Aug. 7, 1951 A. ROSE 2,563,488

BARRIER GRID STORAGE TUBE

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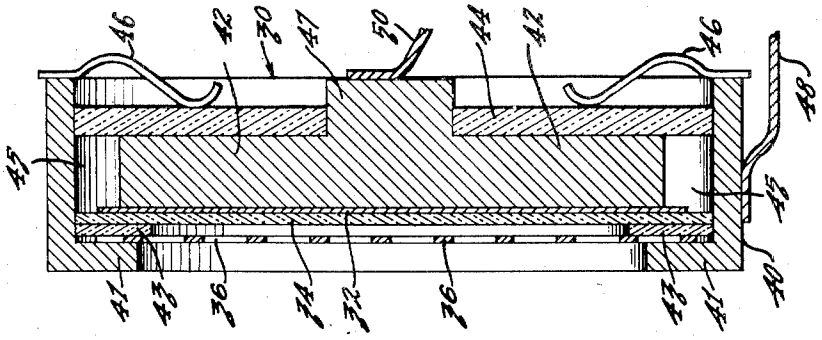


Fig. 2

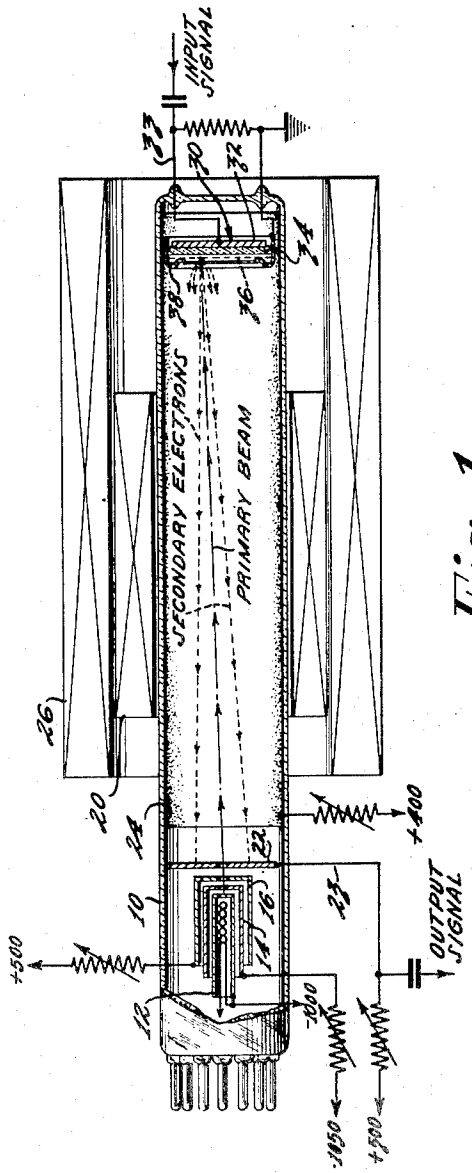


Fig. 1

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BARRIER GRID STORAGE TUBE

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1

This invention relates to cathode ray tubes, and in particular to storage tubes of the cathode ray type in which a charge pattern is established on the insulating surface of the target electrode of the storage tube by signals applied to the signal plate of the target, while an electron beam scans the insulating target surface. The output signal of the tube is that provided by a modulated secondary emission from the insulating target surface. A tube of this type is disclosed in the application of R. L. Snyder, Jr., filed July 24, 1945, Serial 606,812, which issued on April 10, 1951, as Patent No. 2,548,405.

In tubes of this type, the insulating target surface will change in potential with respect to the electrode collecting the secondary emission until an equilibrium potential is reached, at which the number of secondaries leaving the target surface is exactly equal to the number of electrons in the incident electron beam. The remaining secondary electrons collect in the form of a space charge and will rain back or be redistributed on the target surface, charging the unbombarded parts of the surface to a negative potential. These redistributed electrons will partly neutralize any charges already on the target surface and thus make impossible any accurate comparison of signals from scan to scan. A barrier grid or screen connected to a voltage source is closely spaced from the target surface, so that the target equilibrium potential is established with respect to the screen and not the collector electrode. During tube operation, the secondary emission from the target surface will maintain the equilibrium potential of the target a few volts positive relative to the barrier grid or screen.

The spacing of the screen from the dielectric surface is rather critical. If the spacing is too great, redistribution effects will shade the signals, introducing more interline crosstalk, and reduce the resolution. If the spacing is too small, whenever negative signals are applied to the plate, the very negative portion of the target surrounding the beam spot may, by a "coplanar grid effect," erect a potential barrier outside the screen, over which many of the secondaries cannot go. As a result they will be collected by the barrier grid screen, and their absence from the secondary beam each scan will cause a positive signal to appear on the collector.

Accordingly, it is an object of this invention to provide an improved storage tube of the cathode ray type.

It is also an object of this invention to provide a storage tube having uniform collection of signal from the target surface.

2

It is also an object of this invention to provide a storage tube in which shading of the signal by redistribution of secondary electrons on the target surface is eliminated.

It is a further object of my invention to provide a storage tube in which there is eliminated the potential barrier against signal electrons provided by negatively charged areas on the target surface.

The novel features which I believe to be characteristic of my invention are set forth with particularity in the appended claims, but the invention itself will best be understood by reference to the following description taken in connection with the accompanying drawing, in which:

Figure 1 is a cross-sectional view of a storage tube according to the invention.

Figure 2 is a cross section view of a target structure utilizing my invention.

Figure 1 discloses a storage delay tube of the cathode ray type comprising an envelope 10 of glass or any other suitable material. Within the envelope is positioned an electron gun for the purpose of forming and focussing an electron beam upon a target electrode 30. The gun structure consists of a thermionic cathode 12, surrounded by an apertured control grid 14 and an anode electrode 16, for accelerating the electron emission from the cathode 12 and focussing the electrons of the beam onto the surface of a target 30. Two pairs of deflecting coils represented by a yoke structure 20, are positioned along the beam path between the anode electrode 16 and target 30. As is well known in the art, these pairs of deflecting coils each produce electromagnetic fields at right angles to each other and to the path of the electron beam. It is understood that these coils respectively will have varying currents applied, say by a saw-tooth generator, to produce line and frame scansion; or appropriate currents may also be applied to the deflection coils for producing spiral scansion of the target, or line scansion only, as may be desired. The means for producing different types of scansion of the target surface 30 are well known in the art and need not be further described.

The operation of the tube depends upon a signal being generated by the emission of secondary electrons from the target 30, when bombarded by the electron beam. A collector electrode in the type of tube shown in Figure 1, comprises an apertured plate 22 mounted in the envelope 10 coaxial with the electron beam path. A conductive coating 24, applied to the inner surface of the envelope 10, extends from a point adjacent the collector electrode 22 to beyond the target

electrode 30. The conductive coating 24 is connected to a source of D. C. potential (not shown) and maintains, during tube operation, a uniform electrostatic field between the collector 22 and target 30. Outside of yoke 20, is placed a solenoid 26, which, during tube operation, produces a strong magnetic focussing field parallel to the axis of the tube 10.

The target electrode 30, Figure 1, comprises essentially a metal support plate 32 mounted transverse to the path of the electron beam and which functions as the signal plate of the target electrode. On the surface of the signal plate 32, facing the electron gun, is fixed a dielectric layer 34, such as mica. Target 30 may also be formed, using an aluminum signal plate, having a dielectric surface of aluminum oxide, facing the electron beam, formed, for example, by anodizing the aluminum. However, the construction of the target 30 need not be confined to either of these described forms, but may also comprise any other appropriate insulating materials such as titanium dioxide, or silicon dioxide, for example, deposited in any manner such as evaporation or thermal decomposition upon a conductive signal plate. In Figure 1, and closely spaced from the exposed surface of the mica layer 34 is a fine mesh screen 36, or a barrier grid, which may be mounted a few mils from the surface of the dielectric layer 34 by a supporting ring 38, mounted on the target 30.

As the dielectric surface 34 is scanned by the electron beam, secondaries are emitted and drawn away toward collector electrode 22 which is maintained during tube operation, at a high positive potential relative to the potential of surface 34.

The principle of electrostatic storage on an insulating surface has long been known and used in television pickup tubes, such as the iconoscope. If an insulating surface is bombarded by an electron beam, the secondary emission ratio will vary with the energy of the bombarding electrons. If the energy is such that the secondary emission ratio is greater than unity, then the potential of the target surface will change with respect to the electrode which collects the secondaries, until the net number of secondaries leaving the target surface is exactly equal to the number of primaries arriving there. The surface potential, at which this action takes place, is known as the equilibrium potential. The remaining secondary electrons collect in the form of a space charge and rain back on the insulating surface, charging the unbombarded parts of the surface to a negative potential. Thus a charge pattern is built up on the surface in the absence of any applied signal. The returning electrons, of course, partially neutralize any charges already on the surface and, thus, would make any comparison of signals from scan to scan impossible. Several ways have been attempted in the past to eliminate this electron redistribution effect. Screen 36, mounted close to the insulating surface 34, eliminates this redistribution effect, as described below.

In operation, the electron beam strikes the dielectric surface 34 with sufficient velocity to produce a secondary emission ratio greater than unity. To obtain this condition, the screen 36 and signal plate 32 in the specific tube described are maintained at a potential about one thousand volts positive relative to the cathode 12 of the electron gun.

Since target surface 34 is an insulator, the only source of current to it is the primary beam, and the only drain of current from it is the secondary

electron emission. At some equilibrium potential of the target surface, these two must be equal. The barrier grid or screen 36 functions as a virtual collector, so that an equilibrium potential for the target surface 34 is established with respect to the screen and not to the actual collector electrode 22. Wherever the beam strikes the dielectric 34, the potential of the elemental area of the surface 34 under bombardment is raised to this equilibrium potential which exists at a few volts positive with respect to the screen 36, because the initial velocity of most of the secondary electrons is sufficient to lift them over a field of several volts. The exact potential is not very definite, because it is affected by space charge conditions and the geometry of screen 36 and nearby electrodes. At this equilibrium potential, a number of secondary electrons just equal to the number of arriving primaries are sufficiently energetic to penetrate the negative screen 36. These secondaries do not return to the target, as appropriate fields outside screen 36 urge them away and toward the collector 22 as the secondary beam. Meanwhile, the excess secondary electrons are not sufficiently energetic to reach the negative screen 36, and are restricted in their motion by the negative screen 36 to the dielectric surface. Thus their redistribution to portions of the target not directly under the beam is considerably reduced.

In normal operation, the screen 36 over the target surface 34 is maintained at D. C. potential and the conductor plate 32 is connected through a conductor 33 to a source (not shown) of the signal to be recorded. The insulating surface 34 is capacitively coupled to the signal plate 32 and also to the screen 36. When a signal voltage is impressed on a signal plate 32 it also appears, somewhat diminished in amplitude, on the recording surface 34 of the target.

If a signal is applied to plate 32 so that it is driven negative relative to the equilibrium potential, any elemental area of surface 34 under bombardment at the time by the electron beam, will also be driven negative relative to the screen. Under these conditions, a positive field between screen 36 and target 30 will be presented to the surface 34 and, therefore, all of the secondary electrons, released by the impact of the beam electron, are drawn away. Since the number of secondary electrons is greater than the number of primary electrons, there is a net loss of negative charge and the elemental target surface area under the striking beam becomes more positive. If, however, the element of surface 34 is driven positive with respect to the screen 36 at the time of bombardment due to an incoming signal driving plate 32 in a positive direction, a more negative field between screen 36 and target 30 is presented to the surface 34 and all of the secondary emission is suppressed. Since no secondary electrons leave the target surface element, there is a net gain of negative charge and the potential of the target surface under the striking primary beam becomes more negative.

As the beam is deflected across the surface 34, while a signal is impressed on the signal plate 32, it will cause each element of surface area it strikes to come to equilibrium potential, regardless of the potential the surface would otherwise have due to the influence of the signal plate. This action, then establishes a potential difference between the signal plate 32 and the surface element under the beam, which will cause the element to have a potential different from that

of the equilibrium potential, when the beam moves off of the surface element and the signal plate 32 returns to the potential of screen 36. If the beam scans a long path over the target surface 34, while a fluctuating voltage is impressed on the signal plate 32, a band of charges, as wide as the beam, will remain on the path when the beam is cut off. If the signal plate 32 returns to the potential of screen 36, the potential along the path will vary in proportion to the signal voltage impressed during the beam transit. The secondary emission from the dielectric surface, however, fluctuates according to the charging demand. If no change of charge is required by an element, the secondary electrons released therefrom are equal in number to the impinging beam electrons. If a negative charge is to be supplied to the dielectric surface 34 to bring the elemental target area to equilibrium potential, secondary emission is suppressed until the demand has been satisfied. If a positive charge is needed to bring the target area to equilibrium the secondary emission is a maximum until full charge is achieved.

One adaptation of the tube disclosed may be in signal comparison, where both signals are not available simultaneously, or where it is desirable to make the comparison at an arbitrary phase relation. For example, successive signals to be compared are received and mixed with a continuous wave signal of a local oscillator to produce a heterodyned signal, which is impressed on the target 12 at the beginning of each line scansion of the storage tube, at the peak of the saw-tooth wave controlling this scansion. The "stable" portion of the signal compared will produce a beat signal of fixed amplitude, while the "variable" portions of the signals will produce a beat signal of varying amplitude. A charge put down on an elemental area of the dielectric surface 34 by the electron beam, when the potential of the surface is changed from the equilibrium value by a "stable" portion of a signal, will maintain the elemental area at equilibrium potential during succeeding line scansion of the target. However, "variable" portions of the signals, producing a beat signal of changing amplitude, will cause the elemental target areas struck by the beam to correspondingly vary in potential. Thus, the secondary electron emission will be constant from the target areas charged, during the reception of "stable" portions of the signals compared, while the secondary emission will be variable from target areas charged during reception of the "variable" portions of the signal received. This varying secondary emission will be the A. C. component of the secondary emission current collected by the electrode 22 in the output circuit of the tube. In this manner, the difference between the compared signals applied to the tube are detected.

Whenever negative signals are applied to the signal plate 32 charges are deposited by the primary beam upon the dielectric surface resulting in negatively charged areas which may be greater than 70 volts. These negatively charged areas create a negative field over the target surface and act as a potential barrier to suppress the secondary emission from the dielectric surface 34. This negative field will extend out beyond screen 36 and force the secondary emission from the target surface back toward screen 36. As a result, these suppressed secondary electrons will be collected by the screen 36 and their absence from the secondary beam on each screen will cause a positive signal to appear in the collector circuit. I have found that this suppressing negative field or "coplanar grid" effect may be eliminated if the mesh screen 36 is spaced a determinable distance from the target surface, as described below.

Also, when the electron beam scans the target 30, some of the secondary electrons directed toward collector electrode 22 are from the solid parts of the screen 36, which intercept the beam current. The rest of the secondary electrons come from the surface of the dielectric. Those electrons released from the screen are essentially constant in number, because the beam current is fixed and the secondary emission ratio over the screen is quite uniform. Also, the screen 36 is fine enough to average out geometrical effects. However, a second major effect of the "coplanar grid" action is to suppress the secondary emission from the wire screen 36 in the neightborhood of negative areas on the target surface 34. Since this emission is normally saturated and uniform and contributes only a D. C. background, any suppression of this emission will result in spurious signals.

The spacing of screen 36 from the mica surface 34 is rather critical. If the spacing is too great there will be a redistribution of the secondary emission which falls back onto the target surface and which will tend to discharge positive areas of the target other than that which the beam is striking. This will tend to produce a shading of the signals and also reduce the resolution of the signal collected. Also, if the spacing is too small, the negative charges on the target surface will form a negative field which will extend through screen 36 and suppress the secondary emission from both the target and screen 36, as described above.

I have found that best results are obtained, if screen 36 is spaced from the surface of dielectric 34 by a distance which is several times the size of a picture element of the target. A picture element can be defined as the smallest element that can be resolved by the tube. In the tube of Figure 1, the picture element closely conforms with the spot size of the primary electron beam, when it strikes the target surface. In a successfully operated tube similar to that shown in Figure 1, the spot size is between 10–15 mils in diameter. In this same tube, the screen 36 is spaced from the target surface by a distance of 2–3 mils.

The amplitude of the input signal applied to the signal plate 32 will also determine the spacing of the mesh screen 36 from the target surface 34. In a successfully operated tube similar to that of Figure 1, and mentioned above, the amplitude of the signals applied to the plate 32 are less than 100 volts. For this amplitude of signal, a spacing of screen 36 from two to several mils from the target surface 34 has been found to be sufficient. However, if the amplitude of the signals applied to plate 32 were twice as great, the spacing of screen 36 should be twice as far from the surface of the dielectric 34 to efficiently eliminate the "coplanar grid" effects and to prevent redistribution of electrons on the target surface.

Furthermore, to effectively eliminate the negative field effect or the "coplanar grid" effect, the openings in the mesh screen 36 must also be as small or preferably smaller than the size of a picture element or spot size of the primary beam. The spaces in the mesh 36 cannot be larger than

a picture element or the spot size since portions of the screen would not then extend between each picure element to effectively screen one element from another and thus prevent the charges on the picture elements from adversely affecting both the redistribution of secondary electrons on the target surface and the emission of secondaries from the elemental areas. Also, a finer mesh screen would have the same proportional effect as decreasing the spacing of screen **36** from the dielectric surface **34**.

In the screen **36** shown in the tube of Figure 1, there are approximately 230 wires per inch. The approximate distance between successive wires would be around 3 mils and each opening in the mesh **36** would expose a surface of the dielectric **34** having a transverse dimension of approximately 3 mils. With a mesh of this size, the spot size of the primary electron beam of the tube will cover between 2–4 openings at one time. This number of openings in the mesh **36** would represent a picture element. Thus, in a tube similar to that of Figure 1, a screen **36**, of approximately 230 wires per inch, is spaced from the dielectric surface **34** a distance which is of the order of the transverse dimension of an aperture through the screen. In this tube, screen **36** is spaced at least two mils from the dielectric surface **34**. This mesh screen **36** provides an effective screen for eliminating the "coplanar grid" effects and redistribution effects described above and in which the amplitude of the signals applied to the signal plate **32** of the tube are less than 100 volts.

As mentioned above, screen **36** may be of a finer mesh and a closer spacing from the target and still provide the same screening effect for the signals applied to the plate **32**. That is, the ratio of the length of one side of an opening in the screen to the spacing of screen **36** from the target is approximately 1:1. The size of the mesh of screen **36** may be varied as long as this ratio is not changed, to provide effective screening of the dielectric surface. However, the size of the mesh is limited by the picture element as described above.

Figure 2 shows a means for spacing screen **36** from the dielectric surface **34**. The invention is not limited to the specific structure **32**, but the mounting structure shown is by way of example only. The parts of target **30** are mounted within a supporting ring **40** having at one end a flanged lip **41**. The wire mesh screen **36** may be first welded to the inner surface of the flanged portion **41**. A spacer ring **43** is inserted into the supporting ring **40** in order to space the screen **36** from the dielectric on mica disc **34**, which is placed on top of the spacer **43**. The spacer ring or washer **43** may be of any desired material, either conductive or insulating. On the back of the dielectric disc **34** the signal plate **32** is formed in any desired manner. For example, in Figure 2, signal plate **32** is a layer of palladium metal sputtered onto one side of the dielectric disc **34**. To form a rigid supporting means for the relatively thin dielectric disc **34** and spacer ring **43**, a heavy thick metal plate **42** is inserted into the supporting structure **40**. Supporting plate **42** may be of any desired metal and in a successfully operated tube, is a heavy copper plate. The peripheral edge of the supporting plate **42** is spaced as is shown at **45** from the supporting structure **40** in a manner to insulate the supporting plate **42** from the metal mesh **36**. To maintain the insulating spacing **45**, a second dielectric or insulating disc **44** is provided which closely fits into the supporting ring **40**. An aperture within the insulating disc **44** permits the passage therethrough of a stud **47** integral with the supporting plate **42**. In this manner, the relative position of the supporting plate **42** and ring **40** is maintained as shown in the Figure 2. The several parts of the target structure may be held in their assembly relationship within the supporting ring in any desired manner such as, for example, by a spring clip **46** welded to the edge of supporting ring **40** and bearing upon the dielectric disc **44**. Leads may be connected to the structure such as, for example, lead **48** welded to the ring **40** for connecting screen **36** into its circuit. Also, a lead **50** can be fixed to stud **43** of support plate **42** for connecting the signal plate **32** into its appropriate circuit **33**.

The dielectric layer **34** of the target **30** must have a sufficiently high produce of resistivity that an appreciable amount of charge cannot leak through the dielectric layer **34** between scansions. Also, there must be so little surface leakage across the dielectric, and the successive lines of the scan must be sufficiently spaced relative to the spot size of the beam, that the beam cannot remove the charge that was depositied when it previously scanned a neighboring line.

Suitable materials for screen **36** have been found to be stainless steel, copper or nickel. As the electron beam scans across the wires of the screen **36**, a noticeable modulation of the secondary electron signal collected by the electrode **28** is produced due to the difference in secondary electron emission of the screen **36** and the dielectric surface **34**. Since it is desirable that the secondary emission ratio of the screen **36** be approximately unity, during tube operation, the screen **36** is coated by a layer of sputtered gold or other suitable material having a secondary emission ratio close to unity such as carbon, for example.

The transmission of screen **36** is approximately 50 percent of the impinging electron beam. However, if a coarser mesh screen were used, there would be a greater redistribution of the secondary emission electrons suppressed by the screen. The screen **36** functions as an electrostatic shield to prevent the redistribution of secondary electrons to other positive portions of the dielectric surface.

I have described the operation of my storage tube in connection with a moving target indicating system, but this is by way of example only. The improved storage tube may be used in various other ways where storage of information is desired. Signals may be impressed on the signal plate while the beam scans a predetermined pattern over the target. The signal and beam may then be shut off, leaving the information stored in the target. At any desired later time, the beam may be turned on and with no new signals impressed on the signal plate, scanned over the pattern so that the signal impressed during the first operation will be reproduced. The signals need not be recorded in one scansion and utilized in the next scansion. Signals can be stored at one time and reproduced at any later time merely by shutting off and turning on the beam at desired times. In some tubes of the type described signals have been stored on the target surface up to one hundred hours with little loss of definition. As will be evident from the described method of operation, recorded signals may be combined with new signals, enabling one to use the tube for carrying out complex operations by suitable combination of signals.

The various voltage and potential values in-

dicated in the figures and described are given only as illustrative of those used in a successfully operated tube of this type. The invention is not confined to these values and other potentials may also be used successfully.

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.

What I claim is:

1. A target electrode comprising a conductive signal plate, a dielectric film in contact with one face of said signal plate, and a fine mesh screen having uniform apertures therethrough spaced from said dielectric film by a distance approximating the transverse dimension of an aperture of said screen.

2. A target electrode comprising a metal support plate, a dielectric material coating on face of said support plate, and a fine mesh screen having uniform apertures therethrough, said screen being spaced from said dielectric coating by a distance in the order of the transverse dimension of an aperture of said screen.

3. A cathode ray tube comprising an envelope, means within said envelope for forming an electron beam along a path, a target electrode within said envelope mounted transverse to said beam path, said target electrode including a sheet of dielectric material, a conductive material fixed to one face of said dielectric sheet, a fine mesh screen having uniform apertures therethrough and spaced from the opposite face of said dielectric sheet by a distance approximating the transverse dimension of an aperture of said screen.

4. A storage tube comprising an envelope, a target electrode mounted within said envelope and including a support plate having a dielectric surface on one side of said support plate, electron gun means spaced within said envelope from said target electrode for forming a beam of electrons and for focussing said electron beam on said dielectric surface, and a fine mesh screen spaced from said dielectric surface, the apertures through said screen being less than the spot size formed on said dielectric surface by said focussed electron beam.

5. A storage tube comprising an envelope, a target electrode mounted within said envelope and including a support plate having a dielectric surface on one side of said support plate, electron gun means spaced within said envelope from said target electrode for forming a beam of electrons and focussing said electron beam on said dielectric surface, and a fine mesh screen spaced from said dielectric surface, the apertures through said screen being less than the spot size formed on said dielectric surface by said focussed electron beam, said screen being spaced from said dielectric surface by a distance in the order of the transverse dimension of an aperture of said screen.

6. A cathode ray tube comprising an envelope, means within said envelope for forming an electron beam along a path, a target electrode within said envelope mounted transverse to said beam path, said target electrode including a sheet of dielectric material intercepting said electron beam path, a screen spaced from the surface of said dielectric sheet intercepting said electron beam path, a metal signal plate in contact with the opposite surface of said dielectric sheet, said screen space from said dielectric sheet a distance approximating the transverse dimension of an aperture of said screen.

7. A storage tube comprising an envelope, a target electrode mounted within said envelope and including a conductive signal plate and means forming a dielectric surface on one face of said signal plate, electron gun means spaced within said envelope from said target electrode for forming a beam of electrons, means for focussing said electron beam on said dielectric surface, a fine mesh conductive screen mounted in contact with said dielectric surface, the mesh openings through said screen being less than the spot size formed on said dielectric surface by said focussed electron beam, said screen spaced from said dielectric surface by a distance in the order of the transverse dimension of an aperture of said screen.

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