristic of the storage dielectric. Refer to Fig. 2, Typical Secondary Emission Curve.

FIGURE 2
TYPICAL SECONDARY EMISSION CURVE FOR A STORAGE SURFACE DIELECTRIC



Between 0 volts of primary beam energy and the "first cross over voltage" VCR1, approximately 40 volts, the curve indicates a secondary emission ratio less than unity. Therefore in this operating region, more primary electrons are accumulated at the storage surface dielectric than the secondary electrons emitted, and the storage surface is charged in a negative direction.

In the region between the first cross over voltage VCR1 and the "second cross over voltage" VCR2, whose value might be as great as 20 - 25 kilovolts, the secondary emission ratio is greater than unity; the number of secondary electrons emitted at the storage surface exceeds the number of primary beam electrons arriving, and the storage surface is charged in a positive direction.

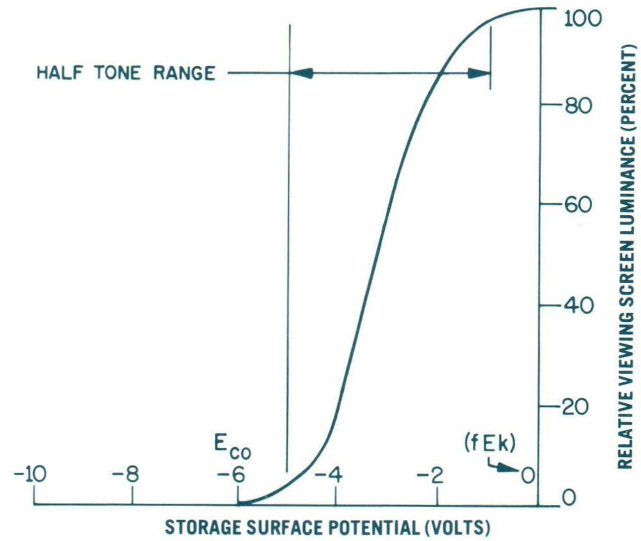
The writing of information upon the storage surface occurs when the charges induced by a primary beam are positive-going, and this is accomplished by the writing gun whose beam energy levels lie within the values required to produce secondary emission ratios greater than unity.

Conversely, erasure of stored information takes place when the storage surface is made increasingly negative. The flooding gun beam, whose energy level is below the first cross over voltage, is used to perform this function.

As has previously been stated, the storage surface consists of a thin film dielectric deposited upon the electron-gun side of a fine mesh backing electrode. The area adjacent to each opening in the storage surface mesh is said to be a storage element, each of which controls the number of flooding gun electrons allowed to pass through its own area into the viewing screen field. The relative brilliance of the viewing screen as a function of storage surface potentials is shown in Fig. 3, Typical Storage Characteristics.

NATURE OF THE STORAGE SURFACE (CONT.)

FIGURE 3
TYPICAL STORAGE CHARACTERISTIC



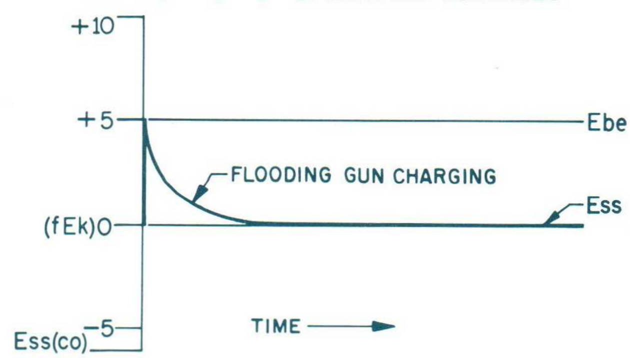
The curve of Fig. 3 reveals one fact important to note: that storage surface potentials in the half-tone range of operation are negative with respect to the flooding gun cathode. Each storage element comprising the storage surface may be considered a virtual "control grid" for flooding gun electrons approaching its area. Thus, if a modulated writing gun beam scans all the storage elements of the storage surface, a varied charge pattern is established which causes varied levels of luminance in exactly the same pattern to appear at the viewing screen.

PRINCIPLES OF OPERATION
INITIAL OPERATION

When operation of the tube is initiated (refer to Fig. 1 for typical electrode voltages), the positive potential applied to the backing electrode, 5 volts, also appears at the storage surface because of the large capacitive coupling between them.

Low energy collimated flooding gun electrons, attracted by the positive gradient, accumulate on the storage surface, rapidly charging it to flooding gun cathode potential. This sequence is shown graphically in Fig. 4.

FIGURE 4
STORAGE SURFACE POTENTIAL AT INITIAL APPLICATION OF OPERATING VOLTAGES



The storage surface, once at flooding gun cathode potential, can accept no additional electrons, and all the flooding gun electrons that subsequently approach the storage surface accelerate into the high voltage viewing screen field.

INITIAL OPERATION (CONT.)

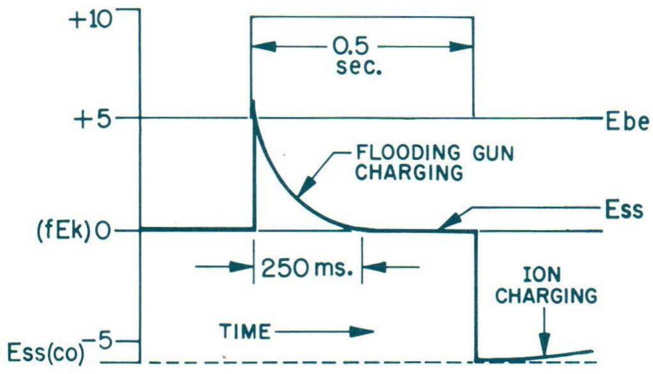
The result of this action is shown on the curve of Fig. 3, Typical Storage Characteristic; where the storage surface potential is the same as that of the flooding gun cathode, the relative viewing screen luminance is 100 percent. At this time, therefore, the viewing screen is in a state of maximum uniform brightness, and the tube is said to be in a "fully written" condition.

PREPARATION FOR WRITING

Before the writing of stored information is possible, the storage surface must be made sufficiently negative to extinguish the light output at the viewing screen. This occurs at "storage surface cut off potential" which, according to Fig. 3, is −6 volts for this tube. At this value, flooding gun electrons are repelled at the storage surface and return to the collector electrode; none reach the viewing screen.

The procedure used to arrive at this condition is called ERASING, and is accomplished most simply by applying a single manually initiated positive pulse of appropriate duration to the backing electrode. Events during the process are shown in Fig. 5, Storage Surface Potentials During Single Erase-pulse Operation.

FIGURE 5
STORAGE SURFACE POTENTIAL DURING SINGLE ERASE-PULSE OPERATION



When the positive pulse having an amplitude equal to the value of storage surface cut off potential is applied to the backing electrode, the storage surface rises a like amount due to their capacitive coupling, but electrons from the flooding gun charge it back down to flooding gun cathode potential. At the end of the pulse, the backing electrode potential drops by the same amount that it had been raised, and again the storage surface is carried capacitively with it, dropping to −6 volts. No flooding gun electrons can land upon the storage surface, now negative with respect to the flooding gun cathode, and a stable condition exists.

Thus, the storage surface is driven to cut off, erasure is complete, and the tube is ready for the writing operation. (Note: the "ion charging" notation in Fig. 5 is explained in the following section.)

WRITING STORED INFORMATION

If a modulated signal is introduced at the control grid (grid no. 1) of the writing gun, its sharply focused beam becomes energized with an intensity proportional to the signal voltage amplitude, and by means of the deflection system, is made to scan the storage surface.

WRITING STORED INFORMATION (CONT.)

By the mechanism described in the section "Nature of the Storage Surface," a charge in a positive direction is established at every storage surface element struck by the beam. In this manner, a "charge pattern" is WRITTEN on the storage surface area.

Since the number of flooding gun electrons permitted to pass into the viewing screen field is proportional to the amount of positive-going charge induced at each storage element (refer to Fig. 3.), the display pattern becomes a reproduction of the charge pattern written on the storage surface. The length of time after writing, during which an acceptable output can be read, is termed "storage retention time," and is determined chiefly by "ion effects" as described below.

Flooding gun electrons do not disturb the charge pattern because, as shown in Fig. 3, the storage surface is negative with respect to the flooding gun cathode over the entire half-tone range; in addition, losses due to storage surface dielectric leakage are very small. Therefore, if storage time were governed only by these relatively stable factors, a charge pattern might prevail without appreciable deterioration for some 100 hours or more.

However, the charge pattern is adversely affected, consequently imposing a limitation on storage retention time, because of the presence of residual-gas molecules within the tube.

As these gas molecules collide with flooding gun electrons, positive ions are formed and are accelerated toward the negatively charged storage surface. Upon landing of these ions, the storage surface is gradually charged in a positive direction, as shown by the "ion charging" notation in Fig. 5. The result is a gradual brightening of the display background, accompanied by a corresponding gradual loss of display contrast.

Generally, the limit of acceptable output occurs when the background brightness rises to approximately 20 percent of equilibrium brightness, at which time the storage surface may be erased and a new cycle begun.

THE ERASING OPERATION

Erasure is the process of charging the storage surface in such a way as to eliminate previously stored information, and at the same time prepare the storage surface for subsequent writing. The operation may be carried out by a single short pulse or a train of very short pulses, depending upon operational requirements.

Where it is necessary that stored information be removed at once, erasure is accomplished by a single manually initiated or electronically timed positive pulse applied to the backing electrode. This technique, termed "static" erasure, is described in the section "Preparation for Writing" and is illustrated in Fig. 5.

If, however, it is necessary or desirable to control the degree of display persistence, pulse-train erasure is employed. In this method, referred to as "dynamic" erasure, storage surface potentials are made to become increasingly negative in discrete steps, by amounts governed by pulse amplitude and pulse-train duty cycle.

THE ERASING OPERATION (CONT.)

Of first importance in dynamic erasure is the determination of correct pulse amplitude. In Fig. 6, Effect of Erase-Pulse-Train on Unwritten Storage Surface, this is shown to be a value sufficient to overcome incremental ion charging so that storage surface potential is held at just cut off. Although the backing electrode potential wave form of Fig. 6 represents a 6 volt pulse amplitude, in actual practice a somewhat greater value may be required to compensate for capacitive and source impedance effects.

FIGURE 6 . . . EFFECT OF ERASE-PULSE-TRAIN ON UNWRITTEN STORAGE SURFACE

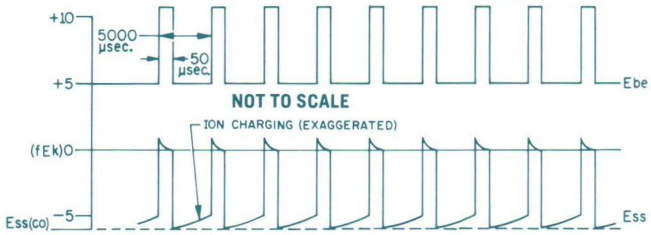
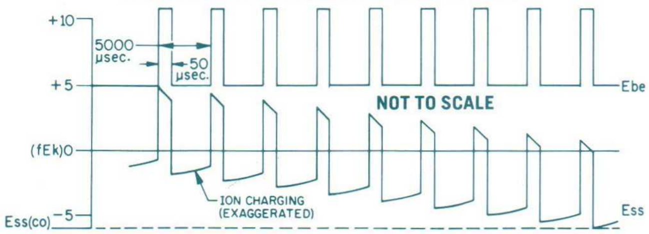
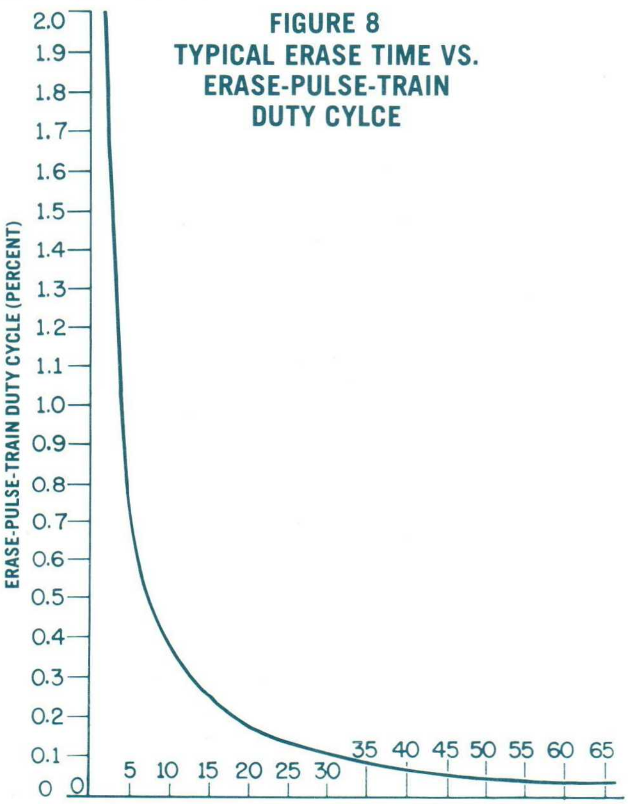


FIGURE 7 . . . GRADUAL ERASURE OF STORED WRITING BY ERASE-PULSE-TRAIN



The effect of dynamic erasure on a written storage surface is demonstrated in Fig. 7, Gradual Erasure of Stored Writing by Erase-Pulse-Train. In this example, the erase-pulse interval and duration indicate a repetition rate of 200 pulses per second, and a duty cycle of 1.0 percent. From the curve of Fig. 8, the time required for the storage surface to go progressively negative to cut off is approximately 5 seconds.

FIGURE 8 TYPICAL ERASE TIME VS. ERASE-PULSE-TRAIN DUTY CYLCE



Since erase time is a function of erase-pulse-train duty cycle, an extension of this time may be achieved either by decreasing the repetition rate . . . the practical limit being the point of discernible flicker . . . or by decreasing pulse duration.

The control of display persistence may be accomplished by adjusting the essentially independent erasing and writing operations so that they are carried out simultaneously.

It is interesting to note at this point that the background illumination is also a function of the erase-pulse-train duty cycle. Since the tube face goes to 100 percent brightness for the duration of each individual erase-pulse, and since each pulse is very brief, the eye integrates these light flashes into an overall average which increases as the pulse-train duty cycle increases.

The bright flash occuring during a single erase-pulse, or those occurring during pulse-train erasure may be eliminated by causing the viewing screen voltage to drop below 2 kilovolts for the duration of each pulse. Application circuitry is available on request.

VIEWING TIME

The principal limitation on storage retention time is the "ion charging" effect at the storage surface; this process is described in the section "Writing Stored Information." The degree of limitation imposed depends upon the pressure of residual gas for a given tube type and size, and may range from several seconds to several minutes; 60 to 90 seconds is representative for a 5-inch Tonotron type.

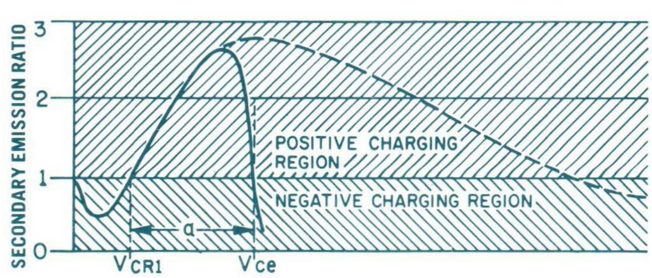
There are several methods of extending storage time, a common one of which utilizes a means to reduce the density of the flooding beam and thus reduce the ion charging effect proportionally. However, with this method, light output is reduced in like proportion, so that the amount of storage extension time that is practicable is determined by the amount of light output trade off that is acceptable.

More complete information is included in the brochure "Application Notes; Extending Storage Time," which is available on request.

OPERATING PRECAUTIONS

Should the circumstance arise whereby the storage surface potential goes beyond the first cross over, flooding beam electrons will have sufficient energy to support a secondary emission ratio greater than unity and drive the storage surface further toward collector electrode potential. This condition is referred to as RUNAWAY CHARGE, and is illustrated in Fig. 9 as the region designated "a".

FIGURE 9 TYPICAL SECONDARY EMISSION CURVE LIMITED BY COLLECTOR ELECTRODE POTENTIAL



OPERATING PRECAUTIONS (CONT.)

Runaway charge may be initiated in several ways:

1. Excessive writing beam current; this sometimes results from an attempt to achieve greater writing speed, or viewing screen brightness, than that which the tube is rated to provide.
2. Excessive writing beam dwell time; in which the writing beam scanning speed is too slow for a given value of beam current. This is also apt to occur in the event of deflection failure.
3. Writing when the flooding beam is turned off; where the limiting action of the flooding beam which prevents the storage surface potential from exceeding that of the flooding gun cathode is absent.
4. Applying erase pulses whose amplitude is too great.

If any of these irregularities is promptly observed and the writing operation stopped at once, in general, no permanent damage at the storage surface will be incurred. It is important to note, however, that these are storage surface effects, and may be present even though the viewing screen is de-energized. In this event, they would not be apparent at all.

Even if the viewing screen is energized, equilibrium brightness is reached at the time the storage surface has risen to flooding gun cathode potential, and a further positive increase produces but very slight additional light output. For this reason, abnormal conditions would still not be obvious, and it is therefore necessary that precautions be taken to forestall them.

Runaway charging at the storage surface, if allowed to develop, may manifest itself by these indications:

1. Inability to erase, caused by regenerative, rather than degenerative action of the flooding beam.
2. Brilliant flashing at random locations on the viewing screen, due to arcing between segments of the storage surface, or between the storage surface and backing electrode.
3. Dark, unstored areas at the viewing screen, indicating damage to corresponding areas of the storage surface dielectric.

Runaway charge, if uncorrected, could bring about arcing between the backing electrode and viewing screen, resulting in the destruction of the aluminized phosphor coating in the arc area. Arc damage could also be caused by a high impedance in series with the backing electrode.

Provided that no permanent damage has been suffered by the storage surface, runaway charge may be overcome and normal operation of the tube resumed. With all other electrode potentials still applied, viewing screen voltage should be switched off, then the backing electrode disconnected from its supply and connected for a few seconds to the collector electrode. After reconnecting the backing electrode to its own supply and restoring proper viewing screen voltage, the tube should erase in the normal manner.

When initiating operation of the tube, the flooding beam should be energized before any writing is attempted, and at the end of operations; the writing beam should be de-energized before the flooding beam is turned off. This procedure avoids the dangers inherent in writing without the flooding beam on.

POWER SUPPLIES AND PROTECTIVE CIRCUITS

Static voltages required for the operation of the tube may be obtained from conventional power supplies. Provision should be made for convenient adjustment of the control grid voltages of both flooding and writing guns, and the potentials affecting flooding beam collimation and writing beam focus.

Since the voltages applied to the writing gun control grid, focusing electrode and accelerating electrode are referenced to the writing gun cathode, they may be readily furnished with a single negative supply and appropriate voltage divider network. This method is suitable for maintaining the ratio of focusing to accelerating voltages, required to maintain good spot size. Should separate power supplies be used, they must incorporate exceptionally good voltage regulation.

Due to the high internal voltage gradient between the backing electrode and viewing screen, it is advisable to provide protection against excessive surge currents. For the viewing screen, a limited energy type supply is preferred, with a high voltage protective resistor of 0.1 to 1.0 megohm, depending upon tube type and size, inserted in series with the viewing screen lead.

It is desirable to interlock both the writing gun control grid bias supply and the deflection voltage source with the writing gun cathode power supply in such a way that, should either the bias voltage or deflection voltage fail, the cathode supply is de-energized. This safety feature has the purpose of avoiding either excessive beam current or excessive dwell time, with their possible damaging effects.

MAGNETIC SHIELDING

Flooding beam collimation in a display storage tube may be adversely affected by magnetic fields having densities as low as 0.25 gauss. For this reason, operation of the tube within an appropriate magnetic shield is required.

In addition, precautions should be taken to avoid exposure to random magnetic fields during transport or storage; for example, enclosing the tube in a magnetic shield container, including a face plate cover.

Specific data on shielding and demagnetization are available on request.

TUBE HANDLING AND MOUNTING

Handling and mounting procedures for conventional cathode ray tubes and other types having highly evacuated bulbs are applicable to the display storage tube; however, these precautions are repeated for emphasis:

1. Avoid bending connector pins, because this may cause undue stress or cracking in the glass to metal seals.
2. The tube should never be placed face down on a surface, since the face plate may be scratched and thus degrade the visual display. Moreover, this procedure creates a serious personnel hazard, as the tube may be caused to implode violently.
3. Under no circumstances should connector pin sockets be rigidly mounted, nor the tube supported by the neck; such methods may impose abnormal stresses on the glass, leading to glass fracture.

For technical data or application assistance with Hughes Tonotron, Typotron®, and Memotron® storage tubes and other advanced display devices, contact Hughes at address noted below.

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HUGHES AIRCRAFT COMPANY
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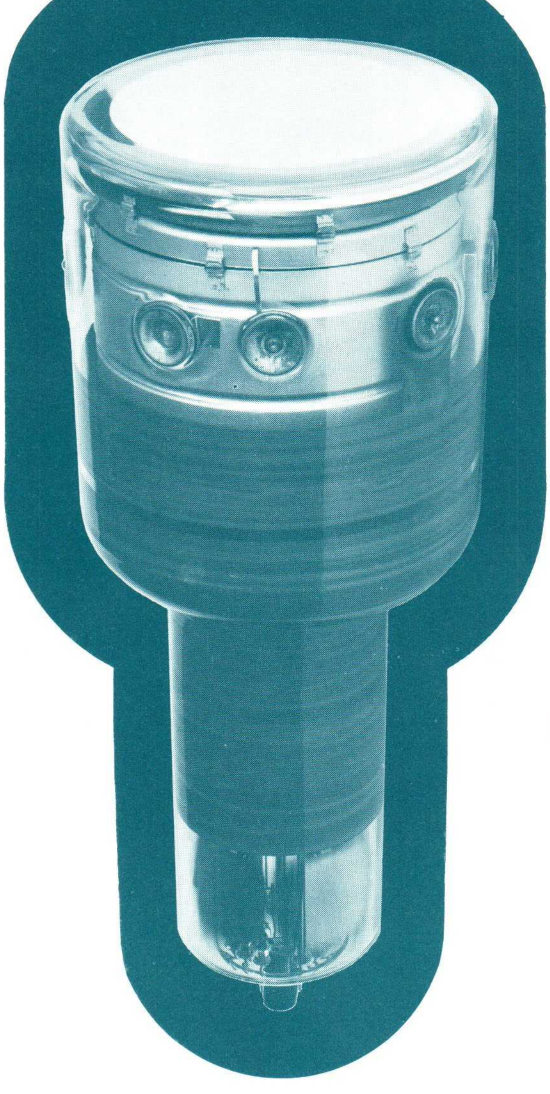
CRST-13C/2.5M/AL/8-62

OPERATION OF THE HUGHES MULTI-MODE TONOTRON* DIRECT VIEW DISPLAY HALF TONE STORAGE TUBE



APPLICATIONS ENGINEERING
PUBLICATION NO. 91-19A-13
APRIL 1962

CREATING A NEW WORLD WITH ELECTRONICS

HUGHES

HUGHES AIRCRAFT COMPANY
VACUUM TUBE PRODUCTS DIVISION
2020 SHORT STREET, OCEANSIDE, CALIFORNIA

TABLE OF CONTENTS

NOTE:

Publication No. 91-19A-5, referred to in this publication, is; "Operation of The Hughes Tonotron Direct View Display Half Tone Storage Tube". This publication (91-19A-13) is a supplement to 91-19A-5 and in every case should be accompanied by 91-19A-5.

GENERAL

The Hughes *"multi-mode"* Tonotron tube is a new type of direct view display half-tone storage tube which is capable of selective erasure, and simultaneous presentation of stored and non stored information.

Selective erasure provides significant additional flexibility in direct view storage tube applications, since it makes possible the erasure from a display of whatever information is undesirable, without detriment to that which is necessary to retain. Moreover, by means of this feature, information can be erased into a fully written display, resulting in a dark trace presentation having higher contrast and appreciably greater resolution than that obtainable with conventional writing.

The non store mode of operation (sometimes referred to as "write through"), permits cathode ray type information such as reference markers, grid lines, or maps to be superimposed on the stored display with no serious degradation to the latter.

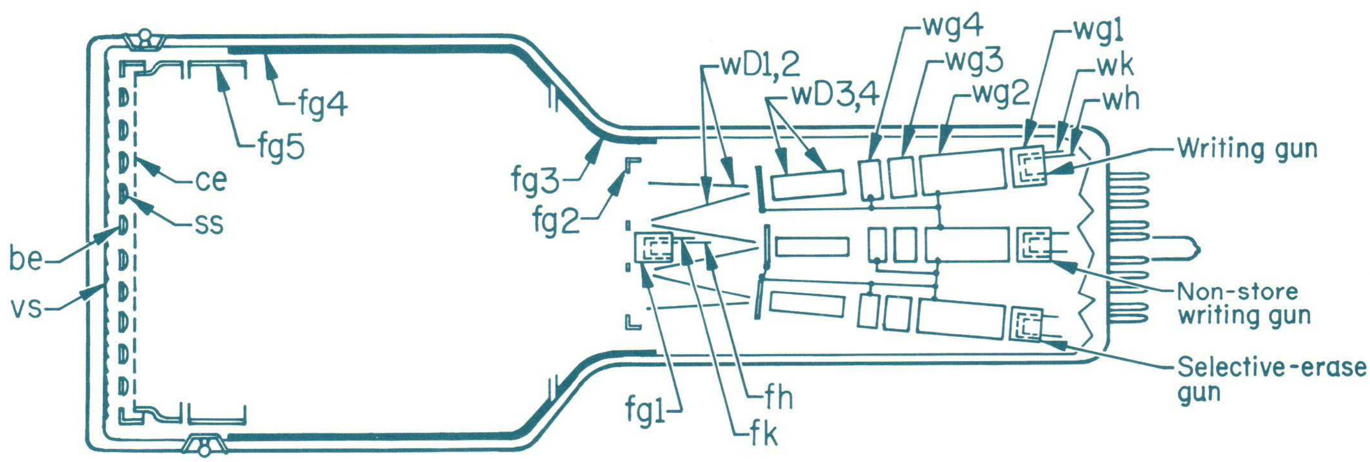
Inclusion of these features into direct view display half-tone storage tubes has not previously been practical chiefly due to the nature of the secondary emission effects on which writing and erasing of stored information are based. However, in the *multi-mode* Tonotron tube, limitations imposed by secondary emission effects are surmounted by the use of a "dual effects" storage surface dielectric.

One effect, secondary emission, charges the storage surface in a positive direction, while the other, bombardment-induced-conductivity, charges it toward backing electrode potential which, under normal operating circumstances, is negative. The effect, and therefore the resulting charging direction, is selected by choice of the appropriate incident beam energy level.

At relatively low energies, about 2.5 kV, the secondary emission effect prevails and the storage surface is written with a positive charge. Conversely, at high energies, 6 kV or greater, bombardment-induced conductivity becomes predominant and the storage surface charges toward backing electrode potential, thus erasing. At some intermediate beam energy level, near 4.5 kV, the charge deposited on the storage surface by secondary emission and that conducted toward backing electrode potential by bombardment-induced currents are very nearly equal, resulting in only a very slight effect on the stored charge pattern. In this circumstance, that portion of the beam not intercepted by the storage surface continues through the storage elements and, upon striking the viewing screen phosphor, produces the display of non stored information.

For the purpose of this presentation, a 5-inch electrostatic type multi-mode Tonotron tube incorporating three independent high energy electron guns is assumed, and is shown schematically in Fig. 1. The three guns are identified by the letters "w", "n", and "r", for the writing, non-stored writing, and selective erase guns respectively. For electrode symbol nomenclature, refer to Page 7 of this publication.

FIGURE 1
5-INCH MULTI-MODE TONOTRON TUBE WITH THREE, HIGH ENERGY ELECTRON GUNS



NOTE:

ELECTRODE DESIGNATIONS FOR THE NON-STORE WRITING GUN AND SELECTIVE ERASE GUN ARE THE SAME AS THOSE SHOWN FOR THE WRITING GUN, EXCEPT THAT THE INITIAL LETTER BECOMES "n" AND "r", RESPECTIVELY, RATHER THAN "w"

BOMBARDMENT-INDUCED CONDUCTIVITY EFFECTS

Bombardment-induced conductivity may be defined as the ability of thin film insulators to conduct when subjected to bombardment by high energy electrons.

This effect is illustrated in Fig. 2A and 2B, where thin film dielectric storage surfaces are shown attached to conductive backing electrodes, and where electric fields having polarities as noted are applied. In Fig. 2A, when primary beam current I p bombards a region of the storage surface, a bombardment-induced current (an electron flow) I c is caused to pass through that region. Under certain conditions, the induced current may be considerably greater than the primary current; a merit factor for the process is obtained by the ratio $\frac{Ic}{Ip}$, and is expressed as the conduction ratio C R . If, as shown in Fig. 2A, the polarity of the electric field is such that the direction of the induced current is the same as that of the primary current, the conduction ratio is said to be positive. In Fig. 2B the mechanism is the same, but since the electric field is reversed, the direction of the induced current (again taken to mean electron flow) is opposite to that of the primary current, and the conduction ratio is said to be negative.

FIGURE 2A **FIGURE 2B**

BOMBARDMENT INDUCED CURRENT

POSITIVE CONDUCTION RATIO **NEGATIVE CONDUCTION RATIO**

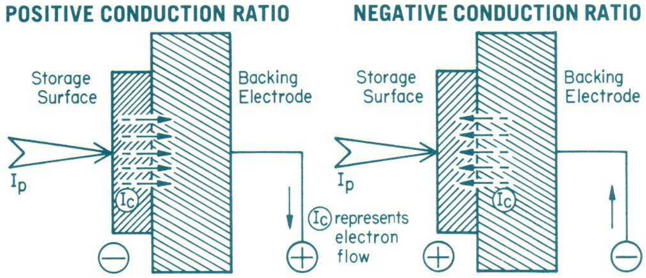
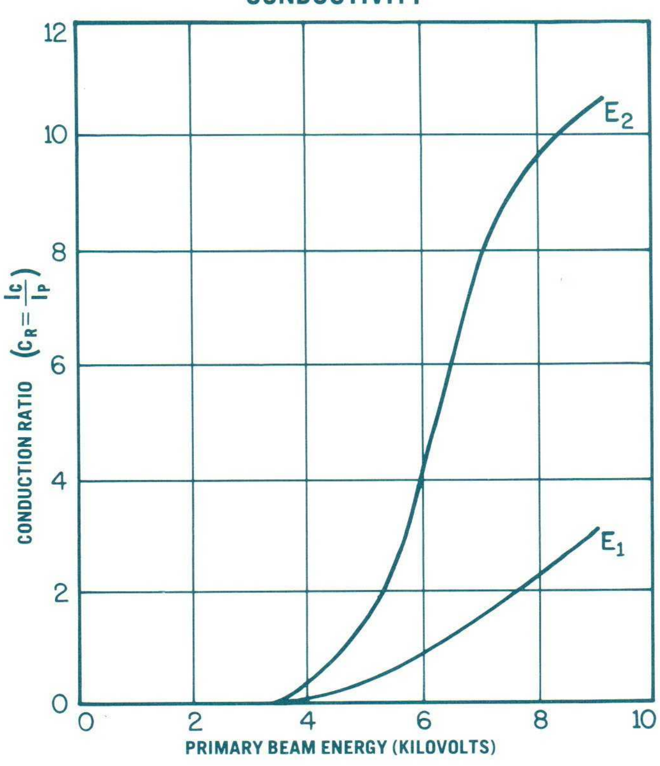


FIGURE 3

TYPICAL CURVES OF BOMBARDMENT INDUCED CONDUCTIVITY



The conduction ratio of a given dielectric material is dependent upon two factors: primary beam energy and the magnitude of the electric field. This is shown by the curves of Fig. 3, where conduction ratio is plotted against primary beam energy for two values of electric field, of which E2 is several times greater than E1 . Note that the conduction ratio remains negligible until primary beam energy reaches "critical voltage" – approximately 3.6 kV in this example, then begins to rise. In the region of critical voltage, the rate of change of conduction ratio is relatively small with either field; however, as primary beam energy is increased into the higher voltage range – 4.5 kV and greater, the conduction ratio curve for E2 , the higher value of field, is seen to be significantly more steep. When the primary beam current and the magnitude of the field are sufficiently great, the conduction ratio saturates at some maximum value. The curves of Fig. 3 represent a positive conduction ratio, but those showing negative values are essentially the same.

The bombardment-induced conductivity effect is explained by simplified semiconductor theory in this way:

When high energy electrons enter an insulator, they ionize atoms along their paths. In the process, some electrons in the insulator are raised into the conduction band, thus creating positive holes. If these electrons and holes come under the influence of an applied field, and recombination and trapping do not occur, they will acquire velocities in the appropriate direction and eventually reach the electrodes. Because an energy of only a few electron volts is necessary for the production of an ion pair, large numbers of pairs may be generated by high energy electrons.

In a 5-inch multi-mode Tonotron display storage tube, the unwritten storage surface potential is the same value as that applied to the backing electrode, typically –10 volts. When the storage surface is written, secondary emission charging effects shift this potential in a positive direction by some amount depending on writing beam intensity and scanning speed. To selectively erase the stored information, the storage surface is bombarded by a high energy beam, and by means of the negative charging effect of the bombardment-induced current, its potential is reverted toward the initial –10 volt value.

Because the conduction ratio decreases with decreasing field, the storage surface cannot discharge beyond backing electrode potential, and even though there may be small variations in the conduction ratio which affect the absolute value to which the storage surface discharges, they are of little consequence when the total voltage across the dielectric is considered.

Although the use of secondary emission effects is suitable for producing stored writing at the storage surface, use of the same effects for selective erasure is accompanied by several disadvantages. From Fig. 2, Page 4 of publication 91-19A-5, it may be seen that either beam energies below V CR1 , the first cross over, or in excess of V CR2 , the second cross over, would be required to achieve selective erasure by this means. The method in which beam energies below V CR1 are used proves unsatisfactory because selective erase speed is comparatively slow and resolution is poor. On the other hand, use of beam energies in excess of V CR2 , which may be as high as 20 - 25 kV, brings serious insulation and deflection

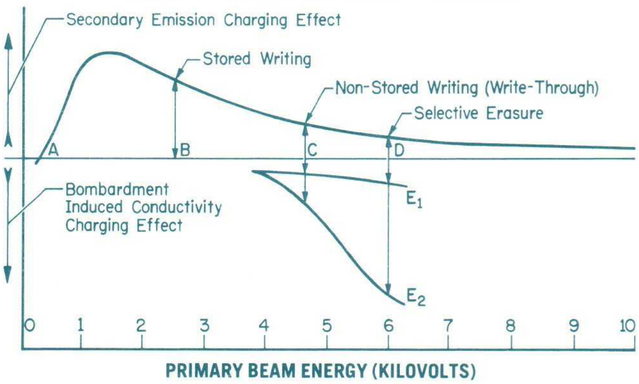
BOMBARDMENT-INDUCED CONDUCTIVITY EFFECTS (CONTINUED)

problems. Moreover, if even the most minute non-uniformities of the storage surface structure exist, then, because of the very shallow angle at which the secondary emission curve intersects unity-secondary emission ratio at V CR2 , non uniform erasure of the storage surface area results.

To overcome these inherent defects, the multi-mode Tonotron tube incorporates a storage surface having a "dual-effects" dielectric, in which secondary emission effects are utilized to charge the storage surface in a positive direction for stored writing, and bombardment-induced conductivity achieves a negative-going charging effect for selective erasure. Principles of operation of a dual-effects storage surface dielectric are discussed in the following section.

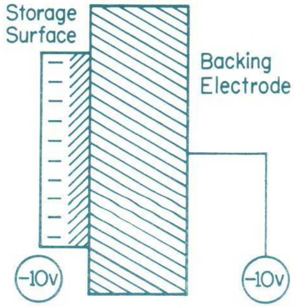
THE DUAL-EFFECTS STORAGE SURFACE

FIGURE 4
TYPICAL CHARGING CHARACTERISTICS OF A DUAL EFFECTS STORAGE SURFACE



Typical charging characteristics of a dual-effects storage surface are demonstrated by the curves of Fig. 4. Since both secondary emission effects and bombardment-induced conductivity effects are functions of primary beam energy, they are plotted on a common axis. The curve in the region above the primary beam energy axis represents positive-charging effects of secondary emission. The two below the axis show negative charging effects of bombardment-induced conductivity for two values of electric field; the lower value, E1 , corresponds to storage surface cut off, while the higher value, E2 , corresponds to storage surface full-brightness condition. Points "A", "B", "C", and "D" are keyed to the simplified functional diagrams of Figs. 5 to 8, inclusive, in which storage surface conditions are shown for the particular primary beam energy level concerned.

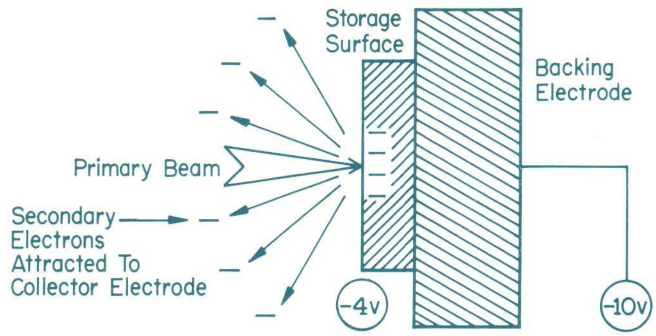
FIGURE 5
STORAGE SURFACE SHOWN CHARGED TO BACKING ELECTRODE POTENTIAL



Assume, initially, a stable condition such as that shown in Fig. 5, in which a typical value of −10 volts is applied to the backing electrode, and the potential at the storage surface is the same. As long as primary beam energy is zero, point "A" of Fig. 4, this condition will remain unchanged.

THE DUAL EFFECTS STORAGE SURFACE (CONTINUED)

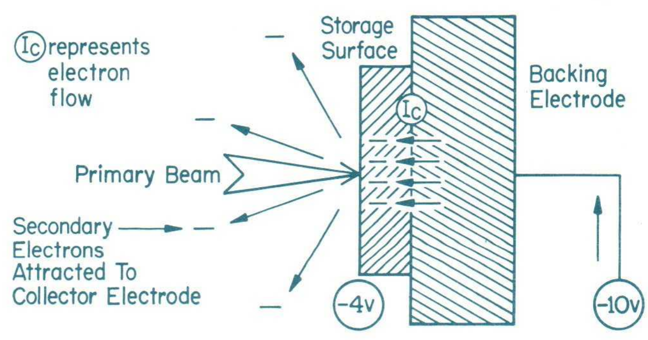
FIGURE 6
STORAGE SURFACE CHARGING IN POSITIVE DIRECTION BY 2.5 KV PRIMARY BEAM; ONLY SECONDARY EMISSION EFFECTS IN EVIDENCE



When the primary beam is energized and raised to approximately 2.5 kV, point "B" of Fig. 4, the secondary emission effect is near maximum, but bombardment-induced conduction, not yet having reached "critical voltage," is negligible; consequently, in Fig. 6, only secondary emission effects are in evidence. Since more secondary electrons are being emitted and attracted toward the collector electrode (+120 volts) than are being supplied by the primary beam, the storage surface charge is positive-going. This process, resulting in the writing of stored information, is the same as that described in the basic document for the conventional Tonotron tube (publication 91-19A-5).

Fig. 4 shows that as the magnitude of primary beam energy is increased beyond the value required for writing stored information, secondary emission effects diminish, while bombardment-induced conductivity effects, beginning at about 3.6 kV, increase quite rapidly. At approximately 4.5 kV, point "C", the two opposing effects become virtually equal; that is, the positive-going charge effect at the storage surface due to secondary emission and the negative-going charge effect due to bombardment-induced conduction are very nearly the same.

FIGURE 7
STORAGE SURFACE AT 4.5 KV BEAM ENERGY SHOWING EQUAL AND OPPOSITE SECONDARY EMISSION AND BOMBARDMENT CURRENT EFFECTS



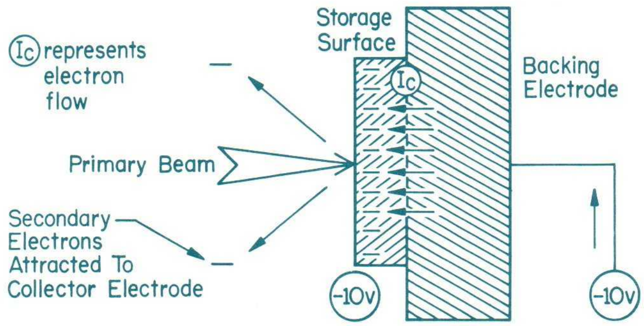
The situation is illustrated in Fig. 7, which points out that at the "equilibrium" value of electric field indicated, 6 volts, whatever the number of electrons emitted from the storage surface due to secondary emission, this number is replenished by the flow of electrons constituting bombardment-induced current Ic . Thus, in this particular instance, the resultant net charge change is zero.

THE DUAL EFFECTS STORAGE SURFACE (CONTINUED)

It is important, however, to recall from the discussion on Page 4 and from observation of the curves lying below the common base line in Fig. 4, that the conduction ratio for bombardment-induced conductivity is a function of both primary beam energy and the magnitude of electric field through the storage surface. Since the charge pattern on the storage surface may represent a relatively wide range of fields among the storage elements, perhaps from zero volts in an unwritten condition to 10 volts in a fully written condition, then the effect of the 4.5 kV beam will not be exactly the same on each. Consequently, unless the storage surface is at equilibrium value, as cited in Fig. 7, the non-stored writing beam will very slightly erase written areas and very slightly write erased areas. The degree to which stored information is degraded is not serious enough to make this mode of operation invalid; on the contrary, it is the best method presently known for accomplishing this function.

Point "D" of Fig. 4 indicates a primary beam energy of approximately 6 kV, at which value the secondary emission effect has become relatively small since the storage surface secondary emission ratio is approaching the second cross over. At the same point, the conduction ratio for the higher value of field, E2 , is comparatively large, so that the bombardment-induced conductivity charging effect is predominant.

FIGURE 8
CONDITIONS WITH 6 KV PRIMARY BEAM; STORAGE SURFACE NEGATIVE-GOING DUE TO PREDOMINANCE OF CONDUCTION CURRENT



Under this condition, shown in Fig. 8, the number of secondary electrons being dislodged from the storage surface is far less than the number of electrons constituting bombardment-induced current Ic , so the storage surface is charging in a negative direction and selective erasure occurs.

As the erase process continues under sustained primary beam bombardment, the field across the storage surface, initially indicated as E2 in Fig. 4, is progressively reduced until it approaches the value E1 , where the bombardment-induced conductivity and secondary emission effects are equal. When this condition is reached, continued primary beam bombardment results in the storage surface being held at this reduced potential.

OPERATION OF THE MULTI-MODE TONOTRON TUBE

The components of the example 5-inch multi-mode Tonotron tube shown in Fig. 1 are essentially the same as those of a corresponding conventional display storage tube, with one major exception: in the multi-mode tube, a special storage surface dielectric which exhibits the dual charging effects discussed in the preceding section is employed. Because of this single structural variance, the basic functions of the two types and, consequently, their operating conditions, are quite different.

The primary objective in a three high energy gun conventional tube is to generate a composite display of several independent input signals without need of time sharing. All three guns are therefore writing guns, operated at approximately the same cathode potential, say −2.5 kV, and, in order that maximum flooding beam current occurs at full brightness, a positive potential of about 5 volts is applied to the backing electrode.

In comparison, each of the high energy guns of the multi-mode tube performs a separate and distinct function, which requires operation of their cathodes at different potentials. Approximate voltages applied to the various cathodes are: writing gun ("w"), −2.5 kV, non store writing gun ("n"), −4.5 kV, and selective erase gun ("r"), −6 kV. Also, to make possible the utilization of bombardment-induced conductivity effects for achieving non stored writing and selective erasure, a negative 5 to 12 volt potential at the backing electrode is necessary.

The process of writing stored information is the same as that in conventional tubes, as mentioned in the preceding section. Display erasure, also, may be carried out by conventional means; that is, if an appropriate positive-going erase-pulse train is applied to the backing electrode, flooding beam erasure of the entire presentation will occur.

Methods available for erasure are not restricted to the flooding beam technique alone, however; provision is also made for selective erasure, whereby partial or complete erasure of very small, discrete areas of the display is possible. And erasure by either means may be carried out simultaneously with, or independently of, the other.

The selective erase feature of the tube is used to advantage in a variety of ways. For example, if the erase beam is made to just precede the writing beam scan, stored information may be retained at optimum brightness until immediately before the next writing sequence. Or, in a situation where information changes from sweep to sweep, the use of selective erasure prevents the smearing caused by the display of successively stored images. By appropriately programming the selective erase beam, any undesirable information may be erased without disturbance to that which is necessary to retain.

OPERATION OF THE MULTI-MODE TONOTRON TUBE (CONTINUED)

High contrast "dark trace" displays may be obtained by using the selective erase gun as a writing gun. In this mode, it is necessary that the viewing screen be initially in full brightness condition, which can be brought about readily by scanning the storage surface with the 2.5 kV writing beam. The erase gun grid is then modulated as the erase beam is scanned over the storage surface, producing a black image on a white background. If a "positive" rather than a "negative" presentation is desired, it is necessary only to invert the signals to the erase gun grid. The higher resolution gained by this method is due primarily to the greater energy of the erase gun beam.

Non stored writing makes it possible to add cathode ray type information to the display at any time, without otherwise seriously degrading it. Examples of information suitable for display in the non stored mode are reference markers, horizon lines, or even maps superimposed on the stored signals.

When the multi-mode tube is placed in service, but before regular operation is begun, it is necessary to collimate the flooding beam, and to establish the optimum operating potential at the backing electrode.

Under properly collimated conditions, electrons of the low energy flooding beam approach the storage surface orthogonally, and uniformly over the entire area. To reach such conditions, the following typical collimation adjustment procedure is suggested:

1. Apply recommended operating voltages to all electrodes.
2. Set backing electrode voltage at the positive end of its operating range, approximately –5 volts.
3. With the writing gun (2.5 kV beam), write the viewing screen to full brightness. From an initial value of zero volts, increase the flooding gun control-grid bias in a negative direction until just beyond the condition of full viewing screen coverage, then go back to the full coverage point.
4. Set flooding gun grid no's 3, 4, and 5 at the voltages specified on the label attached to the tube, then make coarse adjustments to obtain uniform full viewing screen coverage.
5. Increase backing electrode voltage in a negative direction until the display fades to a low half tone level.
6. Adjust flooding gun grid no. 5 for best possible uniformity; make fine adjustments with flooding gun grids no. 4 and no. 3.
7. Return the backing electrode to about –5 volts and repeat steps 3, 4, 5, and 6; re-write the display after each adjustment until no further improvement in uniformity can be observed.

When the backing electrode potential is at optimum value, the best balance between storage time and completeness of selective erasure occurs. Unless this balance is established, either storage time will be less than the maximum value possible, or selective erasure to cut off may not take place, depending on whether the backing electrode voltage is excessively negative, or positive, respectively. A recommended procedure for reaching optimum backing electrode potential is as follows:

1. Set backing electrode voltage at the positive end of its operating range, approximately –5 volts.
2. Using the writing gun (2.5 kV beam), write the viewing screen to full brightness.
3. With the selective erase gun (6 kV beam), scan continuously across the display with video drive at intermediate level; increase backing electrode voltage in a negative direction until erasure to just full black occurs.
4. Check the effect of the adjustment on both writing and erasing by repeating steps 2 and 3.
5. Now with the applied video drive adequate for the scanning speed used, the display should now go to full black in a single scan. If not, make a fine adjustment at the backing electrode to a slightly more negative value.

Although the "Operating Precautions" section and subsequent sections of publication 91-19A-5 are concerned with the conventional Tonotron display tube, the provisions of these sections apply in the same measure to the multi-mode version. In addition, it should be noted that since substantially higher voltages are used with the multi-mode tube, insulation and isolation requirements are correspondingly more severe and must be taken into account.

Should tracking accuracy among the high energy guns be of major significance in a given application, an improvement in this characteristic may be obtained by using a multi-mode Tonotron tube having fewer than three guns. The various modes of operation may then be accomplished by means of appropriate pulse techniques. Application information is available on request.

NOTE:

Publication No. 91-19A-5, referred to in this publication, is; "Operation of The Hughes Tonotron Direct View Display Half Tone Storage Tube". This publication (91-19A-13) is a supplement to 91-19A-5 and in every case should be accompanied by 91-19A-5.

GLOSSARY OF STORAGE TUBE TERMS

CATHODE RAY STORAGE TUBE

A storage tube in which the information is written by means of a cathode ray beam.

CHARGE STORAGE TUBE

A storage tube in which the information is retained on a storage surface in the form of a pattern of electric charges.

COLLIMATE

To modify the paths of electrons in a flooding beam so that they become more nearly parallel as they approach the storage assembly.

CROSS OVER VOLTAGE

The voltage of a secondary emitting surface, with respect to cathode voltage, at which the secondary emission ratio is unity.

DECAY

A change in magnitude or configuration of stored information for any reason other than writing or erasing.

DISPLAY STORAGE TUBE

A storage tube into which the information is introduced as an electrical signal, and read at a later time as a visible output corresponding to the stored information.

EQUILIBRIUM BRIGHTNESS

The viewing screen brightness occurring when the tube is in a fully written stored condition.

ERASE

To reduce by a controlled operation the amount of stored information.

HALF-TONES

Output levels, each related to a different input, that can be distinguished from one another regardless of location on the storage surface.

ION CHARGING

Spurious charging or discharging caused by ions striking the storage surface.

READ

To observe the stored information at the viewing screen.

VIEWING TIME

The time during which the storage tube is presenting a visible output corresponding to the stored information.

WRITE

To establish stored information corresponding to the input signal.

WRITING SPEED

Lineal scanning rate of the beam across the storage surface in writing.

DISPLAY STORAGE TUBE NOMENCLATURE

(From JEDEC Publication No. 33, August 1961)

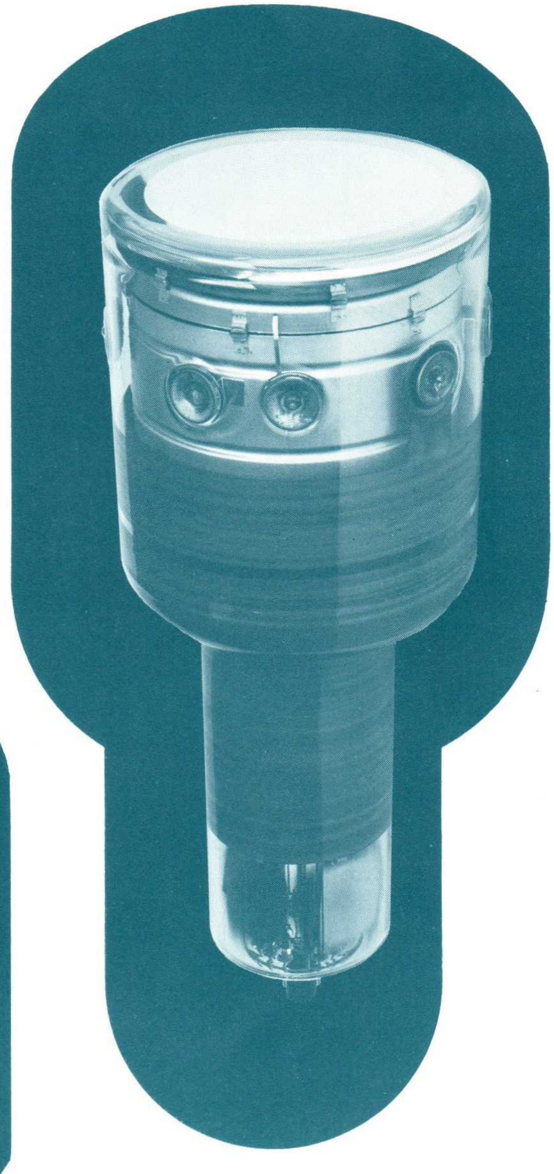
The nomenclature and symbols listed below refer to a generalized tube of the display storage type.

NOMENCLATURE	SYMBOL
Writing gun (write gun)	w
Writing gun (write gun) heater	wh
Writing gun (write gun) cathode	wk
Writing gun (write gun) grids, numbered serially after cathode	wg1, wg2
Writing gun (write gun) deflecting electrodes	wD1,2-wD3, 4
Flooding gun (flood gun)	f
Flooding gun (flood gun) heater	fh
Flooding gun (flood gun) cathode	fk
Flooding gun (flood gun) grids, numbered serially after cathode	fg1, fg2
Ion repeller (if used)	ir
Collector electrode	ce
Storage surface	ss
Backing electrode	be
Screen (viewing screen)	vs

NOTES

1. *Where more than one gun serves a similar function, use w1 for the first writing gun, w2 for the second writing gun, f1 for the first flooding gun, etc.*
2. *Where a gun is designed specifically for either selective erasure or non-store writing, use "r" or "n", respectively, in place of "w" for writing or "f" for flooding.*
3. *Any mesh or mesh-like structure lying in a plane perpendicular to the axis of the tube is named by its function and is not included in the grid numbering system.*
4. *Voltages on specific electrodes are expressed in the following manner:*
   a. *Cut-off voltage on grid no. 1 (w2g1) of writing gun no. 2: w2E(co)c1.*
   b. *RMS voltage on grid no. 1 (w2g1) of writing gun no. 2: w2Eg1.*
   c. *DC voltage on grid no. 4(fg4) of flooding gun: fEc4.*
   d. *Voltage on the screen: Evs.*

For technical data or application assistance with Hughes Tonotron, Typotron®, and Memotron® storage tubes and other advanced display devices, contact Hughes at address noted below.



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World's most complete line of storage tubes!

TONOTRON® TUBE: displays full range of grey scale images for daylight viewing. Ideal for weather radar, PPI presentations, "B" scan projections and other complex radar systems.

MEMOTRON® TUBE: displays successive transients until intentionally erased. Permits direct comparison and analysis of wave forms without photography.

TYPOTRON® TUBE: displays any combination of 63 symbols or characters at speeds to 25,000 per second. Retains presentation until intentionally erased.

STORAGE TUBE CHARACTERISTICS

7220 TONOTRON TUBE Screen diameter: 3" Standard phosphor: P1 Deflection: Electrostatic	7221 TONOTRON TUBE Screen diameter: 5" Standard phosphor: P20 Deflection: Electrostatic
7222 TONOTRON TUBE Screen diameter: 5" Standard phosphor: P20 Deflection: Electrostatic	7033 TONOTRON TUBE Screen Diameter: 5" Standard phosphor: P20 Deflection: Electromagnetic
H1020 TONOTRON TUBE Screen Diameter: 21" Standard phosphor: P20 Deflection: Electromagnetic	H1028 TONOTRON TUBE Screen diameter: 4" Standard phosphor: P1 Deflection: Electrostatic
6498 MEMOTRON TUBE Screen Diameter: 5" Standard phosphor: P1 Deflection: Electrostatic	6577 TYPOTRON TUBE Screen diameter: 5" Standard phosphor: P1 Deflection: Electrostatic

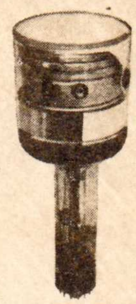
9 additional TONOTRON tubes and 4 additional TYPOTRON tubes available.

For full and complete information on how Hughes storage tubes may fill your particular needs and applications, write or wire: HUGHES PRODUCTS, Electron Tube Division, P.O. Box 90427, International Airport Station, Los Angeles 45, California.

For export information, write: HUGHES INTERNATIONAL, Culver City, California.

7220


7221


7222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H1020


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6498


6577

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Selective Erasure and Nonstorage Writing in Direct-View Halftone Storage Tubes*

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Summary—**A new type of direct-view halftone storage tube that can selectively erase as well as simultaneously display stored and nonstored information has been developed. Heretofore, incorporation of these features into direct-view halftone storage tubes has proved impractical because of the nature of the secondary-emission effect on which the writing and erasing of stored information depend. In this new tube, this limitation is overcome by the use of a dual-effects target. One effect, secondary emission, charges the storage surface positively, while the other, bombardment-induced conductivity, charges it toward the backing-electrode potential, wihch in this case is negative. Selection of the effect and, consequently, the charging direction, is determined by the incident beam energy. At low energies secondary emission predominates and the target is written on, *i.e.*, charged positively. At high energies, the bombardment-induced conductivity prevails and the target is erased, *i.e.*, the positively charged areas are discharged. The two effects cancel at an appropriate intermediate beam energy, thus permitting presentation of nonstored information without otherwise disturbing the display, by means of that portion of the beam current which passes through the backing electrode and strikes the viewing screen.**

A 5-inch, direct-view halftone storage tube that utilizes such a dual-effects target is described. At writing speeds between 10,000 and 15,000 inches per second, the stored resolution is 40 to 50 lines per inch. At erase speeds between 30,000 and 40,000 inches per second, the stored resolution is 100 to 120 lines per inch. Stored and nonstored information can be displayed simultaneously; the stored information may be retained for one minute or more.

With this selective-erasure, direct-view halftone storage tube, new kinds of displays are feasible. For example, in any application it is now possible to erase selectively immediately preceding the writing beam scan, thereby retaining the stored signals at maximum brightness in any region until just before that region is rescanned by the writing beam. Almost the entire display is constantly maintained at full signal brightness and therefore can be viewed under optimum conditions. In contrast, the brightness of the stored information in both cathode-ray and conventional direct-view halftone storage tubes normally starts to decay immediately after the information is written.

Introduction

CONVENTIONAL direct-view halftone storage tubes, such as the Tonotron,[1] can retain cathode-ray information at brightness levels substantially greater than those achieved with cathode-ray tubes; typically, the light output of long-persistence cathode-ray screens is only a few foot-lamberts as compared with thousands of foot-lamberts for storage tubes. Since the retention time of storage tubes can be varied over wide limits, these tubes are well suited for particular types of radar displays such as PPI presentations. The inflexibility of the retention feature, however, presents a problem in utilizing these tubes for certain other applications. For example, it is not possible to control the retention time of a region independently of the entire display as is necessary for selective erasure (the ability to rapidly erase one or more of the smallest written elements as opposed to erasing the entire display). Also, conventional storage tubes cannot be used for applications that require the simultaneous display of stored and nonstored information. Nonstored information may be defined as the presentation of cathode-ray information on the viewing screen without otherwise disturbing the written or erased areas.

The basic principles and detailed operation of these conventional direct-view halftone storage tubes are described in the literature.[2] Briefly, the limitations on their performance can be understood by considering the requirements that must be met: first, for selective (high-resolution) erasure, and second, for the simultaneous display of stored and nonstored information.

With regard to the selective-erasure requirements, a high erase-beam energy is needed to focus the beam into a fine spot. Also, the erasure process which discharges the storage-surface potential must be capable of discharging all erased regions to the same predetermined potential. This requirement must be met if the tube is to exhibit uniform writing characteristics; otherwise, equal writing-gun signals will not exhibit the same stored brightness everywhere on the viewing screen.

The simultaneous display of stored and nonstored information requires the use of a cathode-ray beam that has no charging effect on the written or erased areas of the display. The portion of the beam current that passes through the backing electrode to strike the viewing screen can then be used to present nonstored information without otherwise affecting the written or erased areas of the display.

For conventional direct-view halftone storage tubes which depend on secondary-emission charging effects for writing and erasing, selective erasure at beam energies beyond the second crossover seems promising on first consideration. In practice, however, several obstacles are encountered when this process is used to erase. Since the second crossover potential may be as high as 25 kv for some materials, deflection and insulation problems arise. The erasure process is slow because

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[1] Tonotron is a trademark of the Hughes Aircraft Co.

[2] M. Knoll and B. Kazan, "Advances in Electronics," Academic Press, Inc., New York, N. Y., vol. VIII, p. 447; 1956.

the secondary-emission ratio is close to unity just beyond the second crossover. Furthermore, since the secondary-emission ratio curve is quite flat in the region of the second crossover, the inherent nonuniformities in the process are substantial, *i.e.*, small changes in the secondary-emission ratio produce large changes in the charging characteristics of the surface. For example, the value of the second crossover may vary as much as several hundred volts or more across the surface of the dielectric and may actually shift under bombardment; hence, grossly nonuniform erasue results.[3] Similar objections concerning uniformity can be cited with regard to the simultaneous presentation of stored and nonstored information.

The nature of the secondary-emission effect, therefore, makes impractical both rapid high-resolution selective erasure and the simultaneous display of stored and nonstored information. The problem encountered here is, essentially, that negative charging at high beam energies cannot be effected uniformly with secondary-emission effects. The following discussion will demonstrate how to overcome this difficulty by utilizing bombardment-induced conductivity.

Bombardment-Induced Conductivity

Bombardment-induced conductivity may be defined as the ability of thin insulating films to conduct when they are subjected to bombardment by high-energy beams of ionizing particles, such as electrons, neutrons, and alpha particles. Although this effect was noted more than thirty years ago, it has been only in the last decade that materials exhibiting substantial bombardment-induced-conductivity effects have been reported.

Fig. 1, a representation of this effect, shows a thin insulating film deposited on a conductive backing electrode. A description of the operation of bombardment-induced conductivity is presented below.

Assume that there is a positive charge on the dielectric surface while the backing electrode is grounded. Then, if a primary current I_p bombards the target, a current I_c will flow through the bombarded region of the insulator. Under appropriate conditions, the value of the induced current may be many times that of the primary current; a figure of merit for the process is given by the conduction ratio C_R, which is defined as the ratio I_c/I_p. If the induced current is in the same direction as the primary current, *i.e.*, the backing electrode is positive with respect to the dielectric surface, then the conduction ratio is positive. The conduction ratio is negative if the induced current opposes the primary beam current, *i.e.*, the backing electrode is negative with respect to the dielectric surface as shown in Fig. 1. Various materials have been investigated and described in the literature.[4-6] Fig. 2 summarizes the results and shows the conduction ratio plotted as a function of the bombarding energy with the field across the dielectric E as the parameter.

The curves shown in Fig. 2 are for positive values of the conduction ratio only; the curves for the negative values are essentially the same.

The following is a simplified explanation of the bombardment-induced-conductivity effect: When a high-energy electron passes through an insulator, it ionizes atoms along its path. Some of the low-energy electrons are thus raised into the conduction band and leave behind positive holes. If these holes and electrons come under the influence of an applied field and if recombination or trapping does not occur, they will acquire velocities in the appropriate directions and will eventually reach the electrodes. Since an energy of only about 5 ev is required for the production of an ion pair, large numbers of pairs may be generated by high-energy electrons. The maximum gain, according to one theory,

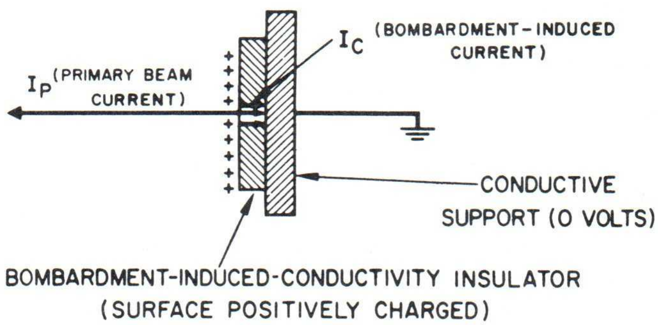

Fig. 1—Pictorial representation of bombardment-induced conductivity in a thin insulating film.

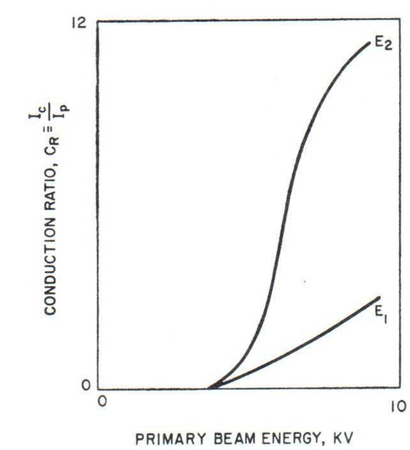

Fig. 2—Typical curves of bombardment-induced conductivity.

[3] *Ibid.*, p. 482.

[4] K. G. McKay, "Electron bombardment conductivity in diamonds," *Phys. Rev.*, vol. 74, pp. 1606–1621; December, 1948.

[5] L. Pensak, "Conductivity induced by electron bombardment in thin insulating films," *Phys. Rev.*, vol. 75, pp. 472–478; February, 1949.

[6] F. Ansbacher and W. Ehrenberg, "Electron-bombardment conductivity of dielectric films," *Proc. Phys. Soc.* (*London*) *A*, vol. 64, pp. 362–379; April, 1951.

will be equal to the number of pairs produced per primary electron. In practice, maximum gains far less and far greater than this value have been measured.

Bombardment-induced conductivity is important in storage-tube operation because it may be used to shift the surface potential of the dielectric. If the charges on the dielectric surface are not replaced, the surface potential will be conducted toward the backing-electrode potential by the currents induced in the dielectric. Since the conduction ratio diminishes with decreasing field, there is no danger of discharging past the backing-electrode potential. Small variations in the conduction ratio produce corresponding changes in the level to which the surface is discharged; however, these changes become less significant when they are compared with the total voltage change across the dielectric. Thus, the nonuniformities inherent in bombardment-induced conductivity discharging are substantially less than those encountered in discharging by the secondary-emission effect. It would therefore be advantageous to utilize a target which employs secondary emission to charge the storage surface positively and uses bombardment-induced conductivity to erase the charge. As will be shown in the following section, such a dual-effects target has many advantages over targets that discharge by the secondary-emission effect.

Dual-Effects Target

Fig. 3 is a schematic of the charging currents that occur when a dielectric film having secondary-emission and bombardment-induced conductivity properties is struck by a high-energy electron beam. Assume that the dielectric surface is charged positively with respect to the conductor. If the dielectric is treated as a series of elemental capacitors, the charging direction is determined by and the charging speed is proportional to the summation of all currents arriving at or leaving the surface of the element. If ΔV represents the change in voltage on the elemental surface of the dielectric during the time Δt, then the charging speed S is

$$S = \frac{\Delta V}{\Delta t} \sim \sum_i I_i = -I_p + I_s - I_c, \tag{1}$$

where I_p is the primary current, I_s is the secondary current, and I_c is the bombardment-induced current. For secondary emission, where δ_e is the secondary-emission ratio,

$$|I_s| = \delta_e |I_p|, \tag{2}$$

while for bombardment-induced conductivity,

$$|I_c| = C_R |I_p|. \tag{3}$$

Substituting (2) and (3) in (1) yields

$$\frac{\Delta V}{\Delta t} \sim I_p(\delta_e - 1 - C_R). \tag{4}$$

If the quantity inside the parentheses is positive, then positive charging, or writing, occurs; if it is negative, negative charging, or erasure, occurs; if it is zero, the storage-surface potential remains unchanged during bombardment. Both δ_e and C_R are functions of the primary beam energy V_p, as discussed previously. In Fig. 4, these functions are plotted with the primary beam energy as the common abscissa. The curve $(\delta_e - 1)$ in the positive region above the x axis represents the positive-charging contribution of secondary emission, while the curves for $(-C_R)$ located below the x axis indicate the negative-charging effects of bombardment-induced conductivity. The conduction ratio is plotted for two values of the field. Let us assume that the higher value of the field corresponds to the full-brightness condition of the storage dielectric, while the lower value corresponds to the cutoff potential.

Examination of Fig. 4 indicates that for the lower range of beam energies, the secondary-emission effect is at a maximum, while the bombardment-induced conductivity is negligible. These conditions are specified by

$$C_R \cong 0, \qquad \delta_e > 1. \tag{5}$$

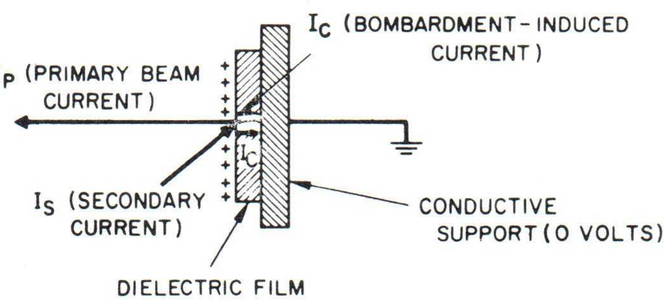

Fig. 3—Schematic of the charging currents for a dual-effects target when subjected to bombardment.

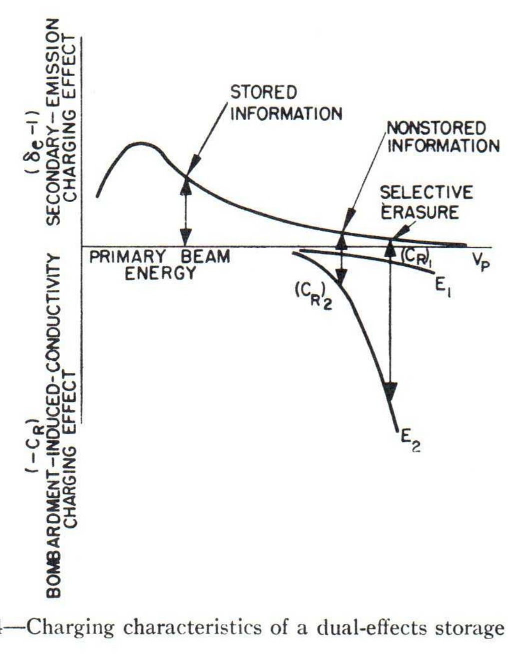

Fig. 4—Charging characteristics of a dual-effects storage target.

In this case,

$$S = \frac{\Delta V}{\Delta t} \sim I_p(\delta_e - 1). \quad (6)$$

Thus, in this energy region, the storage surface will be written on by secondary emission.

At the middle range of beam energies, the secondary-emission ratio diminishes while the conduction ratio increases and is approximately the same for both values of the field. At some value of the beam energy in this region, the two charging effects are of equal amplitude but of opposite sign. In this case,

$$\delta_e - 1 = C_R = (C_R)_1 \cong (C_R)_2; \quad (7)$$

consequently,

$$S = \frac{\Delta V}{\Delta t} \sim I_p(\delta_e - 1 - C_R) = 0. \quad (8)$$

When struck with an electron beam having this energy, the storage-surface potential will be undisturbed in both the written and the erased areas. The portion of the beam current that passes through the backing electrode to strike the viewing screen then serves to display nonstored information without otherwise disturbing the display.

At the higher range of beam energies, the secondary-emission ratio slowly approaches the second crossover, while the conduction ratio increases rapidly, particularly for the higher value of the field. In this case,

$$(C_R)_1 \gg \delta_e - 1. \quad (9)$$

Under these conditions, the bombardment-induced conductivity effect overrides the secondary-emission effect and erasure occurs. As the erasure process continues under sustained electron bombardment, the field across the dielectric is progressively reduced until, at some lower value of the field (closely approximating the cutoff potential of the storage surface), the conduction ratio is reduced to the point where

$$(C_R)_2 = \delta_e - 1. \quad (10)$$

Here the two charging effects cancel and, under bombardment, the storage surface is held at this reduced potential. In the higher-energy region adjacent to the second crossover potential, it is possible to erase to a point of equilibrium. Thus, with the dual-effects target, high-energy bombardment-induced-conductivity discharging is substituted for high-energy secondary-emission-effect discharging. The former technique involves discharging toward a fixed potential, and, consequently, the inherent nonuniformities are of the order of a few volts or less. This is in sharp contrast to high-energy secondary-emission effect discharging, where the nonuniformities are of the order of hundreds of volts or more.

The Bombardment-Induced Conductivity Selective-Erasure Tube

Fig. 5 is a schematic of a developmental five-inch, direct-view halftone storage tube that is capable of selective erasure as well as simultaneous presentation of stored and nonstored information. The components of this tube are essentially those of a conventional tube, with two important exceptions:

1) A high-energy erase gun that can erase selectively at a 6-kv negative cathode potential is added; when switched to -5 kv, it can be used for the presentation of nonstored information. If time sharing of a gun with respect to the various information is possible, then this gun may be omitted; and by appropriately switching the cathode potential, only one gun need be employed for writing, selective erasing, and displaying nonstored information.

2) A special storage target which exhibits the dual charging effects discussed in the previous section is used. In order to utilize the bombardment-induced conductivity discharging for erasure, the field across the dielectric must be of sufficient magnitude to permit the bombardment-induced conductivity effect to override the secondary emission until the storage surface is discharged past its cutoff potential. This means that the backing electrode must be operated at a more negative potential than the cutoff potential of the storage surface. Conventional tubes, in comparison, operate with the backing electrode sufficiently positive to permit the maximum amount of flood-gun current to reach the viewing screen at full brightness. These tubes typically employ mesh of 40 per cent transmission and 250 pitch. When such a mesh is operated at negative potentials of several volts, the viewing-screen current is completely cut off, as shown by the curve in Fig. 6. Essentially, the difficulty in obtaining fuller utilization of the flood-gun current, and therefore greater luminance at a particular value of the viewing-screen voltage, is that the backing electrode too effectively masks the flood electrons from the viewing-screen field. A higher transmission mesh of the same pitch does reduce the masking, but with the penalty of degraded resolution due to overlapping of the storage elements at the viewing screen. Although greater transmission of the current to the viewing screen can be theoretically achieved at higher viewing-screen fields, in practice, 25 to 30 kv/cm is found to be the limiting field because of arcing between the electrodes. These limitations on transmission and viewing-screen field do not make operation at negative backing-electrode potentials impractical. Examination of Fig. 6 indicates that operation at up to -7 volts on the backing electrode is possible at 300- to 400-fl luminance.

The storage operation is the same as that of a conventional tube. The erasure process can be accomplished by either or both of two methods. The entire display

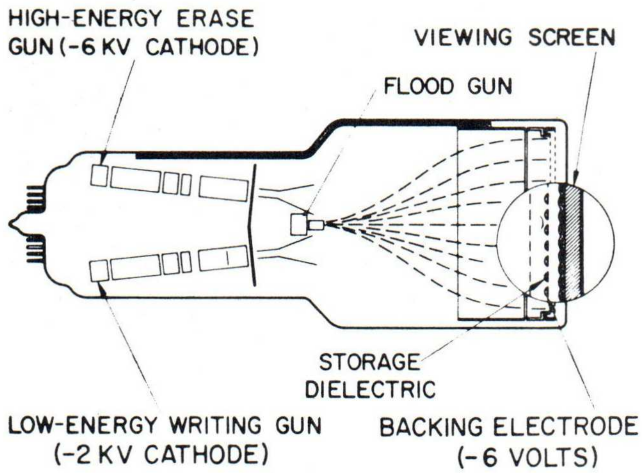

Fig. 5—Schematic of a bombardment-induced conductivity selective-erasure direct-view halftone storage tube.

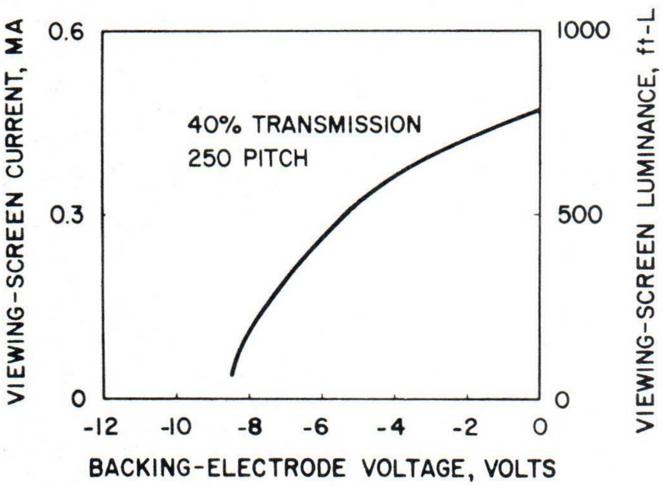

Fig. 6—Viewing-screen luminance as a function of backing-electrode potential. Storage-surface potential = 0; viewing-screen field = 22 kv/cm; collecting field = 380 volts/cm.

may be slowly erased with the flood gun by pulsing the backing electrode, as in conventional tubes. Partial or complete erasure of one or more of the smallest written elements with the 6-kv erase beam can be accomplished simultaneously with or independently of erasure by the flood gun. Nonstored information may be displayed at any time with the erase gun by switching its cathode to −5 kv.

In Fig. 7 performance data are given for a developmental 5-inch tube using a dual-effects target. The upper graph is a plot of linear charging speed and polarity as a function of storage-surface potential. Linear charging speed may be defined as the scanning rate at which the storage-surface potential is charged or discharged by 1 volt. The writing speed represents the average positive linear charging speed divided by the number of volts that the storage surface must be charged to carry it from its erased condition to full brightness (which is 4 volts in this case). The erase

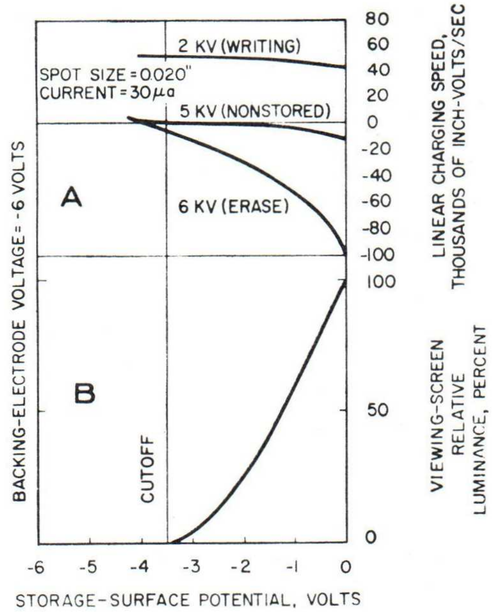

Fig. 7—The portion of the figure labeled "A" shows the charging speed vs storage-surface potential; the "B" portion is viewing-screen luminance vs storage potential.

speed represents the average negative linear-charging speed divided by the number of volts that the storage surface must be discharged to carry it from full brightness to the erased condition (this is also 4 volts). The lower graph shows the relative viewing-screen luminance as a function of storage-surface potential. From both these graphs, the effect of each value of beam energy on the display may be determined.

The 2-kv beam charges the storage surface positively at about 45,000 inch-volts per second almost independently of the storage-surface potential; such a characteristic is consistent with a predominant secondary-emission effect. The writing speed is therefore about 11,000 inches per second at a 30-μa beam current with higher speeds possible at higher values of beam current. The written resolution is 40 to 50 lines per inch. The stored information can be retained at luminance levels of from 300 to 500 fl for as long as one minute without serious deterioration.

The 6-kv beam discharges the storage surface most rapidly at the full-brightness condition; the discharging speed declines exponentially as the storage surface is carried toward equilibrium potential, which is about $\frac{1}{2}$ volt past cutoff. This action of the erase beam is consistent with the theory that the bombardment-induced conductivity effect initially overrides the secondary emission, but as the erasure process continues this conductivity declines exponentially until at equilibrium potential the two effects balance.

The average value of the erase speed is approximately 40,000 inch-volts per second (*i.e.*, 10,000 inches per second to charge 4 volts), as shown in Fig. 7. However, the high energy of the erase beam permits finer focusing than is possible with the 2-kv writing beam. Thus, with this high-energy beam, erase speeds of 30,000 to 40,000 inches per second can be attained with erase resolution of 100 to 120 lines per inch. Operation at still higher erase-beam energies makes it possible to approach the limit of resolution of the combined storage and collector meshes (about 150 lines per inch) without loss of erase speed.

In practice, the energy level for which both charging effects are equal over the entire range of storage-surface brightness is selected by permitting the discharging to slightly override the positive charging. The 5-kv beam energy was selected in this way. Note that the extremely slow erasure characteristic of this value of beam energy makes it suitable for the presentation of nonstored information.

Fig. 8 is a photograph of the developmental 5-inch, bombardment-induced conductivity selective-erasure tube. Fig. 9 shows a stored image on the face of the tube. The stored areas were written by means of a 2-kv beam and then selectively erased by means of a 6-kv beam. No attempt was made to demonstrate nonstored information, which is best shown in a dynamic display.

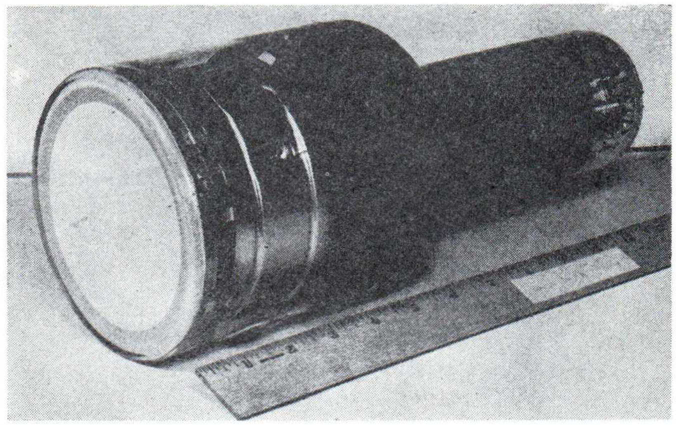

Fig. 8—Five-inch, bombardment-induced conductivity selective-erasure direct-view halftone storage tube.

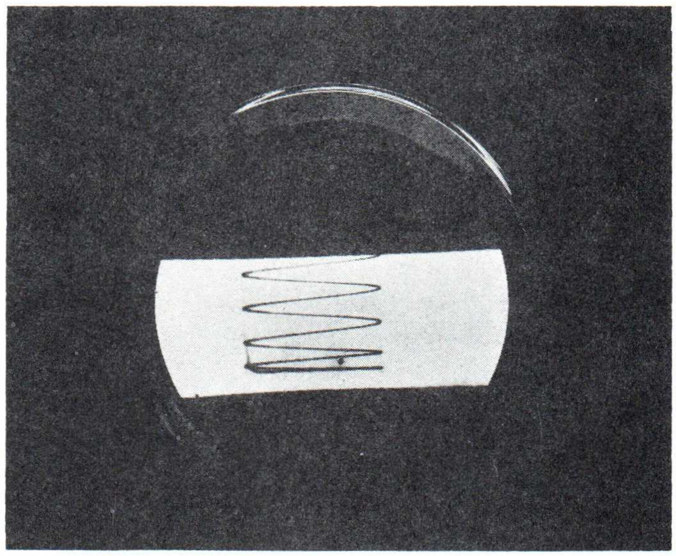

Fig. 9—Display obtained on selective-erasure tube.

Applications

The new bombardment-induced conductivity selective-erasure tube possesses capabilities that are unique in the field of storage-tube operation. Information presentations that have never before been possible can now be achieved through use of this tube. Some of these applications are described below.

Selective Erasure

This capability suggests application of the tube to displays in which the erase beam immediately precedes the writing-beam scan. Stored information is then retained at full brightness until just before it is rescanned by the writing beam. Since almost the entire display is constantly maintained at full signal brightness, it will be viewed under optimum conditions. For presentations in which all the information moves from sweep to sweep, selective erasure prevents smearing caused by the display of successively stored images. Furthermore, by appropriately programming the erase beam, it is possible to erase only undesired information.

Nonstored Information

The nonstorage feature makes possible the addition of cathode-ray information to the display without otherwise disturbing it. This nonstored information may take the form of reference markers, horizon lines, or even maps superimposed over the stored signals. However, simultaneous use of the storage, selective-erasure, and nonstorage features requires the addition of a fourth electron gun. If time sharing of one gun with respect to two or more modes of operation is possible, then the number of electron guns can be reduced accordingly.

Dark-Trace Tube

High-contrast displays can be obtained by using the erase gun as a "writing" gun; however, the viewing screen must be initially at the full-brightness condition. This condition can be brought about by scanning the storage surface with the 2-kv writing beam. The erase-gun grid is then modulated to vary the current as the erase beam is scanned over the storage target to produce a black picture on a white background, or a dark-trace image. Halftones can be obtained by modulating the grid signals to control the degree of erasure. Not only is a high-contrast display produced by this technique but, in addition, the higher energy of the erase beam permits higher resolution than that obtained with the 2-kv writing beam. If the dark-trace image is objectionable, the signals to the grid of the erase gun can be inverted to produce a normal image with considerably higher resolution and at higher charging speeds than can be achieved by means of the 2-kv writing beam.

Conclusion

Conventional direct-view halftone storage tubes depend on the secondary-emission effect for writing and erasing stored information. Such dependence imposes limitations on tube performance, particularly with regard to selective erasure and the simultaneous display of stored and nonstored information.

With the development of the selective-erasure tube, these limitations were overcome by using a dual-effects target, *i.e.*, a target that is written on by secondary emission and erased by bombardment-induced conductivity. Substitution of bombardment-induced conductivity discharging for secondary-emission effect discharging overcomes the nonuniformity difficulties inherent in the latter effect and makes practical selective erasure as well as the simultaneous display of stored and nonstored information. Data are given for a developmental 5-inch tube that writes at 2 kv, erases at 6 kv, and can present nonstored information at 5-kv beam energy. The construction and operating principles of this tube can be applied in the fabrication of larger tubes.

Acknowledgment

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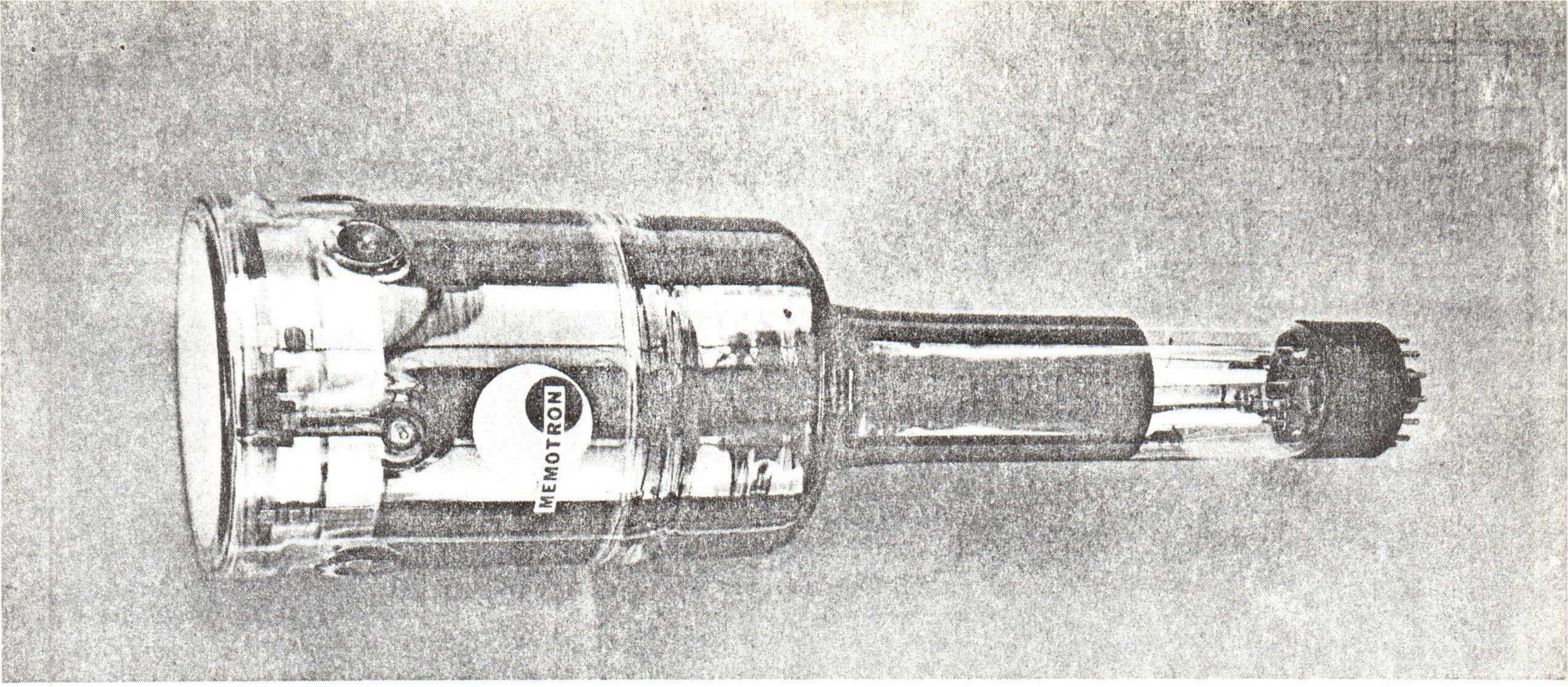


DESCRIPTION

The Hughes Memotron* is a direct display cathode-ray storage tube currently in production in five-inch form at Hughes Products, a division of the Hughes Aircraft Company. Electrical signals applied in a conventional manner to the electrostatic deflection plates provide a bright trace on the face of the tube which may be retained indefinitely--that is, until intentionally erased.

The storage feature is made possible through the use of a dielectric storage mesh and the use of two electron guns—a writing gun and a flood gun. The flood gun sprays the dielectric storage surface with a uniform barrage of low-velocity electrons. The dielectric surface is assumed to be initially at zero potential (flood gun cathode potential). The high-velocity electron beam from the writing gun charges regions of the storage surface positive as a result of secondary electron emission, thus creating areas which are partially transparent to the flood electrons. Those which pass through the positively charged areas are accelerated to high velocity and strike the viewing screen phosphor, producing a continuously visible image of the pattern electrically stored on the dielectric surface.

In addition to providing the electrons necessary for displaying the written information, the flood beam also maintains both the positive and negative potentials of the charged pattern on the storage surface. This pattern may be erased by momentarily lowering the voltage on the secondary collector mesh inserted between the writing gun and the dielectric surface. A given area on the storage mesh may be at one of two stable conditions, either at collector or at flood gun potential. All written information will be displayed at full brilliance with no presentation of half-tone information.

The physical appearance, dimensions, and operating characteristics of the five-inch Memotron tube are given in the attached descriptive data.

PERFORMANCE CHARACTERISTICS:

Writing Speed (Collector at Operating Level)

Beam current of 20 μa . . . . . . at least 50,000"/sec
100,000"/sec selected tubes
writing gun spot size, 0.008 to 0.011

Beam current of 50 μa . . . . . . at least 85,000"/sec
250,000"/sec or better selected tubes
writing gun spot size, 0.011 to 0.012

Beam current is defined as that portion of the current emitted by the writing gun cathode which reaches the storage mesh. In general, writing speed increases with beam current and with collector mesh voltage.

Resolution:

Although writing gun spot sizes vary from 0.008 inch to 0.012 inch with beam currents in the range of 20 to 50 μa, resolution of stored information is largely determined by the size of the openings in the collector mesh, which has 112 openings per inch. These openings are slightly larger than the average spot size.

At 0 volts on the Storage Mesh and 3000 volts on the Viewing Screen . . . . 50-60 lines/inch (obtained by merging raster method)

Best resolution of the written information is obtained with zero or small positive storage mesh voltage. Resolution increases with viewing screen voltage; however, this effect is slight (above 3000 volts).

Brightness of Written Information . . 20 foot-lamberts minimum
50 foot-lamberts average

At 0 volts on the Storage Mesh and 3000 volts on the Viewing Screen

Contrast Ratio . . . . 3:1 minimum

At 0 volts on the Storage Mesh and 3000 volts on the Viewing Screen

The ratio of brightness of written information to that of the background can be increased by lowering the storage mesh voltage below zero volts; however, this improvement is made with some sacrifice of resolution and brightness of the written information. Contrast can be enhanced without sacrifice of brightness and resolution by applying a positive pulse to both the storage mesh and collector mesh having a 10- to 30-volt amplitude, 1000-cycle repetition rate, and 1-percent duty cycle.

<u>Deflection Factor</u>	D_1 and D_2 ,	85 to 115 volts/inch
At 3. 2 kv Cathode-to-Second-Anode Voltage	D_3 and D_4 ,	85 to 115 volts/inch
Deflection plates draw approximately the following currents for full-scale deflection	D_1 and D_2 ,	20 μa
	D_3 and D_4 ,	85 μa

Deflection plate current consists of flood electrons.

<u>Erase Time</u> . . . . 50-200 milliseconds

Erasure is accomplished by momentarily lowering the collector mesh voltage below the retention threshold. The most effective portion of this erasure pulse is the positive slope returning to operating level. The ideal pulse, therefore, is triangular with a steep descent and a slow ascent occupying most of the total pulse width.

INTEGRATING PROPERTIES

It is possible to take advantage of the integrating properties inherent in the Memotron tube. Under normal operating conditions, the tube behaves, to a first approximation, like an RC integrator with a time constant of about 0. 02 second. Since the regenerative action of the flood electron beam bucks integration, effective integration, with the flood gun on, can be achieved only at repetition rates higher than 50 cps. Integration over any period of time is possible if the flood gun can be biased off during the integration period.

STATIC VOLTAGE SUPPLIES

Static voltages must be supplied as listed under the heading, TYPICAL OPERATING VOLTAGES AND CURRENTS. This may be done by use of conventional power supplies. Provision must be made for easy adjustment of: (a) voltage, to adjust the size of the flood beam ; (b) the writing-gun first-anode voltage, for focus; and (c) the collector-mesh voltage.

PROTECTIVE CIRCUITRY

Power supplies should be of the limited-energy type with inherent regulation to limit the continuous short-circuit currents to the value tabulated below. If the effective output capacitance is capable of storing more than 10 microcoulombs, a resistance not less than the value given below should be provided between the electrode and the output of the power supply. The 100, 000 ohms resistance in series with the storage mesh should be provided regardless of output capacitance.

Electrode	Maximum Short Circuit Current	Minimum Resistance
Storage Mesh	3 ma	100, 000 ohms
Collector Mesh	6 ma	200 ohms
Viewing Screen	1 ma	100, 000 ohms
Writing Gun Cathode	3 ma	10, 000 ohms

PROTECTION OF STORAGE SURFACE

Damage to the storage surface may result if excessive voltage is applied between the collector mesh and storage mesh or if the recommended protective resistors are not provided. In general, the collector mesh voltage should not be raised above the level required for satisfactory storage. Equipment should be designed so as to prevent initial surges which might cause the maximum ratings to be exceeded. Precaution should be taken to avoid wrong connections to the front-end electrodes. The writing beam must be defocused or biased beyond cutoff, when not being deflected, to avoid permanent damage to the storage surface. A stationary or slow-moving, well-focused spot is permissible only at very low intensity.

ASTIGMATISM CONTROL

Astigmatism control can be accomplished in a conventional manner by varying the average deflection plate voltage with respect to the second anode.

MAXIMUM RATINGS*

Viewing Screen	4000 volts
Ion Repeller Mesh	350 volts
Second Anode	300 volts
Deflection Plates, average potential	300 volts
Collector Mesh	250 volts
Third Anode	250 volts
Storage Mesh	-50 volts
First Anode	-3300 volts
Cathode, Writing Gun	-3300 volts

GENERAL

Heaters (two) for Unipotential Cathodes

Voltage	6.3 ±10% a-c or d-c volts
Current (each heater)	0.6 amp

Phosphor**

Fluorescence and Phosphoresence	Green P1
Persistence of Phosphorescence	Medium
Focusing Method	Electrostatic
Deflection Method	Electrostatic
Over-all Length	$18\frac{1}{2}'' \pm\frac{1}{2}''$
Greatest Diameter of Bulb	5-5/8" maximum
Useful Screen Diameter	4" minimum
Mounting Position	Any

* All maximum ratings are given with respect to the flood gun cathode potential and represent the absolute maximum departure from this potential.

** Other phosphors available on special order.

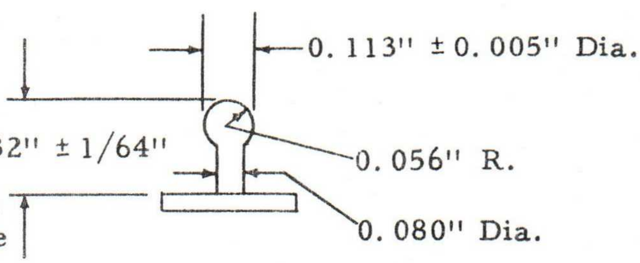
Base-Small-shell Diheptal 14-Pin (JETEC No. B14-38)

Pin 1 Heater (Writing Gun)
Pin 2 First Anode (Writing Gun)
Pin 3 Control Grid (Writing Gun)
Pin 4 Deflecting Flectrode D_2
Pin 5 Deflecting Electrode D_1
Pin 6 Deflecting Electrode D_3
Pin 7 Deflecting Electrode D_4
Pin 8 Second Anode (Both Guns)
Pin 9 Cathode (Writing Gun)
Pin 10 Heater (Flood Gun)
Pin 11 Heater, Cathode (Flood Gun)
Pin 12 Control Grid (Flood Gun)
Pin 13 Control Grid (Writing Gun)*
Pin 14 Heater (Writing Gun)

D_1 and D_2 are nearer the base;
D_3 and D_4 are nearer the screen.

Terminals on Bulb (Small Ball Cap; see sketch below)

Cap No. 1 Viewing Screen
Cap No. 3 Third Anode
Cap No. 4 Ion Repeller Mesh
Cap No. 5 Collector Mesh
Cap No. 6 Storage Mesh



Cap. No. 1 is not recessed;
Caps No. 3, 4, 5, and 6 are partially recessed.

TYPICAL OPERATING VOLTAGES** AND CURRENTS

Viewing Screen Voltage	3000 volts
Ion Repeller Mesh Voltage	250 volts
Second Anode Voltage	200 volts

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* Use Pin 3 for Control Grid socket connection

** All voltages are given with respect to flood gun cathode potential, except the control grid (writing gun) voltage and the first anode (writing gun) voltage, which are given with respect to the writing gun cathode potential.

Collector Mesh Voltage, Operating Level*	85-200 volts
Third Anode Voltage	150 volts
Control Grid (Flood Gun) Voltage, Operating Bias**	20 to -200 volts
Storage Mesh Voltage	0 volts
First Anode (Writing Gun) Voltage for focus*	450-1050 volts
Cathode (Writing Gun) Voltage	-3000 volts
Control Grid (Writing Gun) Voltage† for visual extinction of undeflected focused spot	-40 to -80 volts
Viewing Screen Current	0-300 μa
Ion Repeller Mesh Current	0-4 ma
Second Anode Current	0-3 ma
Collector Mesh Current	-0.5 to +4 ma
Third Anode Current	-0.5 to +2 ma
First Anode (Writing Gun) Current	-15 to +15 μa
Cathode (Writing Gun) Current	0-1000 μa
Storage Mesh Current	-15 to +15 μa
Cathode (Flood Gun) Current	0-3 ma

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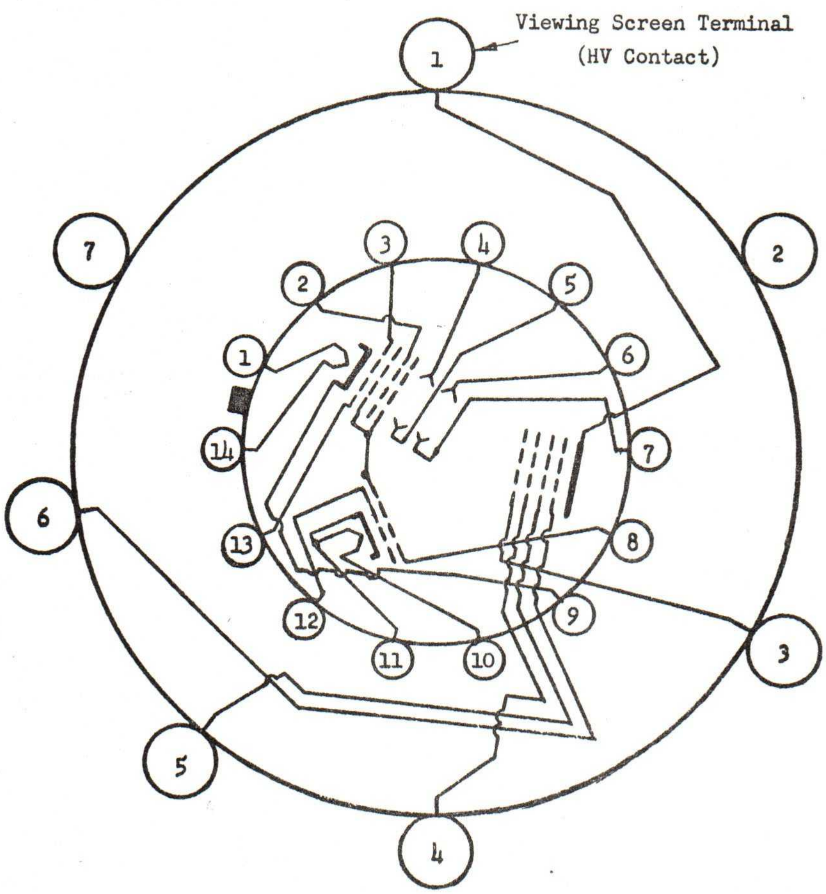
* Suggested Experimental Method for Determining Collector Operating Level: The collector mesh voltage should be raised to some value less than the voltage for which the screen goes positive. A pattern of lines should then be traced on the screen and allowed to remain there. The collector mesh voltage should be reduced by small increments until the storage pattern on the screen begins to fade. The lowest voltage at which traces hold without fading is called the retention threshold. The tube is normally operated with the collector voltage 15 volts above the retention threshold. This latter potential is called the operating level of the tube and will vary from tube to tube.

** Adjust for complete coverage of the viewing screen. Bias shall never be less than 50 volts, in order to avoid damaging the cathode.

† Ibid., p. 4

Connection Diagram



BOTTOM VIEW

With D_1 positive with respect to D_2, the spot is deflected toward Pin 7. With D_3 positive with respect to D_4, the spot is deflected toward Pin 4.

Outline Drawing