July 2, 1957 S. HANSEN ET AL 2,798,185

DIRECT-VIEWING STORAGE TUBE

Filed March 9, 1954

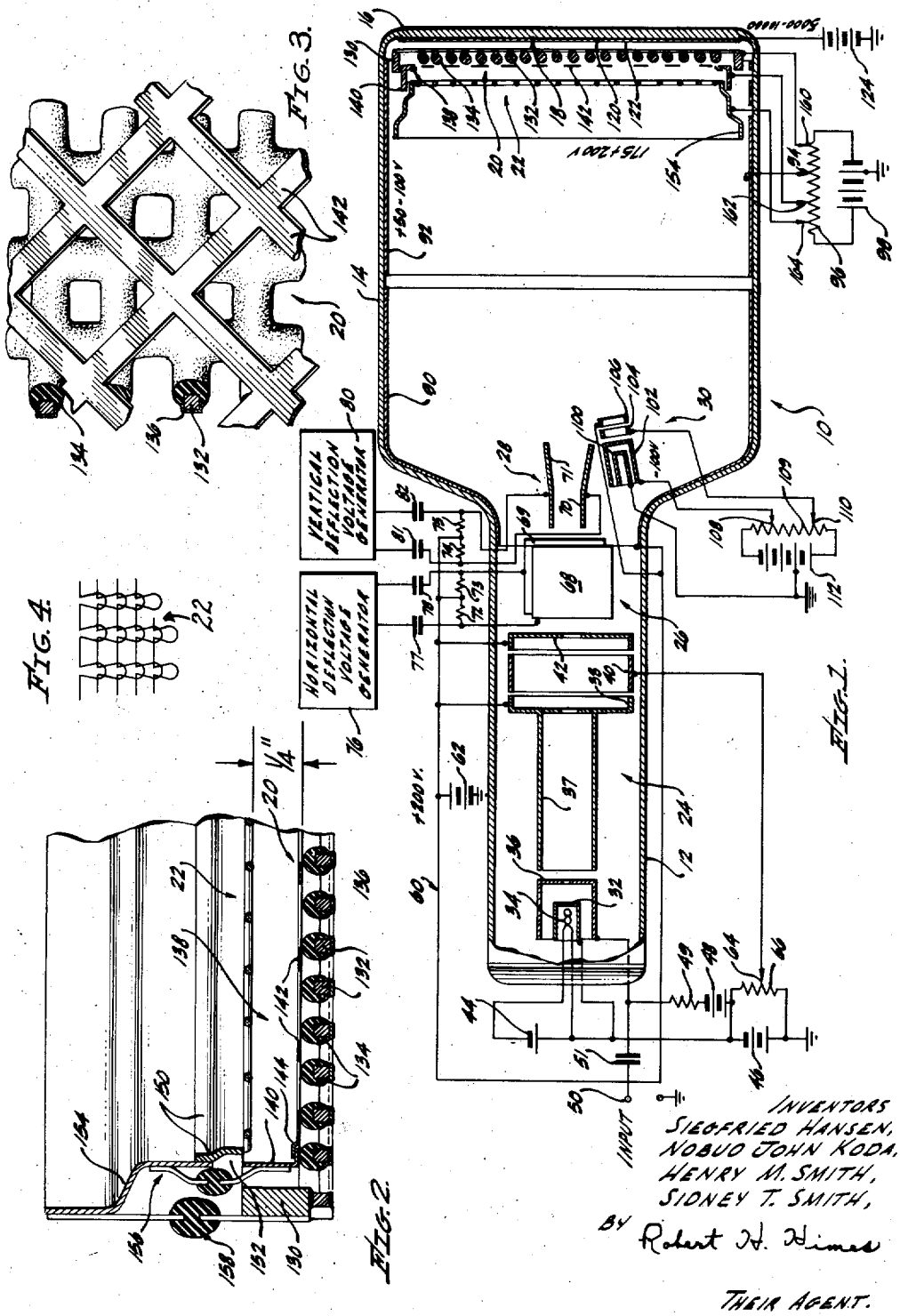


FIG. 1.

FIG. 3.

FIG. 4.

FIG. 2.

INVENTORS
SIEGFRIED HANSEN,
NOBUO JOHN KODA,
HENRY M. SMITH,
SIDNEY T. SMITH,
BY Robert H. Himes
THEIR AGENT.

United States Patent Office

2,798,185

Patented July 2, 1957

2,798,185

DIRECT-VIEWING STORAGE TUBE

Siegfried Hansen, Los Angeles, Nobuo John Koda, Culver City, and Henry M. Smith and Sidney T. Smith, Pacific Palisades, Calif., assignors to Hughes Aircraft Company, a corporation of Delaware

Application March 9, 1954, Serial No. 414,992

5 Claims. (Cl. 315—13)

This invention relates to direct-viewing storage tubes, and more particularly to an improved direct-viewing storage tube incorporating apparatus for repelling positive ions away from the surface areas employed to store electric charge.

The improved direct-viewing storage tube hereinafter described is of the same general type as the storage tube disclosed in a copending United States patent application by Siegfried Hansen, Serial No. 299,363, filed July 17, 1952, and entitled, "Direct-Viewing Storage Tube." In addition, the improved direct-viewing storage tube employs a storage grid assembly of the type disclosed in a copending United States patent application by Henry M. Smith, Serial No. 409,240, filed February 9, 1954, and entitled, "Direct-Viewing Storage Tube."

In the storage tubes of the aforementioned Hansen and Smith applications, "writing" is accomplished by charging selected areas of the storage grid assembly in a positive direction by means of a high velocity electron beam. This storage grid assembly then controls the flow of a broad beam of electrons, known also as "flood electrons," to a viewing screen to produce a visual image of the charged areas on the storage grid assembly. In the operation of these tubes, it was discovered that the writing speed in the central area of the storage grid assembly was considerably slower than the writing speed for the peripheral areas. The cause of this slower writing speed has generally been attributed to contamination of the storage surface areas by positive ion bombardment since, in the manufacture of the tube, there is always some residual gases left in the evacuated envelope. In operating the tube, the broad beam of electrons, which permeate substantially the entire volume of the evacuated envelope, collides with the molecules constituting the residual gases to produce numerous positive ions. Inasmuch as the composite potential of the storage grid assembly is much lower than the potential of the peripheral regions of the tube, the potential of the central region of the tube is more negative than the potential of the peripheral regions. Thus, the positive ions are attracted towards the more negative central region of the tube which results in a more intense bombardment by positive ions of the central area, rather than of the peripheral areas, of the storage grid.

The improved direct-viewing storage tube of the present invention overcomes the aforementioned difficulties by incorporating a highly transparent "ion repeller grid" that is disposed coextensively with and spaced from the storage grid assembly. The function of the ion repeller grid is to isolate the relatively low composite potential of the storage grid assembly from the main body of the tube. Furthermore, the ion repeller grid may be operated so as to actually repel positive ions away from the storage surfaces and thus keep these surfaces from becoming contaminated by the positive ions. A direct-viewing storage tube incorporating the ion repeller grid of the present invention has several advantages over the tubes disclosed in the aforementioned Hansen and Smith applications. By way of example, the writing speed is substantially uniform over the entire area of the storage grid assembly, making it possible to employ the tube at its maximum efficiency at all times. Further, the shielding of the storage grid assembly eliminates the potential variations across the main body of the tube thus enabling the flood electrons to be directed towards the storage grid assembly in a much more uniform beam than in the prior tubes. This generally will enable the tube to be made in much larger sizes than previously practical. In addition, the ion repeller grid enables the flood electrons to be directed towards the storage grid assembly at substantially normal incidence, which minimizes distortion of a visual image controlled by the positively charged areas. The ion repeller grid also makes spot erasing possible. The ion repeller grid will also greatly lengthen the useful life of the tube by reducing the rate at which the storage surface is contaminated by positive ions.

It is therefore an object of this invention to provide an improved direct-viewing storage tube having a uniform writing speed over the entire area of storage surface.

Another object of this invention is to provide a direct-viewing storage tube employing apparatus to prevent contamination of the storage surface by positive ions.

Still another object of this invention is to provide a direct-viewing storage tube incorporating a highly transparent grid to repel positive ions from the storage surface.

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, which are made a part of this description, 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 direct-viewing storage tube of the present invention together with associated circuitry;

Fig. 2 illustrates an enlarged sectional view of a portion of the storage grid assembly and associated electrodes for the tube of Fig. 1;

Fig. 3 shows a plan view of a portion of the storage grid assembly in the tube of Fig. 1; and

Fig. 4 shows a plan view of a portion of the "stocking knit" ion repeller grid in the tube of Fig. 1.

Referring to Fig. 1, there is shown an embodiment of the present invention comprising an evacuated envelope **10** including a neck portion **12** that expands into an enlarged cylindrical portion **14**, the end of which is enclosed by a flat end portion **16**. A viewing screen **18** is disposed on the inner surface of the flat end portion **16** of envelope **10** and a storage grid assembly **20** together with a highly transparent ion repeller grid **22** are disposed coextensive with, as well as adjacent and parallel to the viewing screen **18**.

Facing the storage grid assembly **20** and disposed in the neck portion **12** of envelope **10** is an electron gun **24** for producing a high energy electron beam. Horizontal and vertical electron beam deflecting means **26** and **28**, respectively, are positioned about the path of the high energy electron beam for directing it to selected areas of the storage grid assembly **20**. A flood gun **30** is disposed in the left extremity of the enlarged cylindrical portion **14** of envelope **10**, as viewed in the drawing, for producing a broad beam of electrons directed towards the storage grid assembly **20**.

The electron gun **24** comprises a cathode **32** with a

heating element 34, an intensity grid 36, an accelerating electrode 37, and focusing electrodes 38, 40, and 42. Heating element 34 is connected across a source of potential 44 and has one side connected to cathode 32 as shown. Cathode 32 is maintained at a potential of the order of —3000 volts with respect to ground by means of a connection to the negative terminal of a battery 46, the positive terminal of which is connected to ground. Intensity grid 36 surrounds the cathode 32 except for an aperture on the longitudinal axis of neck portion 12 and is maintained at a potential of from 50 to 100 volts negative relative to the potential of cathode 32 by means of a battery 48 connected in series with a resistor 49 between cathode 32 and grid 36. An input terminal 50 is connected through a capacitor 51 to intensity grid 36 to provide a means for modulating the electron beam.

Electrodes 38, 40 and 42 provide an electrostatic lens for focusing the beam crossover formed near intensity grid 36 on the surface of storage grid assembly 20. These electrodes are annular in shape and have equal diameters of the order of one inch and the outer electrodes 38, 42 have appendages enclosing all but a center aperture on both open ends. Electrodes 38, 40 and 42 are disposed successively along and concentrically about the electron beam intermediate the intensity grid 36 and the storage grid assembly 20, electrodes 38 and 42 being maintained at a potential of the order of 200 volts positive with respect to ground and electrode 40 at an adjustable potential of the order of 2200 volts negative with respect to ground. These potentials are applied by means of connections from electrodes 38, 42 to a bus 60 which is maintained at 200 volts by a battery 62, and a connection from electrode 40 to a tap 64 of a potentiometer 66 which is, in turn, connected across battery 46. Accelerating electrode 37 is a tubular element disposed concentrically about the electron beam and extending from the appendage of electrode 38 to intensity grid 36 to provide a drift space for the beam electrons. Electrode 37 is maintained at the same potential as focusing electrode 38 by being integrally attached thereto.

Horizontal and vertical electron beam deflecting means 26 and 28 comprise horizontal deflection plates 68, 69 and vertical deflection plates 70, 71 which are maintained at a quiescent potential of +200 volts positive with respect to ground by means of connections to bus 60 through isolation resistors 72, 73 and 74, 75, respectively. Horizontal deflection plates 68, 69 are energized by a horizontal deflection voltage generator 76 through capacitors 77, 78, respectively and across isolation resistors 72 and 73. Similarly, vertical deflection plates 70, 71 are energized by a vertical deflection voltage generator 80 through capacitors 81, 82, respectively and across isolation resistors 74 and 75.

Electrodes 90, 92 are disposed concentrically about the inner periphery of envelope 10 in succession from vertical deflection plates 70, 71 to storage grid assembly 20. These electrodes are composed of a conductive coating, which may be provided, for example, by painting the envelope 10 with a colloidal solution of carbon such as "aquadag." Electrode 90 is maintained at a potential of the order of +200 volts with respect to ground by means of a connection to a bus 60 while electrode 92 is maintained at a potential of from 50 to 100 volts positive with respect to ground by means of a connection therefrom to a tap 94 of a potentiometer 96 which is connected across a battery 98, an intermediate terminal of which is connected to ground so that potentiometer 96 provides both positive and negative potentials.

Flood gun 30, in conjunction with electrodes 90 and 92, produces a broad beam of flood electrons that are directed uniformly over the entire area of storage grid assembly 20. Flood gun 30 is disposed adjacent vertical deflection plate 70 and comprises a cathode 100 positioned within an intensity grid 102 which has a circular aperture in its center portion, and annular electrodes 104 and 106, disposed in succession in front of and concentrically about the aperture in intensity grid 102. Cathode 100 is operated at ground potential by means of a connection thereto while intensity grid 102 is maintained at a potential of the order of 100 volts negative with respect to ground. The latter is accomplished by means of a connection from intensity grid 102 to an adjustable tap 108 of a potentiometer 109 which is connected across a battery 112, an intermediate tap of which is connected to ground so that both positive and negative potentials are available from potentiometer 109. Electrode 106 is maintained at a potential of the order of +200 volts with respect to ground by means of a connection to bus 60 while electrode 104 is maintained at a potential of from 150 to 200 volts positive with respect to ground, depending upon the desired diameter of the beam of flood electrons. This potential is applied to electrode 104 by means of a connection thereto from a tap 110 on potentiometer 109.

Viewing screen 18 comprises a transparent conductive coating 120 and a luminescent screen 122 disposed in the order named on the inner surface of end portion 16 of envelope 10. A voltage of the order of from 5,000 to 10,000 volts with respect to ground is impressed on the transparent conductive coating 120 by means of a connection to the positive terminal of a battery 124, the negative terminal of which is connected to ground.

The storage grid assembly 20 and ion repeller grid 22 are disposed approximately ¼ inch apart adjacent to and in planes parallel with the viewing screen 18.

An enlarged cross sectional view showing the storage grid assembly 20 and the ion repeller grid 22 is shown in Fig. 2 and enlarged plan views of a portion of the storage grid assembly 20 and the ion repeller grid 22 are shown in Figs. 3 and 4, respectively. Referring to these figures, the storage grid assembly 20 comprises a metal ring 130 welded to one side of the periphery of an electroformed nickel screen 132, the screen 132 serving as a contrast control grid. A screen suitable for this purpose is of the order of 0.0005 to 0.001 inch thick and has 250 meshes per inch with a light transparency of 40 percent. A coating 134 of dielectric material having a thickness of the order of 0.002 inch and possessing secondary electron emission is disposed uniformly over the same one side of the nickel screen 132 in a manner to overhang the interstices of the screen and yet not clog them entirely. The light transparency of the nickel screen 132 with the coating 134 is from 20 to 23 percent. The coating 134 may be applied to the screen 132 by spraying the screen with a suspension of dielectric material such as, for example, talc simultaneously with the forcing of air through its interstices. Subsequent to coating screen 132 with the talc, it is placed in an oven and subjected to a temperature of 500° C. for 15 minutes. A thin layer of metal 136 is then evaporated over the screen 132 together with those portions of the surface of coating 134 which overhang the interstices thereof to provide a means for maintaining the potential of these surfaces the same as that of the screen 132.

A collector electrode 138 for the storage grid assembly 20 includes an annular electrode 140 and a thin conductive screen 142. Annular electrode 140 is disposed about the periphery of screen 132 just inside of ring 130 and has its edge nearest dielectric coating 134 bent under and in to form a narrow ledge 144. Thin conductive screen 142 which has of the order of from 100 to 200 meshes per inch is disposed over the surface of the dielectric coating 134 and overlaps ledge 144 on the edges, thereby effecting electrical contact to annular electrode 140. The exposed portions of the surface of coating 134 provide the storage surface on the storage grid assembly 20. Further, the meshes of the thin con-

ductive screen **142** are disposed at an angle of from 20° to 40° with the meshes of nickel screen **132** to minimize the moire effect on the flood electrons.

The ion repeller grid **22** is disposed coextensively over the entire area of the storage grid assembly **20** at a distance therefrom sufficient to establish a continuous equipotential field across the tube. This distance will generally depend on the specific characteristics of the grid employed, ¼ inch being satisfactory for the particular grid used. A stocking knit tungsten screen, such as is shown in Fig. 4, having a light transparency of the order of 90% and of the order of 40 strands per inch is a preferable type of screen for use as grid **22**. An additional requisite of grid **22** is that the wires out of which it is composed have sufficient tensile strength so it may be stretched sufficiently taut across the face of storage grid assembly **20** to withstand the forces of attraction therebetween produced by the different potentials. Ion repeller grid **22** is maintained taut across a metal ring **150** which has an annular groove **152** so that it may be inserted in annular electrode **140** and remain in spaced relation therewith. Metal ring **150** is welded to an additional annular electrode **154** which commences as an extension of annular electrode **140** and expands out to a diameter equal to the outer diameter of ring **130**. Insulated supporting rods are attached to ring **130** and annular electrodes **140**, **154** in the manner shown by supporting rods **156** and **158** in Fig. 2 to retain the storage grid assembly **20** and the ion repeller grid **22** in correct relative position with respect to each other.

Referring again to Fig. 1, in the preferable mode of operating the tube of the present invention, contrast control grid **132** is maintained at a potential of the order of −10 volts negative with respect to ground, collector electrode **138** is maintained at a potential from +175 to +200 volts positive with respect to ground, and ion repeller grid **20** is preferably maintained at a potential that is positive with respect to the potential of collector electrode **138** such as, for example, +200 volts with respect to ground but, if desired, may be maintained at the same potential. This latter potential should be sufficiently high so that it predominates across the face of storage grid assembly **20** and, in addition, should be equal to or greater than the potential applied to collector electrode **138** so as to minimize the number of electrons intercepted by the electrode **138**, since higher velocity electrons are less easily diverted. The aforementioned potentials are impressed on contrast control grid **132**, collector electrode **138**, and ion repeller grid **22** by connections therefrom to taps **160**, **162** and **164**, respectively, of potentiometer **96**.

In the operation of the direct-viewing storage tube of the present invention, it is necessary to maintain a potential gradient from the storage surface of storage grid assembly **20** to the collector electrode **138** thereof. This is effected by means of flood electrons produced by flood gun **30**. Flood electrons, emanating from cathode **100** of flood gun **30**, which is maintained at ground potential, are directed uniformly through ion repeller grid **22** over the entire storage grid assembly **20**. The flood electrons incident on the storage surface liberate fewer secondary electrons than incident primary electrons to charge the storage surface in a negative direction until it has reached ground potential, the potential of flood gun cathode **100**. In this manner, a potential gradient is produced from the storage surface provided by the surface of dielectric material **134** within the interstices of thin conductive screen **142** to the conductive screen **142** of collector electrode **138**.

In the above phase of the operation, the contrast control grid **132** is sufficiently negative to allow the flood electrons to penetrate only through the interstices within areas of the storage grid assembly wherein the storage surface is charged positive with respect to ground. In order to accomplish this, however, it is necessary to allow a small percentage of the flood electrons to penetrate the areas of storage grid assembly **20** wherein the storage surface is at ground potential. This percentage, of course, is made as small as possible as it detrimentally affects the contrast of the resultant visual image produced by the tube. Also, the meshes of the thin conductive screen **142** are disposed at an acute angle with the meshes of contrast control grid **132** to minimize the moire effect on the flood electrons as disclosed in the aforementioned Smith application.

Writing on the storage grid assembly constitutes the charging of storage surfaces within selected areas thereof in a positive direction by means of the high energy electron beam produced by electron gun **24**. This electron beam is modulated by means of a signal impressed on input terminal **50**. Positively charged areas are produced on the storage surface by directing this modulated electron beam over the storage grid assembly **20** by deflection means **26**, **28** in a manner consistent with the charge pattern that it is desired to produce. Each high energy electron incident on the storage surface releases numerous electrons which are attracted to conductive screen **142** of collector electrode **138** by the potential gradient to charge the storage surface in a positive direction. Subsequent action of the flood electrons then charges those portions of the storage surface charged more positive than the critical potential of the dielectric material to the potential of collector electrode **138** and maintains these portions at this potential for a period of time dependent on the potential applied to the collector electrode relative to the critical potential of the dielectric material.

A visual image of the positively charged areas on the storage surface is then produced on the viewing screen **18** by the action of the flood electrons. A positive charge on the storage surface effects field penetration through the storage grid assembly **20** to the viewing screen **18**. This enables flood electrons incident on the positively charged portions of the storage surface to penetrate through the interstices in these portions to the viewing screen **18** to produce a visual image of the positively charged portion of the storage surface.

This visual image may be retained so long as collector electrode **138** is maintained at a potential of the order of twice the critical potential of the dielectric storage surface material **134**. When it is desired to erase the image corresponding to the positive charged areas on the storage surface, it is only necessary to momentarily lower the potential of the collector electrode **138** to a potential that is less than the critical potential of the storage surface and then raise it gradually back to its original value. In this event, the potential of the storage surface is returned to the potential of the flood gun cathode **100** by the flood electrons, thereby creating a potential gradient from the storage surface to conductive screen **142**, thus making storage grid assembly **20** ready for writing by the high energy electron beam.

In the above described operation of the direct-viewing storage tube, the flood electrons permeating substantially the entire volume of evacuated envelope **10** produce numerous positive ions from the residual gases remaining in the tube. These positive ions converge towards the center regions of the tube due to the more positive potentials impressed on electrodes **90**, **92** relative to the composite potential of the storage surface and collector electrode **138** of storage grid assembly **20**. Thus, in the absence of the ion repeller grid **22**, the rate of incidence of these positive ions on the storage surface in the center region of the storage grid assembly **20** is substantially greater than the rate of incidence in the outer regions. The effect of the positive ions is to contaminate the storage surface whereby, in addition to the other aforementioned detrimental results, the contaminated areas are charged in a positive direction at a considerably

reduced rate. In the direct-viewing storage tube of the present invention, the positive ions produced in the main body of the evacuated envelope are prevented from impinging on the storage surface by the ion repeller grid **22**. The grid **22** is disposed coextensively over the entire area of the storage grid assembly **20** so as to isolate the more negative composite potential thereon from the main body of the tube. Since ion repeller grid **22** is operated at a potential equal to or more positive than that of collector electrode **138**, only the positive ions produced between the grid **22** and conductive screen **142** of collector electrode **138** will impinge uniformly over the storage surfaces of storage grid assembly **20**. In this range of potentials, the flow of flood or writing electrons to the storage grid assembly **20** is not affected. By preventing the contamination of the storage surfaces, the writing speed is not only made uniform over the entire storage grid assembly but made considerably faster. Furthermore, the shielding of the storage grid assembly **20** by the ion repeller grid **22** eliminates the potential variations within the main body of the tube thus enabling the flood electrons to be directed more uniformly over the storage area making the manufacture of larger tubes more feasible. Also, it is possible for the ion repeller grid to function as an auxiliary collector grid during the erasing operation. This has the effect of increasing the rate at which erasing can be accomplished and also makes spot erasing possible by eliminating the formation of a cloud of secondary electrons near bombarded areas of the storage grid assembly.

What is claimed as new is:

1. A direct-viewing electronic storage tube comprising a storage grid assembly including a collector grid on one side thereof, means for maintaining said collector grid at a first predetermined potential level; means, employing said collector grid, for producing a charge pattern representative of an image to be reproduced on said one side of said storage grid assembly, a viewing screen disposed in a plane parallel to and coextensive with said storage grid assembly on the other side thereof, means including a flood gun disposed in a position facing said storage grid assembly on said one side thereof for directing a broad beam of flood electrons uniformly over said storage grid assembly to act upon said charge pattern and to penetrate through the interstices thereof to said viewing screen to reproduce said image, a transparent grid interposed between said flood gun and the collector grid of said storage grid assembly on said one side thereof, and means for maintaining said transparent grid at a potential not less than said predetermined potential level.

2. The direct-viewing electronic storage tube as defined in claim 1 wherein the light transparency of said transparent grid is not less than 90%.

3. The direct-viewing electronic storage tube as defined in claim 1 wherein said transparent grid is composed of stocking knit tungsten strands.

4. A direct-viewing electronic storage tube comprising an evacuated envelope containing some residual gases; a storage grid assembly within said envelope including a first conductive screen to provide a contrast control grid, a coating of dielectric material disposed uniformly over one side of said first screen overhanging the interstices thereof, and a second conductive screen disposed in contact with the surface of said coating of dielectric material to provide a collector grid, the portions of the surface of said coating of dielectric material within the interstices of said second screen constituting storage surface; means employing said collector grid for producing a charge pattern representative of an image to be reproduced on said storage surface; a viewing screen coextensive with said storage grid assembly disposed in a plane adjacent and parallel thereto on the other side of said first screen; means for directing a broad beam of electrons uniformly over said storage grid assembly to act upon said charge pattern and to penetrate through the interstices thereof to said viewing screen to reproduce said image whereupon said electrons collide with the molecules constituting said residual gases to produce numerous positive ions; and means spaced from said collector grid for repelling said positive ions away from said storage surface.

5. A direct-viewing electronic storage tube comprising a storage grid assembly including a first conductive screen to provide a contrast control grid, a coating of dielectric material having secondary electron emission characteristics disposed uniformly over one side of said first screen and overhanging the interstices thereof, and a second conductive screen disposed in contact with the surface of said coating of dielectric material to provide a collector grid, the portions of the surface of said coating of dielectric material within the interstices of said second screen constituting storage surface; means for maintaining said collector grid at a predetermined potential level; means employing said collector grid for producing a charge pattern representative of an image to be reproduced on said storage surface; a viewing screen coextensive with said storage grid assembly disposed in a plane adjacent and parallel thereto on the other side of said first screen means including a flood gun disposed in a position facing said storage grid assembly on said one side of said first screen thereof for directing a broad beam of electrons uniformly over said storage grid assembly to act upon said charge pattern and to penetrate through the interstices thereof to said viewing screen to reproduce said image; a transparent grid interposed between said flood gun and said storage grid assembly; and means for maintaning said transparent grid at a potential no less than said predetermined potential level.

References Cited in the file of this patent

UNITED STATES PATENTS

1,814,805	Hitchcock	July 14, 1931
2,151,158	Schroter	Mar. 21, 1939
2,259,507	Iams	Oct. 21, 1941
2,449,569	Varian	Sept. 21, 1948
2,544,755	Johnson	Mar. 13, 1951