April 9, 1957 S. HANSEN 2,788,466

DIRECT-VIEWING STORAGE TUBE

Filed July 17, 1952 3 Sheets-Sheet 1

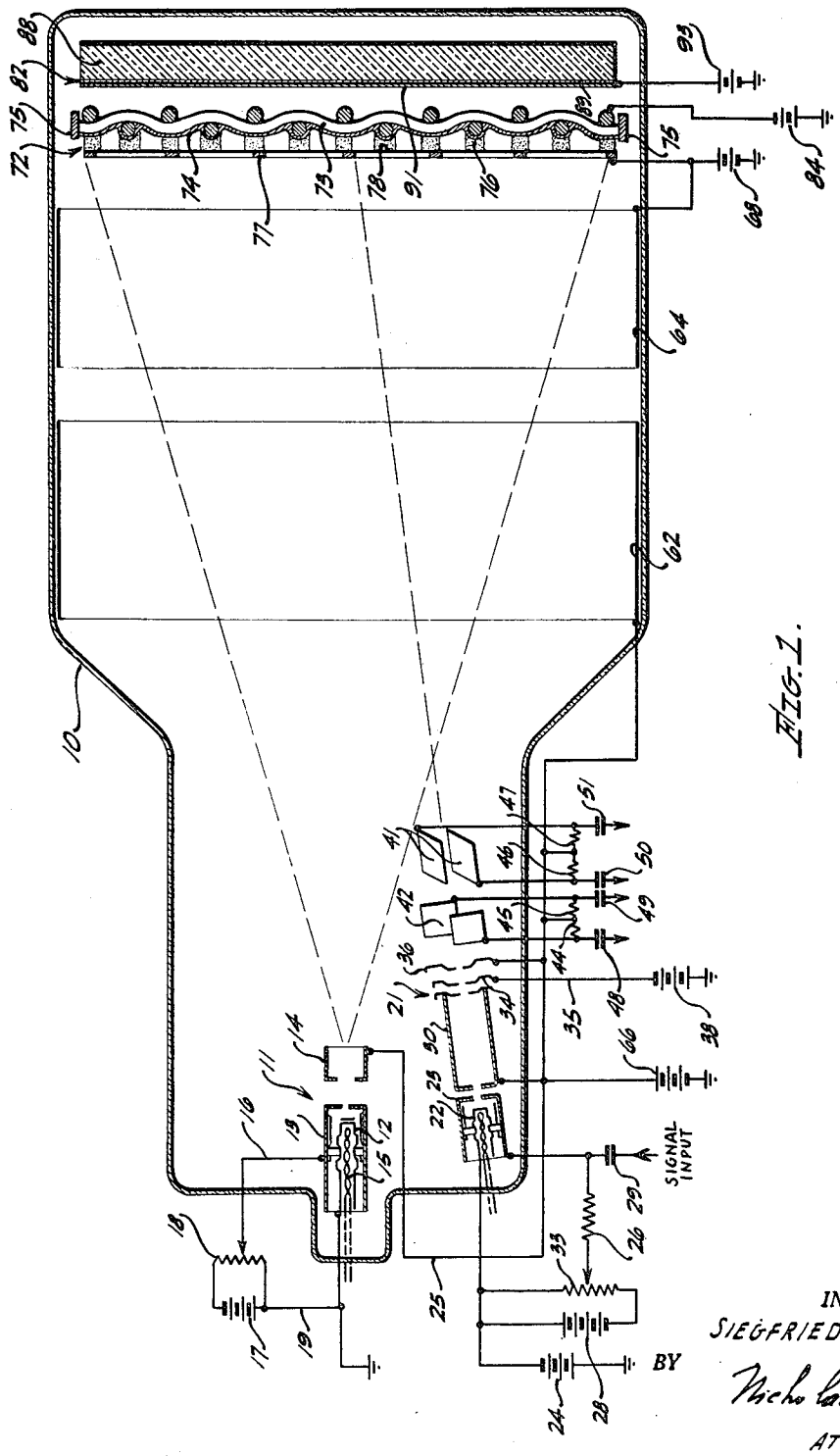


FIG. 1.

INVENTOR.
SIEGFRIED HANSEN,
Nicholas T Volpe
ATTORNEY.

April 9, 1957 S. HANSEN 2,788,466

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Filed July 17, 1952 3 Sheets-Sheet 2

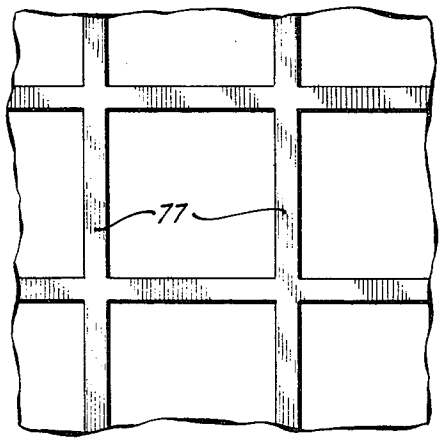


FIG. 2.

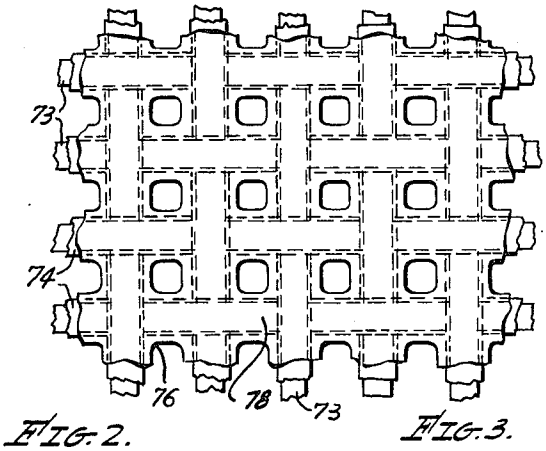


FIG. 3.

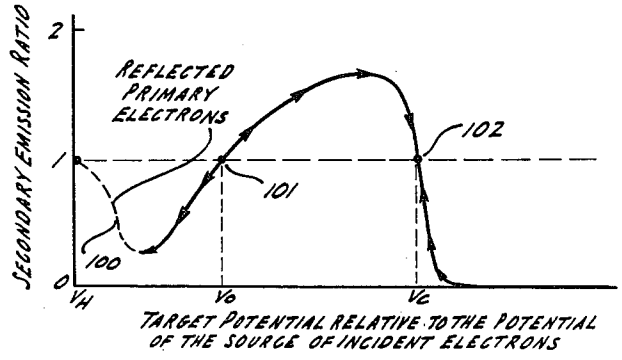


FIG. 4.

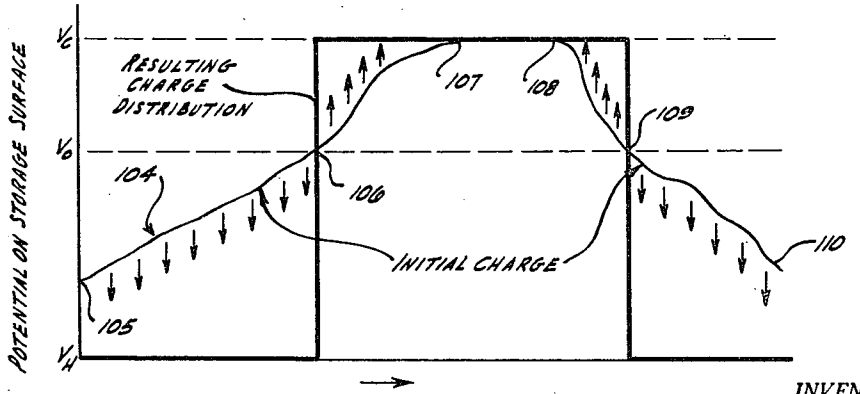


FIG. 5.

INVENTOR.
SIEGFRIED HANSEN,
BY Nicholas T Volk
ATTORNEY.

April 9, 1957 S. HANSEN 2,788,466

DIRECT-VIEWING STORAGE TUBE

Filed July 17, 1952 3 Sheets-Sheet 3

FIG. 6.

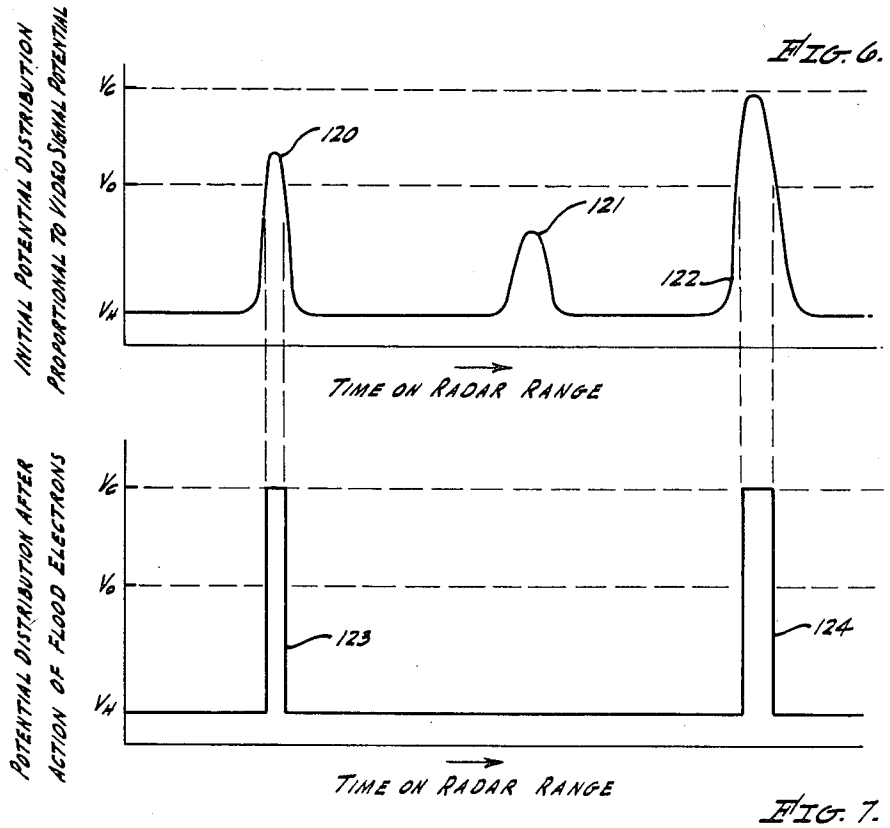
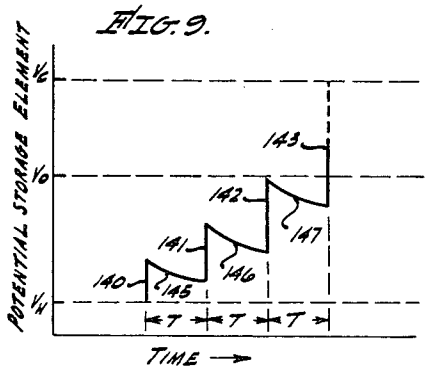


FIG. 7.

FIG. 9.



INTEGRATING ACTION DUE TO REPETATIVE SIGNALS

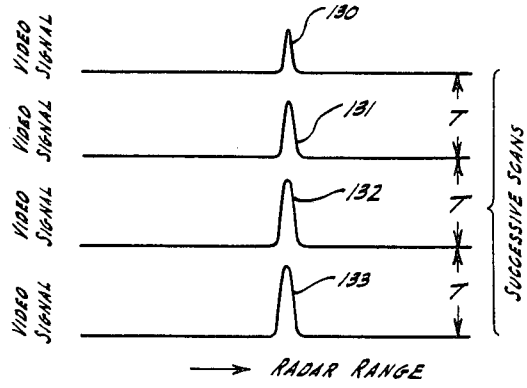


FIG. 8.

INVENTOR.
SIEGFRIED HANSEN,
BY Nicholas T Volak
ATTORNEY.

United States Patent Office

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DIRECT-VIEWING STORAGE TUBE

Siegfried Hansen, Los Angeles, Calif., assignor, by mesne assignments, to Hughes Aircraft Company, a corporation of Delaware

Application July 17, 1952, Serial No. 299,363

4 Claims. (Cl. 315—12)

This invention relates to a direct-viewing storage tube capable of providing visual presentations of charge distributions on a storage screen, and more particularly, to a storage tube incorporating an improved apparatus for producing a charge distribution on its storage surface.

In accordance with the present invention, a direct-viewing type storage tube is provided that incorporates an improved storage grid assembly. This storage grid assembly comprises a contrast control grid, a layer of secondary electron emissive dielectric material disposed over the meshes on one side of the contrast control grid, and a collector grid disposed in actual contact with the layer of dielectric material, the collector grid being thin compared to the contrast control grid. In operation, storage surface is provided by the exposed portions of this layer of dielectric material within the interstices of the collector grid.

The storage tube may comprise, for example, an evacuated envelope with the storage grid assembly disposed at one end thereof, a viewing screen disposed adjacent to and coextensive with the storage grid assembly on the side thereof nearest to the envelope, a writing gun for producing a high energy electron beam of elemental cross sectional area and a flood gun for directing a broad beam of electrons towards the storage grid assembly.

In the operation of the device, the high energy electron beam produced by the writing gun is scanned over the storage screen in a conventional manner. The high energy electrons, in bombarding the storage surface liberate a large number of electrons from their bonds to the dielectric molecules. A positive potential gradient from the storage surface to the collector grid attracts the liberated electrons towards the collector the molecular matrix comprising the dielectric material towards the collector grid thereby charging the surface in a positive direction. The intensity of the electron beam, the magnitude of the potential gradient from the storage surface to the collector grid, and the proximity of the collector grid to the storage surface determine the rate at which the storage surface will be charged in a positive direction. Since the collector grid is in actual contact with the layer of dielectric material which provides the storage surface, the device of the present invention achieves a writing speed that is considerably faster than possible in prior art storage tubes.

Acting simultaneously with the writing gun is the flood gun which produces a broad beam of low velocity flood electrons which are directed uniformly over the entire area of the storage grid assembly. These flood electrons pass through the interstices of each elemental area of the storage grid assembly in proportion to the charge thereon, and are accelerated towards the viewing screen, the combined effect of the flood electrons impinging on the viewing screen being to produce a visual presentation representative of the charge pattern on the storage surface of the storage grid assembly. Simultaneously with this process, the effect of these flood electrons on the

storage surface, due to the effect of secondary emission, is to return the potential of all areas on the storage surface charged to a potential less than the critical potential of the dielectric storage surface material to the potential of the cathode of the flood gun, and to charge areas having potentials positive with respect to the critical potential to the potential of the collector grid. Then, within a period of time, depending upon the amount by which the potential of the collector grid is positive with respect to the critical potential of the dielectric storage surface material, the flood electrons reduce the size of the positive areas until the entire storage surface is at the potential of the cathode of the flood gun.

An advantage of the storage grid assembly of the present device over those of the prior art is the extreme rapidity with which the storage surface can be charged by a writing beam. The tube of the present invention, by having the collector grid in actual contact with the layer of dielectric material providing storage surface, decreases the charging time of an elemental area of storage surface over that required by conventional secondary emission storage tubes, thereby minimizing former difficulties. Also, the nearness of the collector grid to the storage surface enables substantially better resolution to be obtained than available in present-day tubes.

One application of the disclosed storage tube is for the presentation of radar displays. In this event, the tube is operated in a mode which results in a visual image that has no dynamic range. An advantage of the disclosed storage tube is the ability of the storage surface to integrate the rapidly recurring echo pulses from a target on successive scans by a radar system. This integration is accomplished by charging an elemental area of storage surface in steps to a potential which exceeds a critical potential. When the critical potential is reached, the flood electrons preserve the charge for any desired period of time thus enhancing the signal over the accompanying noise. Areas of storage surface not charged to a potential exceeding the critical potential will give only very short persistence indications on the viewing screen, thus eliminating, for the most part, random noise and other disturbances in the presentation.

It is therefore an object of this invention to provide apparatus capable of storing a charge pattern wherein a collector grid is in actual contact with the storage surface.

It is also an object of this invention to provide an apparatus capable of depositing electric charge on a storage surface at high writing speeds.

An additional object of this invention is to provide a storage tube wherein the charge distribution is produced on the storage surface by collecting electrons released by bombardment with high energy electrons through the means of a collector grid disposed in actual contact with said storage surface.

A further object of this invention is to provide a direct-viewing storage tube which incorporates a modulated high energy electron beam to produce a charge pattern on a storage grid assembly by means of a collector grid disposed in actual contact with the storage surface, and a flood gun to provide low velocity electrons which, due to the action of secondary emission, shrink the positively charged areas on the storage surface to zero in a finite length of time and, in addition, penetrate through the interstices of each elemental area of storage grid assembly in proportion to the charge thereon and are then accelerated to a viewing screen to produce a visual image thereon representative of the charge pattern on the storage grid assembly.

The novel features which are believed to be characteristic of the invention, both as to its organization and method of operation, together with further objects and advantages thereof, will be better understood from the

following description considered in connection with the accompanying drawings in which an embodiment of the invention is illustrated by way of example. It is to be expressly understood, however, that the drawings are for the purpose of illustration and description only, and are not intended as a definition of the limits of the invention.

Fig. 1 illustrates a sectional view of an embodiment of the disclosed storage tube.

Figs. 2 and 3 are plan views of elements of the storage screen used in the tube illustrated in Fig. 1.

Figs. 4 through 9 are explanatory diagrams to illustrate the functioning of the disclosed storage tube.

Referring to Fig. 1, there is shown an electron storage tube comprising an evacuated envelope **10** which in its left portion, as viewed in the figure, has an electron flood gun **11**, a writing gun **21** for producing an electron beam of elemental cross sectional area and appropriate means **41** and **42**. A storage grid assembly **72** is disposed adjacent to and coextensive with a viewing screen **82** in the right portion of envelope **10** facing the electron guns, as viewed in the figure. The flood gun **11** comprises a cathode **12**, a control grid **13** and an accelerating electrode **14**. The cathode **12** of the flood gun **11** is maintained at a reference potential such as ground by connecting cathode **12** together with one side of an indirect heater element **15** thereto. Control grid **13** is connected to a source of biasing potential **17** through a lead **16** to an adjustable contact arm of a potentiometer **18** connected across source **17**, the positive terminal of which is connected to cathode **12**. Source **17** may have a potential of the order of −100 volts to enable the contact arm of the potentiometer **18** to be adjusted so as to obtain proper focusing of the electrons into the aperture of electrode **13**. The configuration of the electrodes **13**, **14**, specifically with respect to the diameters of the openings, are such that a divergent beam of "flood electrons" having a substantially uniform density is produced by flood gun **11**.

An "electron optics" system for the flood beam produced by flood gun **11** is formed by means of electrodes **62** and **64** disposed concentrically about the inner periphery of envelope **10** intermediate the flood gun **11** and the storage grid assembly **72**. These electrodes are maintained at different positive potentials with respect to ground and consequently, with respect to the cathode of the flood gun **11**, so as to cause the flood beam electrons passing through the regions dominated by these electrodes to spread out evenly over storage grid assembly **72** and impinge uniformly over each portion of it. Electrode **62** is maintained at an appropriate positive potential by a connection to the positive terminal of a potential source **66** which is, in addition, also connected over a conductor **25** to the accelerating electrode **14** of the flood gun **11**, thus, forming an equipotential region between flood gun **11** and electrode **62** within the envelope **10** to prevent distortion of the flood beam in this region. The magnitude of source **66** may be of the order of +1000 volts with respect to ground. Electrode **64** is maintained at an appropriate positive potential by a connection to the positive terminal of a source **68**, the latter also being connected to a collector grid **77**, an element of storage grid assembly **72**, thus creating an electrostatic equipotential region over the surface of storage grid assembly **72**. The magnitude of source **68** is of the order of +200 volts with respect to ground. As will be hereinafter explained in more detail, electrode **64** also acts as an auxiliary collector of the secondary electrons liberated from the storage surface storage grid assembly **72**.

The writing gun **21** comprises a cathode **22**, an intensity control grid **23**, and beam forming and accelerating electrodes **30**, **34** and **36**. The accelerating electrodes **30** and **36** are connected to the positive terminal of the source of direct potential **66**, while electrode **34** is connected through a lead **35** to the negative terminal of a source of potential **38**, the latter being of the order of −300 volts with respect to ground. Cathode **22** is connected to the negative terminal of a potential source **24** which has its positive terminal connected to ground to maintain cathode **22** at a negative potential with respect to ground and, consequently, at a high negative potential with respect to the potentials applied to the various elements of storage grid assembly **72**. The magnitude of source **24** may be of the order of −700 volts. The intensity control grid **23** is connected through a resistor **26** to the adjustable contact arm of a potentiometer **33**, the latter being connected across a source of biasing potential **28** which is referenced to the potential of the cathode **22**. An appropriate value for this biasing potential may be of the order of −100 volts. The setting of the contact arm of potentiometer **33** is adjusted so as to bias intensity control grid **23** negative with respect to cathode **22** at an appropriate value which may be of the order of −50 volts. A capacitor **29** is connected across load resistor **26** to the intensity control grid **23** to provide a means for modulating the grid **23** with intelligence signals. The intelligence signals modulate the intensity of the high energy writing beam for the purpose of varying the charge deposited on the storage surface of assembly **72**, as will subsequently be explained more fully in this specification. Since electrodes **30**, **34** and **36** constitute conventional beam-forming and accelerating elements of an electron beam gun, they need no further description.

The electron beam deflecting means associated with writing gun **21** comprises vertical deflection plates **41** and horizontal deflection plates **42**. While electrostatic deflecting means is illustrated in the figure, it is to be understood that magnetic deflection coils may also be used, in which case the horizontal and vertical deflection plates are replaced with appropriate magnetic deflection coils. A direct-current potential from potential source **66** is applied to the horizontal and vertical deflection plates through isolation resistors **44**, **45** and **46**, **47**, respectively, so that the average direct potential of the deflection plates is at the same potential level as the beam electrons. Capacitors **48**, **49**, **50** and **51** couple the horizontal and vertical deflecting plates to suitable sources of scanning potentials, the circuitry for which is not illustrated in the figure. The disclosed tube is in no way restricted to a particular mode of scanning and since the invention does not reside in the scanning circuits and, moreover, since suitable scanning circuits are well known in the art, no detailed description of any scanning circuit is necessary. In addition, the operation and construction of electron gun structures of the type described above are also well known in the art and, therefore, requires no additional description since the present invention is in no way restricted to a particular mode of obtaining flood and writing electron beams.

An enlarged cross sectional view of the storage grid assembly **72** is illustrated as an integral part of the storage tube shown in Fig. 1. Storage grid assembly **72** comprises a wire screen **73** which provides a contrast control grid, a flat screen **77** which functions as a collector grid, and a layer **76** of dielectric material having secondary electron emission characteristics sandwiched between screens **73** and **77**, as shown in the drawing. The portions of layer **76** exposed within the interstices of collector grid **77** provide the storage surface of storage grid assembly **72**. An enlarged plan view of a portion of collector grid **77** is shown in Fig. 2 and a proportionately enlarged plan view of contrast control grid **73** with the dielectric storage surface material **76** disposed thereon is shown in Fig. 3.

A suitable material for contrast control grid **73** may be a wire cloth screen, representative specifications for which are a stainless steel wire cloth composed of wires having a diameter of the order of 0.0016 inch, spaced with a pitch of 0.004 inch between centers, the resulting size of a hole being 0.0024 by 0.0024 inch. The number of wires

per inch and the diameter of the wire used for making contrast control grid 73 is not especially critical, the primary consideration determining the above parameters being the ultimate electron transparency of the assembly, the field penetration required and the ultimate definition desired. The wire screen 73 is supported by a metal frame 75 which also serves as a mechanical support for the remaining elements of storage grid assembly 72.

One side of screen 73 is coated with protective glaze 74, such as lime glass, which may be sprayed on the meshes thereof in the form of a powder and then fused at 750° centigrade. Glaze 74 is deposited only on the side of the wires facing the electron guns, and may have a thickness of the order of 0.0003 inch. Glaze 74 does not fill the holes of wire screen 73, its purpose being to prevent short circuits between the screens 73 and 77 which may occur because the dielectric storage surface material 76, being rather soft, may not be able to electrically isolate the two screens due to the intense electrostatic forces produced by the potential gradient therebetween.

Applied directly on glaze 74 is a dielectric storage surface material 76, the expoesd surface within the interstices of screen 77 of which comprises a storage surface 78. Dielectric material 76 must be a material which has a very high specific resistance and, in additon, must exhibit secondary electron emission characteristics when subjected to bombardment by high energy electrons.

Any dielectric material having a good secondary emission ratio is satisfactory for providing the storage surface 78, resprosentative materials capable of being used in the disclosed storage tube being willemite, zinc sulfides, and calcium tungstate phosphors.

The general configuration of storage surface 78 is illustrated in Fig. 3. It comprises dielectric material 76 exposed to the action of the electron beam produced by the writing gun. Any desired method of applying the insulator may be used as long as the above requirements are satisfied. Mounted in front of and in contact with the storage surface 78 is the screen 77 which comprises a flat metallic mesh as shown in Fig. 2. The metallic mesh of collector grid 77 may be comprising an appropriate conducting material such as an electrodeposited nickel or aluminum mesh having a thickness of the order of 0.0003 inch, a pitch of 0.010 inch and hole size of 0.008 inch by 0.008 inch. As stated previously, glaze 74 is used for preventing accidental shorting between the two grid screens 73 and 77. It is to be noted that it may be desirable to have the meshes of contrast control grid 73 in alignment with those of collector grid 77 for the purpose of obtaining a faster charging time. Alignment of corresponding wires of the screens 73 and 77, however, was found to be unnecessary, in addition to being rather difficult to obtain mechanically, because of the critical dimensions involved.

Contrast control grid 73 is maintained at an appropriate potential so as to regulate the flow of flood electrons through storage grid assembly 72 towards viewing screen 82. An appropriate potential for contrast control grid 73 may be of the order of −10 volts with respect to ground and is applied by means of a connection to a source of direct-current potential 84. Collector grid 77, as previously mentioned, is connected to potential source 68, which maintains grid 77 at a potential of the order of +200 volts with respect to ground.

Viewing screen 82 is positioned within envelope 10 adjacent to and behind storage grid assembly 72 with respect to the electron guns. This screen comprises a glass plate 88, which may be the flat portion of tube envelope 10 if desired, a conductive transparent layer 89 deposited on the side of plate 88 facing the electron guns, and a thin phosphor layer 91 disposed on layer 89. Conductive transparent layers, such as conductive layer 89, are known in the art and generally consist of a layer of stannous oxide formed by the action of stannous chloride on the glass surface. Various other viewing screen materials may be used depending in the presence of oxygen on the particular application of the storage tube, the construction of such viewing screen not being critical for the purposes of this invention. Conductive layer 89 is maintained at an appropriately high positive potential so as to accelerate electrons passing through the interstices of storage grid assembly 72 to a sufficiently high velocity so that their kinetic energy will be converted to a desired amount of light at the time of impingement upon the viewing screen. This potential is applied by a connection to the positive terminal of a potential source 93 the negative terminal of which is connected to ground. The magnitude of the potential provided by source 93 may be of the order of from +3000 to +10,000 volts.

The mode of operation of the storage tube illustrated in Fig. 1 is as follows. The writing gun 21 produces the high energy electron beam which is caused to scan storage grid assembly 72 in any desired manner by means of electron beam deflecting plates 41 and 42. The electron beam is intensity modulated by the application of a signal through capacitor 29 to the intensity control grid 23 of writing gun 21. This modulating signal is synchronized with the electron beam deflecting potentials applied to the vertical and horizontal deflecting plates 41 and 42 in accordance with the particular type of scanning used.

In a radar display device, it is desirable to have each target indication, irrespective of range, appear at the same intensity and have a persistence dependent on the time interval between subsequent scans in the same direction. In general, it will be necessary to return the potential of every storage element to a common reference potential between each subsequent scan in order to prevent the viewing screen from saturating and because of possible relative motion of the target. It is also to be noted that the charging of a storage element, for the particular mode of operation described, can only take place in the positive direction, is proportional to the intensity of the bombarding electron beam, is essentially independent of a prior charge on a storage element, and is limited by the potential of the collector grid 77.

Accordingly, the described mode of operation of the disclosed storage tube involves four distinct steps, namely, the charging of each elemental area of storage surface on storage grid assembly 72 by an amount proportional to the instantaneous value of signal at the time of scanning; the returning of the potential on each elemental area of storage surface either to the potential of the source of the flood electrons or to the potential of the collector grid 77, by means of the flood electrons, depending on the initial potential; the returning of the potential of each positively charged elemental area of storage surface to a common reference potential by the continued action of the flood electrons prior to the next subsequent scan with the electron writing beam; and the penetration through the interstices of each elemental area of the assembly 72 by the flood electrons in proportion to the predominating charge on the storage surface contained therein. Thus when the flood electrons penetrating through the interstices are accelerated towards and intercepted by the viewing screen, a visual image representative of the over-all charge pattern on the storage surface 78 of assembly 72 is produced.

As previously specified collector grid 77 is maintained at a potential of the order of +200 volts with respect to ground and the cathode 12 of flood gun 11 is maintained at ground potential, hence it is apparent that the range of potentials constituting the charge pattern on storage surface 78 will vary from ground to +200 volts positive with respect to ground. Inasmuch as cathode 22 of writing gun 21 is maintained at a potential of −700 volts negative with respect to ground, the energy of incident electrons of the electron writing beam will be at least 700 electron volts. The application of the aforementioned potentials to the collector and contrast control grids 73, 77 results

in a positive potential gradient being produced from the storage surface **78** to the collector grid **77** due to the action of the flood electrons on the storage surface **78**.

The incident electrons from writing gun **21** have sufficiently high energy to liberate numerous electrons from the storage surface **78**, which are attracted to the more positive collector grid **77** thereby charging the storage surface in a positive direction. The extent to which the storage surface bombarded by high energy electrons is charged positive is a function of the intensity and the duration of the exposure of the storage surface to the electron beam. Since the conventional forms of scanning would generally expose each elemental area of storage surface of the storage grid assembly **72** for an equal length of time, the charge produced will be proportional to the intensity of the electron writing beam and, hence, the instantaneous value of signal potential.

Acting simultaneously with the writing gun **21**, is the flood gun **11** which produces a continuous supply of low velocity electrons which are directed uniformly over the storage grid assembly **72** and preferably strike it at substantially normal incidence. In the described mode of operation, the action of the flood electrons on the storage surface **78** is based on secondary electron emission principles. In this respect the collector grid **77** is maintained at a potential positive with respect to the operating range of potentials on the storage surface **78**. In addition, electrode **64** serves as an auxiliary collector electrode and is maintained at the same positive potential as that of collector grid **77** to prevent penetration of an extraneous electric field through the interstices thereof. A curve representing the secondary electron emission that would then take place is illustrated in Fig. 4. In the disclosed storage tube, since collector grid **77** is in direct contact with storage surface **78**, it is realized that a portion of the "secondary electrons" may actually be conduction electrons. Accordingly, effective secondary electrons are defined as the total number of electrons attracted to and picked up by the collector grid **77**, including repelled and reflected primary electrons and conduction electrons, in addition to true secondary electrons liberated from the storage surface material due to incident primary electrons. Secondary emission ratio, is then defined as the ratio of the number of incident primary electrons to the number of secondary electrons.

Referring to Fig. 4, it is seen that electrons arriving at the storage surface **78** with zero velocity would not have sufficient energy to penetrate the potential barrier at the surface of the material and hence, all incident primary electrons would be repelled, the resultant secondary emission ratio being equal to one. As the energy of the electrons incident on the storage surface is increased, more and more incident primary electrons penetrate the potential barrier at the surface of the material until a secondary emission ratio of considerably less than one is obtained, this range being represented by a dashed portion **100** of the curve of Fig. 4.

As the energy of the electrons incident on the storage surface is increased still further, the incident primary electrons commence to liberate an increasing number of true secondary electrons until the secondary emission ratio has again increased to one, as indicated by a point **101** in Fig. 4. The magnitude of the potential that produces this result is referred to as the "critical" potential, V_0, of the storage surface material **76**. Increasing the energy of the incident primary electrons to a value approximately twice the critical potential of the storage surface **78** results in a secondary emission ratio that may increase to approximately two or three, depending on the material. When the potential of the storage surface tends to exceed the potential of the collector grid **77**, the prospective secondary electrons are attracted back to the storage surface **78**, instead of to the collector grid **77**. Thus, the potential of the storage surface cannot be charged to a potential that is substantially more positive than the potential of collector grid **77**. When the potential of the storage surface is substantially equal to that of the collector grid **77**, the number of primary electrons must equal the number of secondary electrons, that is, the secondary emission ratio is equal to one as indicated by a point **102** in Fig. 4. When the potential of the storage surface is more positive than that of the collector grid **77**, all electrons are attracted to the storage surface. The resulting accumulation of electrons reduces the charge on the storage surface to the potential of the collector grid **77**, represented by point **102** in Fig. 4.

Thus, it is seen that when the energy of the primary electrons incident on a nonconducting surface in terms of electron volts is less than the critical potential, V_0, of the surface storage **78**, the secondary electron emission ratio will be less than one. This means that more electrons are being placed on the surface than electrons leaving. The potential of the secondary electron emitting surface is thus reduced until it is equal to the potential of the source of primary electrons. On the other hand, if the initial potential through which the incident primary electrons are accelerated in arriving at the storage surface is greater than the critical potential of the storage surface **78**, the secondary electron emission ratio will be greater than one resulting in more electrons leaving the surface than incident upon it, thereby charging the surface in a positive direction. This charging continues until the potential of the bombarded elemental areas of storage surface is equal to the potential of the collector grid **77**, at which point the prospective secondary electrons can no longer be attracted away from the surface. Should the initial potential of the storage surface **78** be greater than the potential of the collector grid **77**, the incident primary electrons will charge the surface in a negative direction until the potential of the collector grid **77** is reached.

Referring now to Fig. 5, there is illustrated an initial arbitrary charge distribution **104**, as produced by writing gun **21** along the storage surface **78** of a scanned portion of grid assembly **72**. It is to be noted that portion **107** to **108** of potential distribution **104** was initially charged to a potential equal to that of collector grid **77**. The effect of the flood electrons on the charge distribution **104** is to first decrease all potentials less than the critical potential V_0 to the potential, V_H, of the flood gun cathode **12**, namely, portions **105** to **106** and **109** to **110** of potential distribution **104**. Simultaneously with this action, the flood electrons return all potentials greater than the critical potential, namely portions **106** to **107** and **108** to **109** of potential distribution **104**, to the potential, V_C, of collector grid **77**. The potential of the portion **107** to **108** that is already charged to the potential, V_C, of collector grid **77**, remains unchanged. If the potential of the collector grid **77** is maintained at approximately twice the critical potential of the storage surface **78**, the resulting charge distribution may be preserved indefinitely.

However, as previously mentioned, it is necessary to have the storage surface **78** at a common reference potential before each subsequent scan of the electron writing beam. One method of accomplishing this is by momentarily lowering the potential of collector grid **77** to a value less than the critical potential, V_0, of the storage surface material **76**, thereby causing all the potentials on storage surface **78** to be returned to the potential of the cathode **12** of flood gun **11** by the action of the flood electrons. An alternate method of returning the potentials constituting the charge pattern on storage surface **78** to a common reference potential between subsequent scans of the electron writing beam is to maintain the potential of the collector grid **77** at a value, depending on the desired persistence, equal to approximately 1.3 times the critical potential, V_0, of storage surface **78**. With the collector grid **77** at this po-

tential, the effect of the flood electrons on the potential distribution is to decrease all potentials that are less than the critical potential to the potential, V_H, of the cathode **12** of flood gun **11**, and to raise all potentials that are greater than the critical potential, V_0, to the potential of collector grid **77** as was illustrated in Fig. 5. This process generally takes place in a very short interval of time which is somewhat longer than the time interval between successive scans of the radar system but considerably shorter than each subsequent scan across an elemental area of storage surface. The continued effect of the flood electrons then is to "shrink" the size of the areas charged to the potential of collector grid **77** until entire portions of the storage surface **78** are at the potential, V_H, of the cathode **12** of flood gun **11**. The advantage of this method over the prior method described, is that the persistence of the charge distribution on each portion of the storage surface **78** can be adjusted to a maximum making full use of the time interval between subsequent scans on each portion of the storage surface **78**, whereas in the prior method, all portions of a charge distribution on the storage surface are "erased" at the same time.

The fourth step is the penetration by the flood electrons through the interstices within each elemental area of storage grid assembly **72** in proportion to the charge predominating therein. In the operation of the storage tube, an elemental area is defined as the smallest portion of the assembly **72** which can be distinguished in the output signal from other differently charged portions. Hence, the diameter of the electron writing beam at the surface of storage grid assembly **72**, which may extend across approximately five to twenty meshes of the contrast control grid **73**, determines the size of an elemental area of storage surface. Control of the flow of flood electrons through the interstices of storage grid assembly **72** is made feasible by the application of a potential of the order of −10 volts with respect to ground to the contrast control grid **73**, thereby reducing the field penetration from viewing screen **82** through storage grid assembly **72** to an extent that allows the potential on an elemental area of storage element to be the controlling factor. Since the potential, V_H, of cathode **12** of flood gun **11** is maintained at ground potential, the flood electrons will not penetrate through areas of storage surface **78** charged to a potential, V_H, because of the negative field produced by contrast control grid **73**. However, in areas on storage surface **78** charged to a positive potential equal to that of the collector grid **77**, the negative field produced by contrast control grid **77** will be neutralized, allowing the flood electrons to proceed through storage grid assembly **72**. Hence, proper adjustment of the potential applied to contrast control grid **77** can control the flow of flood electrons through each elemental area of grid assembly **72** in accordance with the charge predominating thereon.

After the flood electrons have penetrated through storage grid assembly **72**, they are accelerated towards phosphor layer **91** by the high positive potential applied to conductive coating **89** of viewing screen **82**, the combined effect of the flood electrons impinging on phosphor layer **91** being to produce a visual image of the charge pattern on storage grid assembly **72**.

As stated previously, the disclosed direct-viewing storage tube is designed for the presentation of various types of radar displays. Figs. 6, 7, 8 and 9 illustrate the operation of the described storage tube displaying typical radar echo signals. Referring now to Fig. 6, there is illustrated a typical train of echo signals **120**, **121** and **122**, received after the transmission of an exploratory pulse. The echo signals will control the intensity of the electron beam produced by writing gun **21** as the beam is caused to sweep across storage grid assembly **72** to produce an initial potential distribution on storage surface **78** corresponding to the received echo signals **120**, **121** and **122**. As shown in Fig. 6 echo signals **120** and **122** will cause the writing beam to charge portions of the storage surface **78** to potentials which exceed the critical potential, V_0, while at the same time, echo signal **121** does not have a sufficient magnitude to cause the writing beam to charge corresponding portions of the storage surface **78** to a potential greater than the critical potential, V_0.

Then, as illustrated in Fig. 7, the action of the flood electrons will raise the potential of the storage elements **123** and **124** charged to potentials exceeding the critical potential, V_0, representative of echo signals **120** and **122**, to the potential, V_C, of collector grid **77**, and decrease the potential of storage elements at potentials less than the critical potential, V_0, representative of echo signal **121**, to the potential, V_H, of cathode **12** of flood gun **11**. The time interval required for this action by the flood electrons to take place may extend over several successive scans of the radar system.

Because of the noise generally received along with radar echo signals, any method of enhancing a target echo over the noise level is desirable. Since a target echo signal is normally received during from four to six successive scans of the radar, the commonly exposed storage elements may be used to integrate the received signals so as to produce a potential greater than the critical potential, V_0, thus separating it from the random noise. Fig. 8 illustrates how a series of echo signals **130**, **131**, **132** and **133** may be received from the same target on four successive scans by the radar system, the time, T, between successive echo signals being equal to the pulse repetition rate of the radar system. Presuming the pulse repetition rate to be sufficiently rapid, say, for example, 2,000 per second, the writing beam may still be charging the same storage elements over the several successive scans. Since the flood electrons do not have sufficient time between successive scans to discharge the initial potential on a storage element, an integrating action takes place whereby the potential on the storage element may add over several successive scans until the critical potential, V_0, is exceeded whence the flood electrons continue to cause the potential to increase until the potential, V_C, of collector grid **77** is reached. This integrating action of the flood electrons on the storage surface is illustrated in Fig. 9 wherein portions **140**, **141**, **142** and **143** represent, respectively, the corresponding increase in potentials due to echo signals **130**, **131**, **132** and **133**. Portions **145**, **146** and **147** of the curve are portions between the successive scans where the action of the flood electrons commenced to discharge the storage element.

Thus, it is seen that the disclosed storage tube embodies an improved storage grid assembly capable of effecting high speed writing on its storage surface, along with means for integrating the charge on an elemental area of storage surface over several successive scans, and means for controlling the persistence of the writing.

What is claimed as new is:

1. An electronic storage tube including a unitary storage grid assembly comprising a first perforated conductive screen, a layer of dielectric material disposed over one side and coextensive only with the meshes of said first screen, said dielectric material having secondary electron emission characteristics, and a second perforated conductive screen on said one side of said first conductive screen in contact with said layer of dielectric material, the portions of said layer of dielectric material exposed within the perforations of said second screen constituting storage surface; a viewing screen disposed adjacent to and coextensive with said storage grid assembly on the other side of said first screen; means for maintaining said second screen sufficiently positive with respect to said first screen to collect secondary electrons emitted from said storage surface; means utilizing the secondary electron emission characteristics of said layer of dielectric material for producing an electric charge pattern rep-

resentative of a signal on the storage surface of said storage grid assembly; and means for directing flood electrons through the interstices of said storage grid assembly in proportion to the charge on the storage surface thereof to said viewing screen to produce a visual presentation of said charge pattern.

2. The electronic storage tube as defined in claim 1 wherein said means utilizing the secondary electron emission characteristics of said layer of dielectric material for producing an electric charge pattern includes means for directing flood electrons uniformly over said storage grid assembly to liberate secondary electrons from the storage surface thereof, said flood electrons emanating from a source maintained at a potential that is negative relative to the potential of said second screen whereby said secondary electrons are collected by said second screen, thereby charging said storage surface to the potential of said source to produce a potential gradient from said storage surface to said second screen; means for generating a high energy electron beam of elemental cross sectional area; means for intensity modulating said electron beam with said signal; and means for scanning said storage grid assembly with said modulated electron beam in synchronism with said signal to liberate electrons from each scanned portion of said storage surface in proportion to the intensity of the beam thereon, whereby said liberated electrons are attracted to said second screen by said potential gradient to produce said charge pattern on said storage surface.

3. The electronic storage tube including the storage grid assembly as defined in claim 1 wherein said layer of dielectric material is a phosphor dielectric.

4. The electronic storage tube including the storage grid assembly as defined in claim 1 wherein said second conductive screen is an electrodeposited metallic screen having a thickness less than 0.001 inch.

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