Dec. 31, 1957 S. T. SMITH ET AL 2,818,524

MULTI-COLOR STORAGE TUBE

Filed Oct. 2, 1956 2 Sheets-Sheet 1

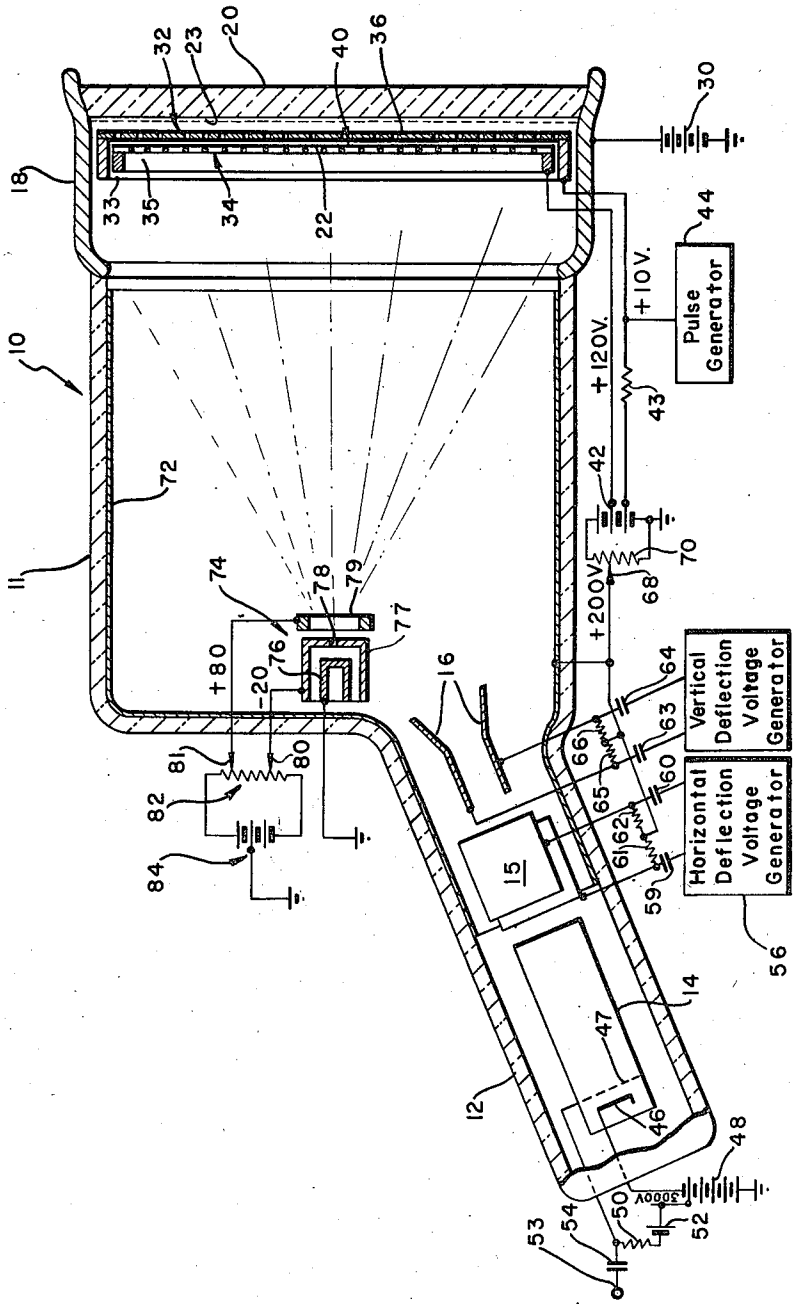


Fig. 1.

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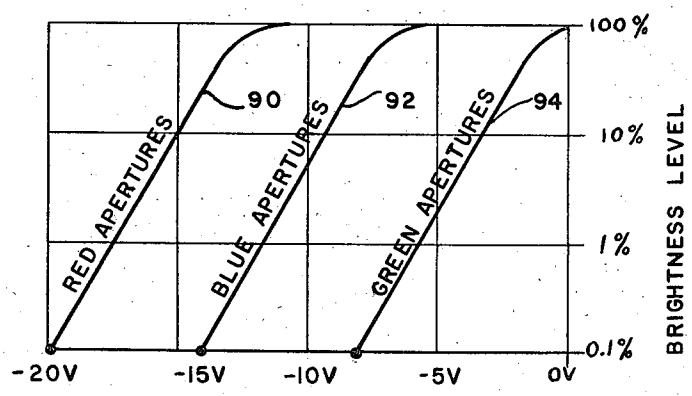


Fig. 3.

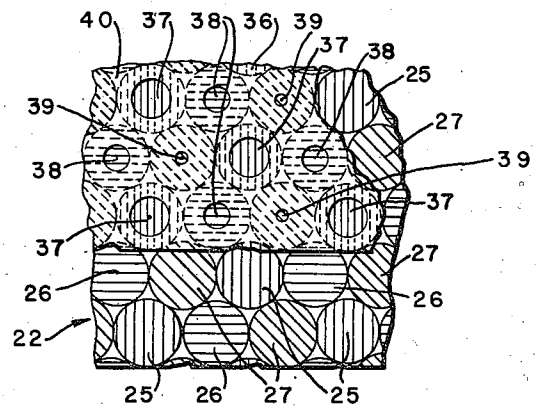


Fig. 2.

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MULTI-COLOR STORAGE TUBE

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Application October 2, 1956, Serial No. 613,413

5 Claims. (Cl. 315—12)

This invention relates to a direct-viewing half-tone type color storage tube and more particularly to a direct-viewing storage tube for presenting a radar display wherein signals are presented in various degrees of brightness and color. That is, in the tube of the present invention, multiple colors are employed to produce a presentation having an increased range of half-tones and not to reproduce a scene in color.

It is an object of this invention to produce a half-tone type storage tube wherein variations in tone appear in different colors.

Another object of the invention is to provide a direct-viewing type storage tube particularly adapted for producing a radar presentation wherein target echo signals normally appear in a different color from that of noise signals.

Still another object of the invention is to provide an improved multi-color half-tone storage tube which requires no special convergence or color purity circuits or special electron beam deflection components and, in addition, has a brightness and writing speed several times that of conventional color storage tubes which employ a shadow mask.

According to the invention, a conventional phosphor dot viewing screen is employed which, in the event three colors are used, has each phosphor dot of a particular color touching phosphor dots of different colors. A storage screen with its associated collector grid is disposed adjacent to and coextensive with this phosphor dot viewing screen. This storage screen is characterized by the fact that it has one aperture disposed in alignment with each phosphor dot of the viewing screen. Further, the size of each aperture in alignment with a particular color of dot is different from the apertures in alignment with the remaining colors. Thus, if the viewing screen is, for example, composed of red, blue and green phosphor dots, the area of apertures in alignment with the red dots may, for example, be six times the area of the apertures in alignment with the blue dots, which apertures may, in turn, be six times as large as the apertures in alignment with the green dots. Also provided is an electron writing gun for producing a charge pattern on the storage surface of the storage screen and a flood gun for directing flood electrons uniformly over the entire area of the storage screen.

In operation the cathode of the flood gun is operated at a potential positive with respect to the potentials constituting the charge pattern produced on the storage surface by the electron writing gun. In producing the charge pattern, the extent to which an elemental area of storage surface is charged positive is determined by the amplitude of the signal applied to the intensity grid of the electron writing gun. As in present day direct-viewing half-tone storage tubes, the charge on the storage surface controls the flow of flood electrons through the storage screen to the viewing screen. In the tube of the present invention, however, due to the different sizes of the apertures in alignment with the different colored phosphor dots, a low level signal will produce a charge on the storage surface which

will allow flood electrons to flow only through the larger apertures in alignment with the red dots. As the signal becomes increasingly greater, a 100 percent brightness will be reached on the red dots and flood electrons will commence to flow through the smaller apertures in alignment with the blue dots. As the amplitude of the signal increases still further, a charge is produced on the storage surface which will allow 100 percent brightness on both the red and blue dots and will commence to allow flood electrons to flow through the apertures in alignment with the green dots. Finally, a charge of sufficient magnitude is produced on the storage surface to allow sufficient food electrons to flow through the apertures in alignment with the red, blue and green apertures to correspond to 100 percent brightness. The presentation on the viewing screen corresponding to this charge will appear white. As is evident from the above, no color mask is required to produce the different colors in the device of the present invention in contrast with most present day color storage tubes. This, of course, greatly enhances efficiency of operation and the writing speed capable of being achieved.

The above-mentioned and other features and objects of this invention and the manner of attaining them will become more apparent by reference to the following description taken in conjunction with the accompanying drawings, wherein:

Fig. 1 shows a cross-sectional schematic view of one embodiment of the present invention;

Fig. 2 shows an enlarged portion of the phosphor dot viewing screen and a cut-away portion of the storage screen; and

Fig. 3 shows the relative degrees of brightness on the red, blue and green apertures for various potentials on the storage surface.

Referring now to the drawings, Fig. 1 shows a direct-viewing storage tube in accordance with the present invention. This tube comprises an evacuated envelope **10** which includes a comparatively large cylindrical section **11** which has a non-axially aligned neck portion **12** at the left extremity, as viewed in the drawing, for housing an electron gun **14** for producing an electron beam of elemental cross-sectional area and horizontal and vertical deflecting plates **15** and **16**, respectively, for controlling the deflection of the electron beam. The right extremity of the cylindrical portion **11** of evacuated envelope **10**, as viewed in the drawing, has an extension which constitutes an annular metallic ring **18**. This annular metallic ring **18** is, in turn, sealed off by a face plate **20**.

A viewing screen **22** is disposed on the inner surface of the face plate **20**. This viewing screen **22** includes a transparent conductive coating **23**, such as "Nesa," disposed over the entire inner surface of face plate **20** and in electrical contact with the metallic annular ring **18** of evacuated envelope **10**. An array of phosphor color dots are then disposed on the transparent conductive coating **23** in alignment with the storage mesh apertures. These dots may, for example, be disposed on the transparent conductive coating **22** in a conventional manner by using a shadow mask which matches the storage mesh to be used as a master. In the described embodiment, the colors of the phosphor dots are chosen so that approximately white light is produced when all three colors are at full brilliance. Colors of phosphor dots capable of producing white light are red, blue and green. Referring to Fig. 2, there is shown an enlarged portion of the viewing screen **22**. In this figure the dots **25** are red, dots **26** are blue and dots **27** are of green phosphor. Each dot is of the order of 13 mils in diameter and is in contact only with dots of another color. In operation the screen **22** is maintained at a potential of the order of

5,000 volts positive with respect to ground by means of a connection from the annular ring **18** to the positive terminal of a battery **30**, the negative terminal of which is connected to ground.

Disposed adjacent to and co-extensive with viewing screen **22** are a storage screen **32** and its associated collector grid **34** supported by concentric metallic rings **33** and **35**, respectively. The storage screen **32** comprises a thin sheet of metal **36** composed, for example, of cupronickel. The metallic sheet **36** is of the order of from 3 to 6 mils thick. As shown in Fig. 2, the cupronickel sheet **36** is provided with apertures in alignment with each phosphor dot on the viewing screen **22**. As previously specified, the diameter of the apertures in alignment with the different colors of phosphor dots are different. In particular, the diameter of apertures **37** in alignment with the red phosphor dots is approximately 6.25 mils, the diameter of apertures **38** in alignment with the blue phosphor dots **36** is approximately 2.5 mils, and the diameter of the apertures **39** in alignment with the green phosphor dots **27** is approximately 1.0 mil. The storage surface is provided by a layer **40** of dielectric material disposed over the remaining areas of metallic sheet **36** on the side thereof opposite the viewing screen **22**. This layer **40** of dielectric material may constitute, for example, a layer of magnesium fluoride of the order of 5 microns thick evaporated on one side of the cupronickel sheet **36**.

Disposed adjacent to and co-extensive with the storage surface side of storage screen **32** is the collector grid **34**. The collector grid may be provided by either a woven or electroformed mesh having a pitch of approximately 150 meshes per inch. In operation the metallic sheet **36** of storage screen **32** and the collector grid **34** are maintained at potentials of +10 volts and +120 volts, respectively, by means of connections therefrom to intermediate terminals of a battery **42**, the negative terminal of which is connected to ground. In particular the lead of the metallic sheet **36** of storage screen **32** is connected to the battery **42** through a load resistor **43**. This enables the output from a pulse generator **44** to be connected directly to the cupronickel sheet **36**. Pulse generator **44** provides pulses having positive excursions, which pulses raise the potential of the storage surface, thus enabling it to be erased by the flood electrons as will be hereinafter explained in more detail.

As previously specified, neck portion **12** of evacuated envelope **10** houses electron writing gun **14** together with the horizontal and vertical deflecting plates **15** and **16**, respectively. The gun may, of course, be magnetically deflected equally well in cases where magnetic, rotating deflection yokes would be used, i. e., for a P. P. I. display. The electron writing gun **14** includes a cathode **46** and an intensity grid **47**. The cathode **46** of gun **14** is maintained at a potential of the order of —3000 volts with respect to ground by means of a connection therefrom to the negative terminal of battery **48**, the positive terminal of which is connected to ground. Further, the intensity grid **47** of gun **14** is maintained at a quiescent potential of the order of 75 volts negative with respect to cathode **46**. This is accomplished by means of a connection from the grid **47** through a load resistor **50** to the negative terminal of a source of biasing potential **52**, the positive terminal of which is referenced to the cathode **46**. Means for modulating the intensity of the electron writing beam is provided by a connection from an input terminal **53** through a capacitor **54** across the load resistor **50** to the intensity grid **47** of gun **14**.

The electron beam produced by electron writing gun **14** is scanned over the storage screen **32** in the desired manner by means of horizontal and vertical deflection voltages generated by horizontal and vertical deflection voltage generators **56** and **58**, respectively. The horizontal deflection signal is applied to the horizontal deflecting plate **15** through capacitors **59**, **60** across isolating resistors **61**, **62**. Similarly, the vertical deflection signal is applied to the vertical deflecting plates **16** through capacitors **63**, **64** across isolating resistors **65**, **66**. The horizontal and vertical deflecting plates **15**, **16** are maintained at a quiescent potential of the order of 100 volts positive with respect to ground by means of connections from the common junctions between resistors **61**, **62** and **65**, **66** to a tap **68** of a potentiometer **70** which, in turn, is connected across the terminals of the battery **42**. In addition to the above, an equipotential region is maintained intermediate the deflecting plates **15**, **16** and the annular ring **18** by means of a conductive coating **72** disposed over the inner surface of the evacuated envelope **10** throughout this region. This conductive coating **72** may, for example, be composed of "Aquadag" and is maintained at a potential equal to that of the quiescent potential applied to deflecting plates **15**, **16** by means of a connection therefrom to the tap **68** of potentiometer **70**.

A point source of flood electrons is provided by a flood gun **74** disposed along the longitudinal axis of the cylindrical portion **11** of evacuated envelope **10** at the left extremity thereof, as viewed in the drawing. Flood gun **74** includes a cathode **76**, an intensity grid **77** which encloses the cathode **76** except for an aperture **78** disposed over the central portion of the cathode **76**, and an annular electrode **79** disposed adjacent to and concentrically about the aperture **78**. In operation cathode **76** of flood gun **74** is maintained at ground potential by means of a connection therefrom to ground. Further, the intensity electrode **77** and the annular electrode **79** are maintained at potentials of the order of —20 and +80 volts with respect to ground by means of connections therefrom to adjustable taps **80** and **81**, respectively, of a potentiometer **82**. The potentiometer **82** is, in turn, connected across the positive and negative terminals of a battery **84** and an intermediate terminal thereof referenced to ground.

According to the present invention, the operation of the disclosed direct-viewing half-tone storage tube is similar to that of the half-tone storage tube disclosed in Patent No. 2,790,929 entitled Direct-Viewing Half-Tone Storage Device, issued to Elvin E. Herman et al., on April 30, 1957, which patent is assigned to the same assignee as the present application. In general the flood gun **74** is operated to provide a uniform collimated flow of low velocity electrons over the entire storage area of storage screen **32**. This is accomplished by suitable adjustments on the taps **80**, **81** of potentiometer **82** which determine the potentials applied to the intensity electrode **77** and annular electrode **79**, respectively, of the flood gun **74**. These potentials will, of course, vary somewhat with configuration of the tube envelope **10** and the potentials at which conductive coating **72** and collector grid **34** are maintained. The storage surface of storage screen **32** is prepared for writing by applying a 10 to 20 volt positive pulse generated by the pulse generator **44** to the cupronickel sheet **36** of the storage screen **32**. Initially the flood electrons will have charged the storage surface to the potential of the flood gun cathode **76**, which potential is ground. Because of the capacitance between the storage surface and the cupronickel sheet **36**, the application of the pulse to the cupronickel sheet **36** raises the potential of the storage surface by a corresponding amount. The flood electrons then charge the storage surface to ground potential. Upon completion of the pulse, the potentials of the storage surface follow the negative excursion of the trailing edge of the pulse whereby the storage surface assumes a potential of from 10 to 20 volts negative with respect to ground.

Writing is accomplished by applying a signal to input **53**, thereby to current modulate the high-energy high-current density electron beam produced by the electron writing gun **14**. This high-energy current-modulated electron beam is caused to scan the storage surface of the storage screen **32** by the application of suitable deflection

voltages generated by horizontal and vertical voltage generators **56**, **58** to the deflecting plates **15**, **16**, respectively. As the storage screen **32** is scanned by the high energy electron beam, the storage surface is charged towards the potential of flood cathode **76** by an amount which is a function of the input signal impressed on terminal **53**. The potential on the area of storage surface surrounding a given aperture controls the flow of flood electrons through that aperture and thus controls the brightness of illumination of the corresponding phosphor dot. Because of the different sizes of the apertures aligned with each of the sets **25**, **26**, **27** of phosphor dots, the useful range of storage surface potential is different for each color. For example, a weak signal will allow flood electrons to flow only through the apertures **37** aligned with the red dots **25**, a medium signal would allow flood electrons to flow through both the red and blue sets of apertures **37**, **38** aligned with the red and blue sets of phosphor dots **25**, **26**, respectively, and a strong signal would allow flood electrons to flow through all three sets of apertures **37**, **38**, **39** to the phosphor dots **25**, **26** and **27**. Thus, the resulting color produced on the viewing screen **22** depends upon the strength of the input signal initially applied on terminal **53**. Because of the nature of the storage mechanism, scan-to-scan integration can also be used. For example, a weak signal which repeats on successive scans may appear red on the first scan, red-blue on the second scan and white on the third scan. This is a useful mechanism because it enables low-level signals to be easily distinguished from noise. It is to be noted that no processing of input data is required, but that if it is desired to present additional information, it can easily be added to the incoming signal. For example, a white bar could be written beside selected targets.

The greater range of half-tones provided by the tube of the present invention is evidenced from a consideration of the brightness of the individual sets of phosphor dots **25**, **26**, **27**. It is assumed that there is a logarithmic variation of sensation with brightness and that the human eye can conveniently distinguish between two levels of brightness wherein one of the primary colors differs in brightness in the two levels by a factor of three. With these considerations, different storage surface potentials would provide the following visual responses:

Storage surface potential relative to flood cathode 76	Brightness in percent			Level
	Red	Blue	Green	
More negative than:				
−20 volts	0	0	0	1
Do	.1	0	0	2
−19 volts	.3	0	0	3
−18 volts	.9	0	0	4
−17 volts	2.7	0	0	5
−16 volts	8.1	0	0	6
−15 volts	24.3	0	0	7
−14 volts	72.9	.1	0	8
−13 volts	100	.3	0	9
−12 volts	100	.9	0	10
−11 volts	100	2.7	0	11
−10 volts	100	8.1	0	12
−9 volts	100	24.3	0	13
−8 volts	100	72.9	.1	14
−7 volts	100	100	.3	15
−6 volts	100	100	.9	16
−5 volts	100	100	2.7	17
−4 volts	100	100	8.1	18
−3 volts	100	100	24.3	19
−2 volts	100	100	72.9	20
−1 volt	100	100	100	21
0	100	100	100	

In order to illustrate the above data, Fig. 3 shows graphs **90**, **92** and **94** of the brightness level of the red, blue and green sets **25**, **26** and **27** of the phosphor dots for storage surface potentials commencing from more negative than −20 volts relative to flood gun cathode **76** and increasing to a potential equal to that of flood cathode **76**. It is evident that under the above assumptions there are about 21 distinguishable levels of brightness and hue between "black" and "white," a factor of three increases over that of conventional half-tone storage tubes. It is, of course, realized that the use of a different number of colors or alternate combinations thereof is obviously within the scope of the teachings of this specification. It is further evident that the tube of the present invention may incorporate an aluminized viewing screen **22**; a magnetically deflected writing gun **14**; a ring-type flood gun **74**; continuous erasure effected by the application of a train of +10 to +20 volt pulses of short duration to the storage screen **32** by the pulse generator **44**, and of such an amplitude and duration as to erase noise, but allow signal integration from scan-to-scan; and use of color dots corresponding in size to the beam of flood electrons passing through each size aperture at zero storage surface potential, e. g., 5, 10, 15 mils, respectively.

What is claimed is:

1. A direct-viewing multi-color half-tone storage tube comprising a viewing screen having a plurality of integrated sets of different colored fluorescent dots; a storage screen disposed adjacent to and co-extensive with said viewing screen, said storage screen having a single aperture in alignment with each of said fluorescent dots of said viewing screen, the size of the apertures in alignment with any one of said sets of dots being equal and the sizes of apertures in alignment with different colored fluorescent dots being different; means for producing a charge pattern on said storage screen; and means for directing flood electrons uniformly over said storage screen whereby the charged storage area surrounding each aperture controls the flow of said flood electrons therethrough to said viewing screen to produce a presentation wherein different potential levels of said charge pattern correspond to different colors.

2. The direct-viewing multi-color half-tone storage tube as defined in claim 1 wherein said flood electrons emanate from a source maintained at a predetermined potential level that is positive with respect to the potentials constituting said charge pattern.

3. The direct-viewing multi-color half-tone storage tube as defined in claim 2 including means for increasing the potentials constituting said charge pattern to potential levels that are positive with respect to the potential of said source of flood electrons, thereby to erase said charge pattern.

4. The direct-viewing multi-color half-tone storage tube as defined in claim 1 wherein said viewing screen has three sets of different colored fluorescent dots, said dots being arranged so that the periphery of the dots in any one set is contiguous to the periphery of the dots in the remaining two sets.

5. The direct-viewing multi-color half-tone storage tube as defined in claim 4 wherein said three sets of fluorescent dots produce the colors red, blue and green upon bombardment by electrons, the apertures in said storage screen in alignment with the red dots being substantially six times greater in area than the apertures in alignment with said blue dots, which apertures are, in turn, six times greater in area than the apertures in alignment with said green dots.

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