Dec. 20, 1955 L. PENSAK 2,728,020

STORAGE TUBE

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FIG. 1

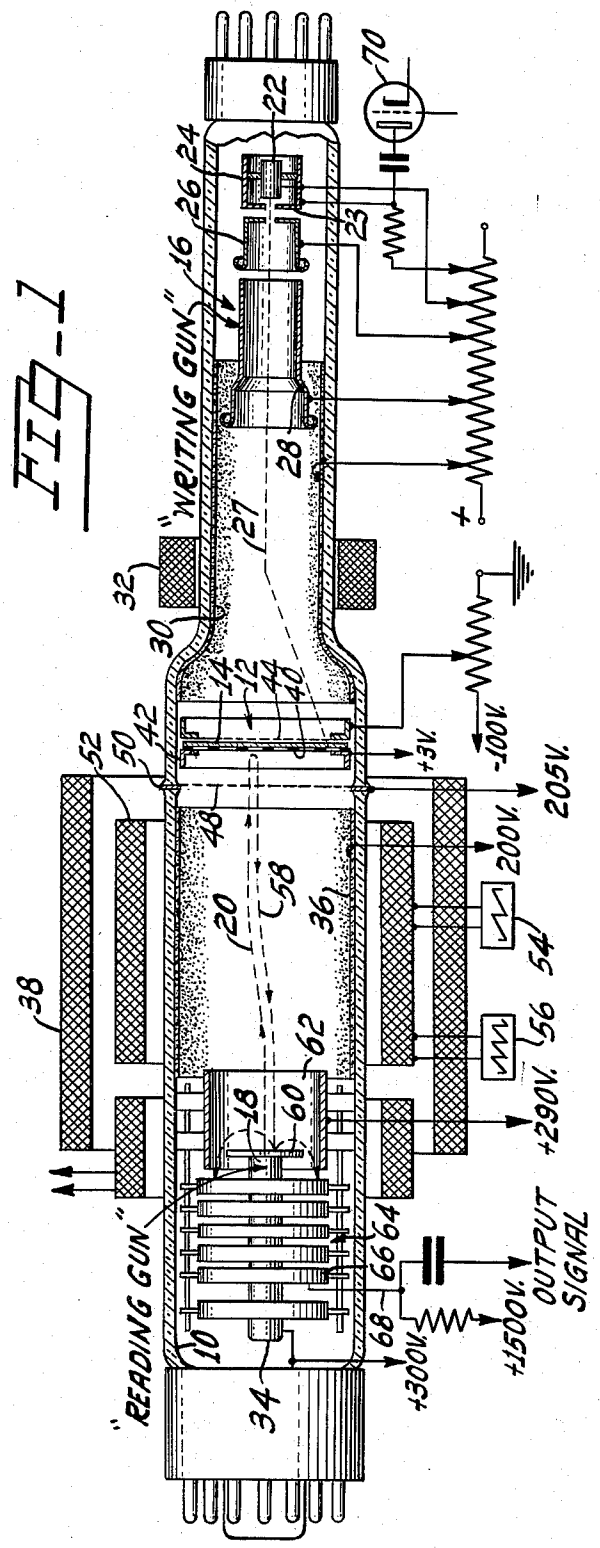
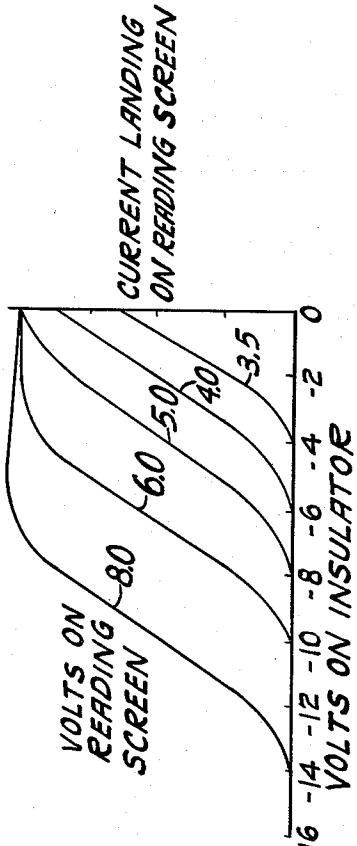


FIG. 4



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Dec. 20, 1955 L. PENSAK 2,728,020

STORAGE TUBE

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FIG_2

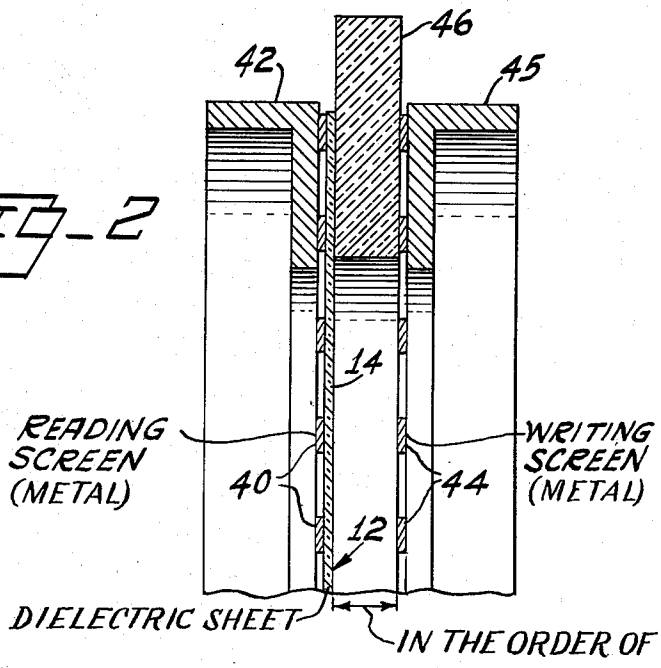
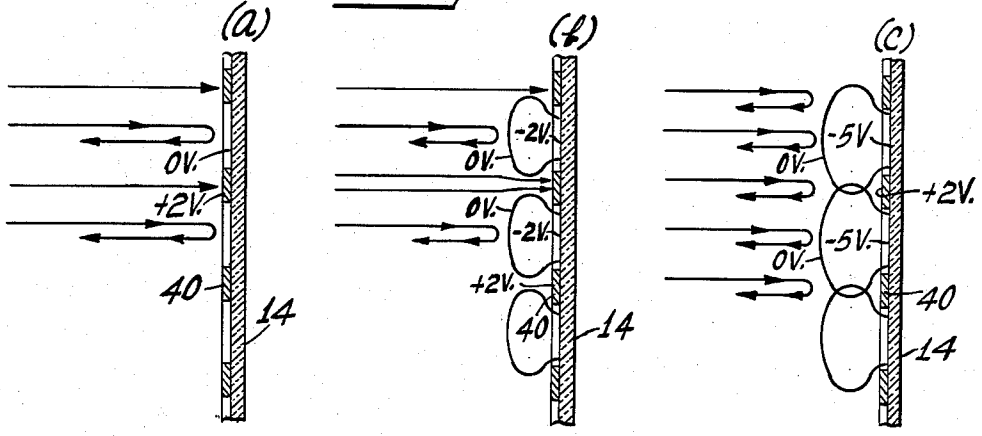


FIG_3



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United States Patent Office 2,728,020 Patented Dec. 20, 1955

2,728,020

STORAGE TUBE

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Application December 1, 1951, Serial No. 259,344

7 Claims. (Cl. 315—8.6)

This invention is directed to an electron discharge device and, more particularly, to a storage tube for the purpose of storing signals of variable intensity, which can be used to produce output signals corresponding to those stored.

A storage tube is one which can be used for applications in which it is desired to store signals of variable intensity in an arbitrary scanning pattern and produce output signals proportional to those stored. One type of storage tube is that disclosed in my copending application Serial Number 29,746, filed May 28, 1948, now abandoned and assigned to the same assignee as the present invention. This tube has a dielectric target electrode formed of an insulating sheet of material and upon which is established a pattern of charges. The charge pattern is produced on one surface by scanning the dielectric target with a beam of electrons, which is modulated by incoming signals. Because of the insulating nature of the target sheet, the charge pattern remains on the target for a period of time. During this time the target surface is scanned by a second beam of electrons to produce a variable secondary electron emission from the charged target surface, which is collected to produce an output signal of the tube. The output signals may be produced by a different scanning pattern than that by which the charged pattern was established on the target.

In a storage tube of the type described above, it is desirable that it be possible to obtain many copies of the output signal. Also it is desirable that such a tube resolve "half-tone" signals lying between the maximum and minimum signals applied to the tube. An example of such an application would be in the reception of radar signals from an airplane behind a cloud. The signal from the airplane will be stronger than that from the cloud itself. In this application, it is desirable that the signal from the airplane be not lost because of the simultaneous signal from the cloud. It is desirable, therefore, to be able to store both signals and to be able to distinguish between the signals from the cloud and from the airplane.

It is, therefore, an object of this invention to provide an improved charge storage tube in which it is possible to obtain many copies of the output signal from a single stored pattern.

It is another object of my invention to provide an improved charge storage tube, in which it is possible to resolve "half-tone" signals for various applications.

It is another object of my invention to provide an improved storage tube capable of receiving, storing, and regenerating electric signals without loss of "half-tone" values.

It is a further object of my invention to provide an improved charge storage tube, which can store signals of varying intensity and reproduce them as television signals without loss of intensity values and for a large number of copies.

My invention is specifically directed to a charge storage tube having a thin dielectric target sheet. An electron gun means is arranged to produce and scan one surface of the dielectric target sheet with a beam of low velocity electrons. A second electron gun, positioned on the opposite side of the target from the first gun, is used to scan the opposite surface of the dielectric target sheet with a beam of high velocity electrons. On the first surface of the dielectric sheet, there is formed a fine mesh grid used as a collector electrode for the low velocity beam electrons. Closely spaced from the opposite surface of the dielectric target sheet, is a suppressor screen or grid. Incoming signals are used to modulate the high velocity electron beam, which strikes the dielectric target to produce a secondary electron emission therefrom. The suppressor screen is operated at a low negative potential to drive most of these secondary electrons back to the target surface, whereby a negative charge pattern is established on the target surface in accordance with the modulated beam scanned over the target. The negative charges of the pattern establish a corresponding negative field on the other surface of the dielectric sheet to control the landing of the low velocity beam upon the positive collector grid on the target surface. The number of electrons which land on the collector grid from the low velocity beam is inversely proportional to the negative potential field at each point. The electrons of the low velocity beam not landing on the collector electrode are returned to an anode collector electrode to form the output signal of the tube.

Figure 1 is a sectional view of a charge storage tube in accordance with my invention.

Figure 2 is a greatly enlarged partial sectional view of the target used in the tube of Figure 1.

Figure 3 is a schematic showing of the conditions at the target during the operation of the tube of Figure 1.

Figure 4 is a graphical showing of the conditions at the target during the operation of the tube of Figure 1.

The tube shown in Figure 1 has an evacuated envelope 10 of substantially tubular configuration. Mounted in the center portion of the tube is a target electrode 12, consisting principally of a dielectric sheet 14 mounted transversely to the axis of the tube envelope. On one side of the target electrode 12, there is positioned an electron gun structure 16, which is used to establish on the adjacent surface of dielectric sheet 14, a charge pattern. Electron gun 16 may also be referred to as the "writing gun." On the opposite side of target 12 and coaxially aligned with the writing gun 16, there is a second electron gun 18 for providing a low velocity electron beam 20, which is scanned over the adjacent surface of target 12. The low velocity beam 20 is modulated by the charge pattern established by the writing gun on the opposite target surface to provide the output signal of the tube. Electron gun 18 is also considered the "reading gun" of the tube.

The writing gun 16 is of a conventional type and consists of principally a tubular cathode 22 having a closed end portion facing target 12, which is coated in a well-known manner by a mixture of strontium and barium oxides to provide a source of electrons. Enclosing cathode 22 is a tubular control grid 24 having an apertured wall portion 23 overlying the activated cathode surface. Coaxially aligned with the cathode 22 and control grid 24 are mounted in a spaced relationship, a screen grid electrode 26 and a tubular accelerating electrode 28, each having openings therethrough for the passage of electrons from cathode 22 to screen 12.

The gun 16 forms the electrons from cathode 22 into an electron beam 27 which is accelerated toward the target 12. A second accelerating electrode 30 is formed as a conductive wall coating on the inner surface of the tube envelope and is operated at a higher positive potential

than the first accelerating electrode **28** to provide therebetween a focussing field for bringing the electrons of beam **27** to a small well-defined spot on the surface of target **12**. Electron beam **27** is scanned over the surface of target **12** in any well-known manner, such as by magnetic scanning fields provided by two pairs of coils mounted around the tubular envelope **10** as a neck yoke **32**. If the writing gun **16** is used with radar signals, the deflection yoke **32** may be of the type to produce a radar P. P. I. scan pattern. Such a scansion is well known and is also discolsed in U. S. Patent 2,412,670. Figure 1 indicates voltage values which may be applied to the several electrodes of the writing gun **16**. These are by way of example only and are not limiting.

The reading gun **18** is of the type used in the Image Orthicon pickup tube and is disclosed in greater detail in U. S. Patent 2,540,621 to Ralph E. Johnson. The gun consists primarily of a cathode, a control grid (both not shown), a first accelerating electrode **34**, and a second accelerating electrode consisting of a conductive wall coating **36**. When appropriate voltages are applied to the several electrodes of the reading gun, the electron emission from the cathode is formed into an electron beam **20**. A magnetic focussing field is provided by a coil **38** between the accelerating electrode **34** and target **12** to focus the electrons of beam **20** to a well defined point on the surface of the target **12**.

The dielectric target sheet **14** may be of a thin sheet of mica or a film of glass having a resistivity in the range between 10^{14} ohm centimeters and 10^{18} ohm centimeters. On the surface of the dielectric sheet **14** facing the reading gun **18**, there is formed a fine conductive screen or grid **40** of between 500 and 700 mesh per inch.

If the dielectric sheet **14** is mica, screen **40** may be formed by sputtering on the surface of the mica a metal film. The surface is then masked with a fine mesh screen held in contact with the surface. The metal film is used as one electrode in a gaseous discharge and is desputtered to expose the mica surface not covered by the masking screen. Upon removing of the masking screen there remains on the mica surface, portions of the original metal coating in the form of a screen network. This method is described in detail in the copending application of Harold B. Law, Serial Number 218,797, filed April 2, 1951, now Patent No. 2,702,274, and assigned to the same assignee as the present invention.

However, if the dielectric sheet **14** is a film of glass, the target has been formed by stretching a fine mesh nickel screen across a mounting ring **42**. A bubble of glass is blown until the glass is of the correct thickness in the order of 0.1 mil as determined by counting the absorption lines in the spectrum of reflected white light. A portion of the bubble is then laid over the mounting ring **42** which is then subjected to a high temperature and in a nonoxidizing atmosphere until the glass of the bubble softens and lays down over the mesh screen **40**. At the elevated temperature, the glass will seal to the metal screen **40** and also the screen **40** will become fused to the mounting ring **42**. The assembly is then cooled slowly to the freezing point of the glass. Since, the heat capacity of the glass is less than that of the metal, the assembly is cooled in the order of 100° C. per hour initially followed by a cooling of around 500° C. per hour to room temperature.

As indicated in Figure 1, the fine mesh screen **40** is connected to a source of potential, which is substantially three volts positive relative to ground or cathode potential of gun **18**. Closely spaced, in the order of from five mils from the dielectric sheet **14** there is mounted on the writing gun side of target **12** a second fine mesh screen **44**. As shown in detail in Figure 2, a mica spacer ring **46** may be used to space screen **44** from the dielectric sheet **14**. Screen **40** may be indicated as "the reading screen," while screen **44** may be indicated as the "writing screen." The writing screen **44** may be mounted on a support ring **45**. During tube operation, the writing screen is maintained at a potential between 50 and 100 volts negative to ground potential.

Adjacent to the target **12** on the reading side of the target there is mounted a screen electrode **48**, which during tube operation is maintained slightly positive with respect to the accelerating electrode coating **36** to repel positive gas ions passing down the tube toward the target and which would discharge the negative charge pattern established in the target. As indicated in Figure 1, screen **48** may be maintained across a supporting ring **50** which is sealed through the envelope wall **10** to provide an external terminal for the screen electrode **48**. The electron beam **20** passing through screen **48** enters an intense retarding or decelerating field between the screen electrodes **48** and **40**. Screen **48** provides a uniformity of decelerating field over the adjacent surface of the target **12**.

During tube operation, the electron beam **20** is magnetically scanned over the adjacent surface of target **12** by fields provided by two pairs of scanning coils indicated in Figure 1 by the deflection yoke **52**. The deflection yoke is of a conventional design, and as is well-known, each pair of coils are connected respectively in series with each other to sources of sawtooth currents **54** and **56** for respectively providing frame and line scansion of beam **20** over the target surface.

The electron beam between the screen electrodes **48** and **40** is slowed down to a very low velocity so that it will strike the target electrode **12** with an energy of only a few volts. The energy of the beam electrons is under these conditions below that required for initiating secondary electron emission from either the reading screen **40** or the dielectric surface of film **14**. When the writing gun **16** is turned off, the electrons of beam **20** approaching portions of the positive reading screen **40** will be collected thereby and conducted away. However, the electrons of beam **20** landing on the insulating surfaces of film **14** will drive the dielectric surface of film **14** negatively toward gun cathode potential, at which point the remaining electrons of the beam are reflected as a return beam **58** back toward the reading gun **18**. This condition is schematically shown in portion (*a*) of Figure 3. The return beam **58** has less beam current than the incident beam **20** due to the collection of beam electrons by the positive reading screen **40**. The return beam **58** passes down the tube envelope **10** and strikes a dynode surface **60**, which is a portion of the first accelerating electrode **34** of gun **18**.

The electrons of the return beam **58** strike the dynode surface **60** with energies sufficiently great to initiate a secondary emission therefrom, which is directed by a persuader electrode **62** into an electron multiplier section **64** of the type disclosed in U. S. Patent 2,433,941 to Paul K. Weimer. The electrons are multiplied through several stages and finally collected by the multiplier anode electrode **66** to provide an output signal in the circuit **68** of anode **66**.

A charge pattern corresponding to signals to be stored is established on the surface of the dielectric sheet **14** facing the writing gun **16**. The incoming signals may be from any source such as, for example, those produced by the reception of reflected radar signals. These signals are applied between the control grid **24** and cathode **22** of the writing gun **16**, which is connected in a circuit with a tube **70** for driving the control grid **24**. The signals thus applied to gun **16** modulate the electron beam **27** as it is scanned over the surface of target **12**. As mentioned above the scansion of beam **27** may be a radar P. P. I. pattern by coupling the deflection yoke **32** to the movement of the radar antenna, as is well-known.

The electron beam **27** will strike the dielectric target sheet **14** at energies sufficiently great to initiate a secondary emission from the target surface greater than the primary beam current. However, since the writing

screen 44 is held at around 100 volts negative relative to ground potential the secondary electrons will be readily suppressed and driven back to the target film 14, thus, driving that point of the target surface negatively to ground. The current of beam 27 is maintained at a small value, so that, as the beam is scanned from point to point, the target surface will be driven negatively in the order of five volts for the maximum beam current. Since beam 27 is modulated, other portions of the target will be struck by less than the maximum beam current and will be driven negatively to a correspondingly less degree.

When the dielectric target sheet 14 is driven negatively by the writing beam 27 and to a potential something less than the maximum 5 volts, the zero equipotential surfaces, which, before the writing beam was turned on, were in the surface of dielectric sheet 14, now emerge on the reading side of the target and extend outwardly through the openings of mesh 40. This is schematically shown in Figure 3(*b*). These zero equipotential surfaces cut down the area through which the electrons can enter to land on the conductive collector mesh 40. When the dielectric sheet is driven more negatively, at any point by the writing beam 27, the zero equipotential surfaces now spread out and overlap in this particular area and prevent any landing of the beam electrons on the collector grid 40. This is schematically shown in Figure 3 (*c*).

As the insulator sheet 14 is driven negatively, the reading beam current landing on the collector mesh 40 is correspondingly decreased, while the reflected return beam current is correspondingly increased. Figure 4 shows the relationship of the reading beam current collected by the reading screen 40 to the charge potential established at any one point on the dielectric target 14 by the writing beam. Figure 4 indicates that for positive voltages between 3.5 and 8, established on the reading screen 40, the reading beam current collected by mesh 40 is inversely proportional to the negative voltage established at any one point on the insulator sheet 14 by the writing beam.

As set forth above, the modulated writing beam landing on any one spot of the target will drive that spot negatively by a value between 1 to 5 volts. The potential to which the spot is driven is limited by the current value of the writing beam at that spot. However, if the spot is hit repeatedly, the charge accumulated on the target surface 14 increases linearly.

Normal operation of the tube is that in which the collector screen 40 is maintained at around 3 volts positive. This does not provide an excessive difference of potential between the positive grid 40 on one surface of the dielectric sheet and the negative charge pattern established by the writing beam on the other surface. At low potential differences between the target surfaces, the charge pattern is stored on the dielectric sheet for longer periods of time.

In general a charge pattern is established on the writing side of target 12 as described above. The reading beam 20 in scanning the opposite surface of target 12 provides a return beam 58 which is modulated in accordance with the number of electrons collected by the positive grid 40 and in accordance with the charge pattern established on the writing side of target 12. The modulated return beam 58 is amplified by passing through the multiplier section 64 and provides the output signal of the tube. If different information is to be stored on the target surface the previous information can be erased by setting the suppressor screen 44 back to 0 potential and scanning the whole target area with the writing beam. This will drive the writing side of the dielectric side 14 to the potential of the suppressor grid 44 and thus erase the previous charge pattern established on the target surface. Or, in a similar manner any given area of the target can be erased by setting the suppressor grid 44 to zero potential and scanning only that portion of the dielectric surface of sheet 14 with the writing beam.

An application of the tube described above is that in which incoming radar signals are applied to the control grid 24 of writing gun. The writing beam 27 is scanned over the surface of target 12 with a radar P. P. I. pattern. For example such a pattern is one in which the beam 27 sweeps from the center of the target radially outward in a 500 micro-second sweep. The beam 27 and the deflection current of yoke 32 are cut off for a second 500 microseconds. The beam then is turned on again and strikes the center of the target. In the third 500 microsecond period, the beam again is deflected from the center radially outward but along a path which is at a small angle to the path traced on the previous sweep. In this manner, the beam is scanned to provide 1000 traces or sweeps per second. It takes approximately 6 seconds for the beam to trace the 360° about the center point of the target and return to its original trace. This is the same time as that for one rotation of the radar antenna which sent out 1000 pulses per second. Each radar pulse is synchronized with the beginning of the start of each trace of the electron beam 27 from the center of the target 12. The radar pulses reflected back to the antenna from various objects provide additional pulses during each 500 microsecond period which constitute the signal applied to the control grid. These reflected pulses or signals modulate the electron beam between the beginning of each trace and the end of the trace at the edge of the target. The control grid 24 of the writing gun may be biased negatively to cut off the electron beam at all times unless pulsed or driven positively by a radar signal sent to the control grid by the circuit of tube 70. In this manner then there is established on the writing side of the dielectric target 14, a charge pattern corresponding to the radar picture obtained.

In the radar application described, it is necessary that, as the writing beam 27 scans over a previous trace on the target 12, new information be put down on the target. This then requires that the previous information put down on the same trace be erased before the beam traces over the line again. The erasure of any radar trace by the beam prior to a succeeding trace may be accomplished by any appropriate method which would erase the old picture at or very close to the instant of writing, so that no trailing or integration effect occurs to distort the picture.

The tube described above may also be uesd for storage purposes other than radar application. For example, a single transient oscilloscope trace can be put down on the target by the writing gun and be viewed as long as desired by the reading gun.

Often it is desired to write at extremely high speeds, such as for short duration single transient signals, as found in oscilloscope practice. In such cases, it is necessary to raise the writing beam voltage in order to get more writing current density. The upper limit of the writing beam voltage is set by the thickness of the dielectric sheet 14. For thin films it is possible to find voltages such that the beam penetrates through and causes emission of secondary electrons from the far side of the insulator sheet. Thus, at excessive voltage it may be impossible to charge the insulator negative as is required for this type of operation.

It is also possible to magnetically focus the writing beam by extending the focus coil 38 of the reading beam and using an orthicon deflection yoke similar to 52 for the writing beam gun. This has the advantage in that the writing beam will also land perpendicularly on the target. The same effect may be accomplished by electrostatic means. Perpendicular writing has the advantage of preventing trouble in applications where it is desired to selectively erase and write at any point chosen by the deflection system. With the kinescope type of deflection for the writing beam shown in Figure 1, the change in

writing screen potential from writing to erasing values, cause a deflection of the beam spot due to the angle of approach of the writing beam to the screen 44. With perpendicular landing, this is prevented.

Where the writing gun is spaced at voltages above the second crossover potential of the dielectric target surface, it is possible to obtain erasure on the writing side by the addition of a spray beam of electrons at a lower voltage or by operating the writing gun between first and second crossover potential, during the erasure time.

While certain specific embodiments have been illustrated and described, it will be understood that various changes and modifications may be made therein without departing from the spirit and scope of the invention.

I claim:

1. A charge storage device comprising, a target electrode including an imperforate dielectric sheet of material, a conductive grid in contact with one surface of said dielectric sheet and a foraminous electrode spaced from the other surface of said dielectric sheet, means for providing a modulated electron bombardment of said other surface of said dielectric sheet to provide a charge pattern thereon, an electron gun for providing a beam of electrons to be scanned over said one surface of said dielectric sheet, and an electrode for collecting beam electrons returned from said dielectric sheet.

2. A charge storage device comprising, a target electrode including an imperforate dielectric sheet, an electron gun means for scanning one surface of said target sheet with a beam of low velocity electrons, a foraminous collector electrode in contact with said one surface of said dielectric sheet, an electron suppressor electrode spaced from the opposite surface of said dielectric sheet, and means spaced from said opposite surface for providing a modulated electron bombardment of said opposite surface.

3. A charge storage device comprising, a target electrode including an imperforate dielectric sheet, an electron gun means for scanning one surface of said target sheet with a beam of low velocity electrons, a collector screen mounted on said one surface of said dielectric sheet, an electron suppressor screen spaced from the opposite surface of said dielectric sheet, means spaced from said opposite surface for providing a modulated bombardment of said opposite target surface, and an anode electrode spaced from said one target surface for collecting beam electrons reflected from said target.

4. A charge storage device comprising, a target electrode including an electron impermeable dielectric sheet, a first electron gun means for scanning one surface of said target sheet with a beam of low velocity electrons, a collector screen mounted on said one surface of said dielectric sheet, a second electron gun spaced from said opposite surface for providing a high velocity beam directed at said opposite target surface, and a suppressor screen mounted between said second gun and said opposite target surface.

5. A charge storage device comprising, a target electrode including an electron impermeable dielectric sheet having a resistivity in the range between 10^{14} ohm cm. and about 10^{18} ohm cm., an electron gun for scanning one surface of said dielectric sheet with a beam of low velocity electrons, an electron collecting screen mounted in contact with said one dielectric surface, means spaced from the opposite surface of said dielectric sheet for providing high velocity electrons directed at said opposite dielectric surface, a suppressor electrode between said means and said opposite dielectric surface.

6. A charge storage device comprising, a target electrode including an imperforate glass sheet having a resistivity between 10^{16} and 10^{18} ohm cm., a first electron gun for scanning one surface of said glass sheet with a beam of low velocity electrons, a collector screen mounted over and in contact with said one glass sheet surface, a second electron gun for directing a beam of high velocity electrons at the opposite surface of said glass sheet, an electron suppressor screen spaced from said opposite glass sheet surface, and an anode electrode for collecting beam electrons reflected from said first glass sheet surface.

7. A charge storage tube comprising, a target electrode including an electron impermeable dielectric sheet having high resistivity, means including a first electron gun for scanning one surface of said dielectric sheet with a beam of low velocity electrons, a collector screen over and in contact with said one dielectric sheet surface, means including a second electron gun for scanning a beam of high velocity electrons over the opposite surface of said dielectric sheet, a secondary electron suppressor screen spaced from said opposite surface of said dielectric sheet, said second electron gun including a control grid for modulating said high velocity beam, and an anode electrode for collecting electrons reflected from said one surface of said dielectric sheet.

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