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3,109,062

ELECTROSTATIC WRITING AND PRINTING DEVICE

Filed Oct. 27, 1960

2 Sheets-Sheet 1

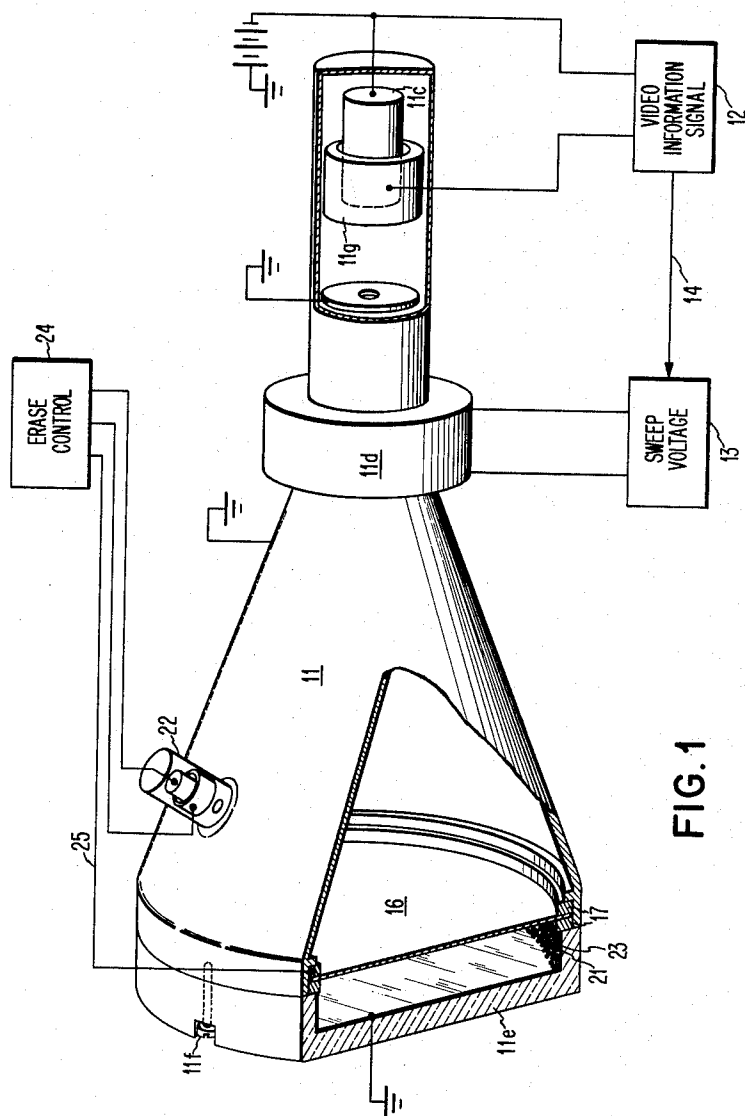


FIG. 1

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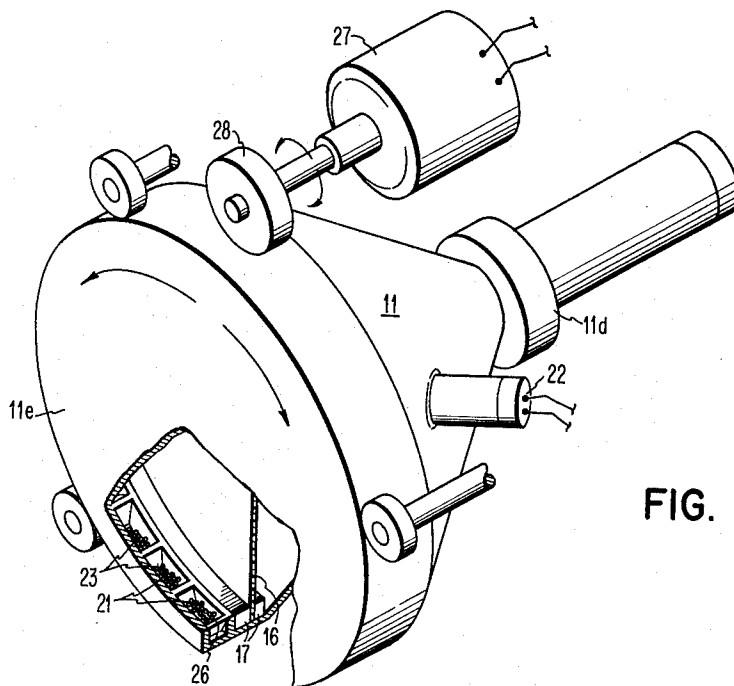


FIG. 2

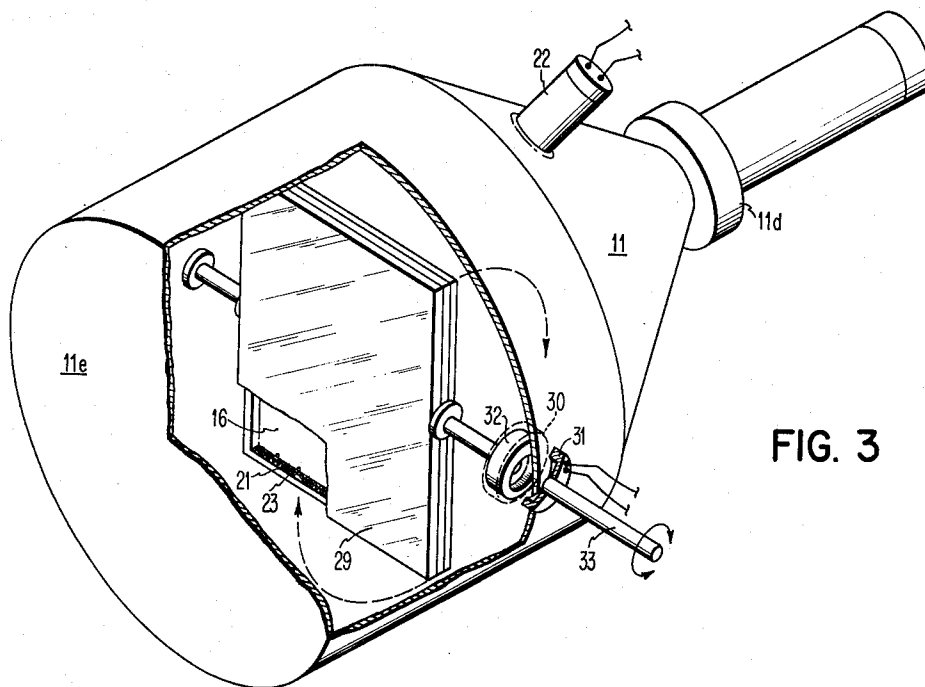


FIG. 3

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ELECTROSTATIC WRITING AND PRINTING DEVICE

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5 Claims. (Cl. 178—7.5)

The present invention relates in general to electronic display devices and relates more particularly to apparatus for producing a visible display of information represented by an information-bearing electrical signal which is converted to an electrostatic charge distribution pattern.

There are numerous applications where it is desirable to provide a static visual display of information transmitted in the form of electrical signals, such as those transmitted over a video communication link. The conventional method of displaying such information is, of course, through a cathode ray tube having a phosphor coated face on which an electron beam impinges to produce a visible display in response to the information which modulates either the intensity or the deflection of the electron beam. However, the use of phosphors for displays of the type contemplated herein is not particularly satisfactory, owing to the persistence problems associated with most phosphors, which necessitates frequent scanning of the phosphor to maintain the stationary image visible. This requirement of frequent scanning is objectionable both from the standpoint of the bandwidth requirements which it places on the transmitting link and also from the standpoint of registration problems on successive scans, since it is difficult to produce exact registration on successive scans of an electron beam over a phosphor tube face.

An alternative prior art solution which is somewhat more satisfactory for the purposes of producing a visible display involves the formation of an electrostatic image of the information to be displayed on a target surface in an evacuated envelope, and the dusting of this electrostatic image with small particles of an opaque material. These particles are deposited on and attracted to the electrostatically charged surface to produce a visual indication of the information represented by the electrostatic charge distribution. In this prior art embodiment, however, the charged particles which are attracted to the electrostatically charged member to form the visible image are disposed closely adjacent the target surface during the writing on or charging of the electrostatic target surface, and it is necessary to keep the electrostatic target surface continuously vibrated during writing to prevent the charged particles from adhering to the target surface during the writing. In one embodiment of this prior art structure, the charged particles are disposed between the electron writing beam and the target surface and are maintained in a "cloud" adjacent the target surface as a result of the vibration of this surface during writing. However, the disposition of the charged particles between the target surface and the electron beam is objectionable in that the interaction between the writing beam and the particles makes it difficult to obtain the desired resolution of the beam on the electrostatic target surface. In another embodiment of this prior art device, the charged particles are disposed on the opposite side of the target surface from the writing beam and hence do not interfere with the writing beam, but the particles in this embodiment still are disposed closely adjacent or on the target surface and are kept from the target surface only by the continual vibration of the target surface during writing. This embodiment, while eliminating the possibility of interference between the writing beam and the vibrating particles, still is objection-

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able in that the particles are closely adjacent the vibrating target surface during writing and hence may be influenced by the electrostatic field during the writing. It will be appreciated that both of these prior art embodiments also present a substantial problem in maintaining the writing electron beam in the desired areas of the vibrating target surface.

The present invention contemplates apparatus in which an electrostatic image is formed by an electron beam directed toward an electrically non-conductive surface capable of storing electrostatic charges in small discrete areas thereof. The electrostatic target surface is disposed in one end of an evacuated envelope having a transparent window or face plate therein. The target surface is disposed adjacent to but spaced from the transparent window, and disposed in the space between the target surface and the transparent window is a supply of small particles capable of retaining an electric charge and of a suitable color to produce a visible image.

During writing of the electrostatic charge pattern on the front surface of the target surface, these particles are maintained out of the influence of the electrostatic field. Upon completion of the electrostatic writing on the target surface, the charged particles are cascaded across the rear or reverse side of the target in some suitable manner. The electrostatic field resulting from the deposition of electrical charges in different discrete areas of the target surface extends through the thin target member and exerts an attractive force on the cascading charged particles, causing them to adhere to the reverse side of the target surface in the charged areas thereof. The adherence of the suitably colored charged particles to the oppositely charged areas of the target surface produces a visible image of the information which had been written on the target surface in the form of an electrostatic charge distribution pattern. The visible image may then be viewed or photographed through the transparent face plate at the end of the evacuated envelope or utilized in any other manner, depending upon the nature of the application.

When it is desired to erase the electrostatic image and the visible image, a flood beam of electrons within the envelope is activated to flood the charged side of the target surface with electrons. The accelerating velocity of the electron beam forming the flood beam is such in relation to the secondary emission properties of the insulating material forming the target surface that the secondary emission ratio from the target surface is greater than unity under the action of the electron flood beam. This means that for every incoming electron from the flood beam, more than one electron leaves the target surface, until equilibrium is reached and the electrostatic charge on the target surface has been removed. The flood beam is then turned off and the target surface is available for storage of the next electrostatic image thereon.

Objects and advantages of the present invention in addition to those discussed above will be apparent from the following description when read in connection with the accompanying drawings, in which:

FIG. 1 is a perspective view, partly in section, illustrating the one embodiment of the present invention for forming an electrostatic image on a target surface within an evacuated envelope and for producing a visible image from this electrostatic image;

FIG. 2 is a perspective view illustrating one method of cascading the charged particles across the charged electrostatic target surface by rotation of the evacuated envelope forming the tube of the present device; and

FIG. 3 is a perspective view illustrating an alternative embodiment of the present invention in which the target surface is movable within the evacuated envelope, such movement of the target surface being produced after com-

pletion of the charging of the electrostatic target surface to cascade the charged particles across the back of the target surface.

Referring to FIG. 1 by character of reference, numeral 11 designates an evacuated envelope of a suitable material, such as glass or metal in which the electrostatic storage apparatus operates. Envelope 11 may be of any suitable shape, such as that of a conventional cathode ray tube having means at one end thereof for generating a beam of electrons and having at the other end thereof an enlarged face plate member. As shown in the drawing, the electron beam generating means includes a cathode 11c and a grid 11g to which modulating signals are applied to regulate the intensity of the electron beam emitted from the electron gun elements including cathode 11c. The modulating input signals representing information to be stored and visibly displayed on the device of the present invention may be from any suitable source, such as from a video output device represented schematically at 12. Video input network 12 applies a modulating input to grid 11g relative to the cathode structure to modulate the electron emission in response to variations in the input information signals. The modulated electron beam is preferably swept across the target surface by suitable deflection means, such as a deflection yoke 11d disposed around the neck of envelope 11. Deflection yoke 11d is energized by a suitable source of sweep voltage signals, such as the sweep voltage generator 13. As indicated, sweep voltage generator 13 may receive a synchronizing pulse from the video signal source 12 through a conductor 14 to synchronize the beginning of the beam sweep with the start of the information signals to be displayed.

Envelope 11 is provided at the end opposite the electron beam generating means with a transparent face plate member 11e. Transparent face plate window 11e may be a unitary part of envelope 11 or may, as shown, be a separate element which is secured to the end of envelope 11 in air tight relation by suitable means such as screws 11f. Face plate 11e is provided with an electrically conductive transparent coating on its inner surface to provide for connection of a source of accelerating voltage, as will be described more in detail below.

Spaced from but adjacent to the transparent window member 11e is an electrical insulating member 16 on which the electrostatic charge is placed by the controlled beam and to which the charged particles adhere to produce a visible image of the electrostatic charge distribution pattern. Insulating material 16 may be of any suitable type such as the polyester resin film marketed under the trade name "Mylar" by E. I. du Pont de Nemours. Another suitable material is a polyvinyl fluoride impregnated with titanium dioxide to produce a white opaque sheet member, the material being marketed under the trade name "Tesar" by E. I. du Pont de Nemours.

Insulating member 16 is preferably very thin and we have found for example that a sheet of "Tesar" or a sheet of "type C" Mylar of 1/2 mil thickness is very suitable. Member 16 is mounted in the evacuated envelope by suitable means, such as a clamping ring 17 having separable halves between which the member 16 is tightly stretched. Clamping ring 17 may then be firmly seated against a shoulder in the end of envelope 11 to hold target member 16 firmly in position in the enlarged end of envelope 11.

In the space between member 16 and transparent window member 11e there is provided a plurality of small particles of electrical insulating material which are capable of retaining an electrical charge. Such particles 21 are preferably of a dark color so as to produce a maximum contrast with the insulating member 16 when the particles adhere thereto in response to the electrostatic charge distribution pattern. Particles 21 may be charged in any suitable manner, such as through the triboelectric effect in which the particles 21 to be charged are mixed with other particles 23 of a dissimilar nature so that agitation

of the two dissimilar particles produces opposite electrical charges thereon. The two types of particles utilized may be of any suitable type having the required relationship in the triboelectric series. One example of suitable materials is the use of resin or plastic particles 21 and small glass beads as particles 23. The granular particles 21, being electrically insulated, retain their electrical charge after agitation with beads 23 so as to be charged for attraction to the electrostatic target surface 16. The charged particles 21 are disposed in the space between electrostatic target member 16 and transparent window member 11e, but are maintained away from the target member 16 and the electrostatic charge distribution pattern thereon during the writing on member 16 by the modulated electron beam. In the embodiment illustrated in FIG. 1, it will be noted that charged particles repose in the bottom of envelope 11 behind clamping ring 17 and thus are maintained away from the charge existing on member 16. It will also be noted that the charged particles 21 are behind target member 16 and hence do not interfere with the electron beam producing the electrostatic charge on member 16.

To remove the electrostatic charge distribution pattern and the charged particles adhering thereto from the target surface, means such as an electron gun 22 may be utilized to generate a flood beam of electrons directed at the writing side of target member 16. As shown in the drawing, electron gun 22 extends through envelope 11 and is operative when energized to produce a large quantity of electrons which are accelerated toward target surface 16. Flood gun 22 preferably operates by producing a secondary emission ratio greater than unity for electrons striking target surface 16. For many electrical insulating materials, such as the material of target member 16, the secondary emission ratio is greater than unity within a given range of accelerating voltages applied to electrons directed at the material. This means that within this range of accelerating voltages, for every incoming electron from the electron flood beam, more than one electron is emitted by secondary emission from the target surface 16 until equilibrium is reached. Flood gun 22 is energized from an erase control network 24 which supplies a suitable potential between the cathode and grid of gun 22 to generate a flood beam so as to produce in material 16 a secondary emission ratio greater than unity. This flood beam bombardment causes the electrons forming the electrostatic charge on member 16 to be removed from member 16, thus dissipating the electrostatic charge on member 16 and preparing it for receiving another electrostatic charge pattern from the modulated electron beam. After erasure of the electrostatic charge pattern, the loose particles 21 are cascaded across the reverse side of target 16 to remove the charged particles adhering thereto.

Erase network 24 may be connected by a conductor 25 to the back half of metallic clamping ring 17 to apply a potential to this ring during erasing. The application of this potential causes this half of clamping ring 17 to act as a collector electrode for the secondary emission electrons from target 16, thus preventing the return of these electrons to the target and thereby hastening the complete erasure of electrostatic charge distribution pattern on target 16.

In operation then, the information to be visibly displayed is supplied in the form of video signals through video input network 12 to modulate the intensity of the electron beam generated by the electron gun elements of tube 11. This modulated beam is deflected across the face of target surface 16 by means of the deflection signals supplied from sweep voltage generator 13 to the deflection yoke 11d. As the modulated electron beam sweeps across target 16, it will produce thereon small discrete areas of electrostatic charge in accordance with the beam intensity. There is thus produced on target member 16 an electrostatic charge distribution pattern varying in accordance with the information represented by the video input sig-

nals supplied through network 12. This electrostatic distribution pattern as written by the electron beam will be invisible to the human eye, but will represent an electrostatic charge distribution pattern corresponding to the information to be presented.

Upon completion of the production of the electrostatic charge distribution pattern on member 16, which pattern may be produced by a single sweep of the electron beam across target member 16, a visible image of the pattern may be formed by cascading the charged toner particles 21 across the reverse side of target member 16 to cause particles to adhere to the reverse side of target member 16 in those areas which have an electrical charge opposite to the charge of the particles 21. In the illustrated embodiment it is assumed that the charge produced on target 16 by the electron beam is a negative charge, and that the particles 21 receive a positive charge as a result of their agitation with particles 23 in accordance with the triboelectric effect. However, it will be appreciated that these charge polarities could be reversed without affecting the operation of the invention. As the positively charged particles 21 are cascaded across the reverse side of member 16, the negative charges on the different discrete areas of target 16 attract the charged particles to cause them to adhere to the target surface in those areas having a negative charge thereon. Since, as indicated above, the particles 21 are preferably of a dark color, they form on member 16 a visible image of the electrostatic charge distribution which may be viewed or photographed through the transparent end window member 11e.

Cascading of the charged particles across the reverse side of the charged target member 16 may be accomplished by any suitable means, such as manual manipulation or rotation of envelope 11 to produce a gravity flow of the charged particles across member 16 to produce the desired adherence of the particles to the charged areas of the target surface. Preferably, however, the cascading is accomplished by automatic or semiautomatic means. FIG. 2 schematically illustrates one form of apparatus for producing such cascading by rotating the envelope assembly after writing of the electrostatic charge distribution pattern. In FIG. 2 the charged toner particles are disposed in a plurality of bucket-like depressions 26 in the space between target member 16 and transparent window member 11e. Envelope 11 is adapted to be rotated by means including a motor 27 which drives an idler wheel 28 engaging the rim of the enlarged end of envelope 11.

When motor 27 is energized, it drives wheel 28 to rotate envelope 11 through 180° of rotation, thus causing the charged particles 21 in buckets to be carried around by the rotation until they are spilled from their respective buckets and cascaded across the reverse side of target surface 16, thus causing the charged particles to adhere to the charged areas of member 16. Upon completion of this cascading, the direction of rotation of motor 27 is reversed to rotate tube 11 in the reverse direction and return it to its initial position. By thus utilizing only 180° of rotation, rather than a complete full circle of rotation, problems in connection with commutating the electrical connections to the flood gun 22, deflection yoke 11d and the electron gun elements 11c are eliminated, since the electrical leads to these elements may be made of suitable length and flexibility to permit 180° rotation of envelope 11 without disrupting the connections. By suitable design of the shape of buckets 26, they may be caused to retain particles 21 therein until each bucket is almost at the top point in its rotation, thus producing maximum coverage across the member 16 by the cascading particles.

FIG. 3 illustrates alternative apparatus for producing cascading of the charged particles across the charged target member 16. In FIG. 3 the target member 16 is pivotally mounted within envelope 11 so that the assembly may be rotated within envelope 11 to produce the desired

cascading. As shown in FIG. 3, a transparent member 29 is secured to the reverse side of member 16 and spaced therefrom to form a chamber for holding charged particles 21 and particles 23. The assembly including member 16, charged particles 21 and cover plate 29 is rotatably mounted within envelope 11 on bearings 30 disposed within envelope 11. In connection with the embodiment of FIG. 3, it will be noted that transparent end member 11e is spaced from the assembly including elements 16, 21 and 29 a sufficient distance to permit pivoting of the assembly on bearings 30 within the tube.

The target assembly may be pivotally driven by any suitable means, but to reduce sealing problems in connection with the transmission of pivotal movement through the walls of envelope 11 to the target assembly, the drive is preferably in the form of a pair of magnetic members including an electromagnet 31 disposed outside envelope 11 adjacent bearing 30 and a soft iron member 32. Electromagnet 31, when energized, produces magnetic flux which extends through the wall of envelope 11 to link with soft iron member 32 which is connected to the target assembly, so that members 31, 32 form an electromagnetic clutch linking the target assembly within tube 11 to a drive shaft 33. Thus, with electromagnet 31 energized, rotation of shaft 33 produces pivoting of the target assembly including charged electrostatic target member 16, charged particles 21 and cover plate 29, to cause the particles to cascade across the reverse side of the target surface. After this cascading, the direction of rotation of shaft 33 is reversed to return the target assembly to its initial position and to present the visible image thereon for viewing or other use through transparent end member 11e. It will be noted that the use of electromagnetic coupling means 31, rather than permanent magnet means, eliminates any problems which might arise in connection with magnetic interference with the electron beam in sweeping across target surface 16.

As an example of the operation of apparatus built in accordance with the teachings of the present invention, applicants constructed and operated a device substantially as shown in FIG. 1 of the drawing. In this tube structure, the filament and cathode were operated at a potential of -16 kilovolts with respect to the transparent electrically conductive coating on the face of window member 11e. This transparent conductive coating was connected to ground, as was the shell of the tube, to produce a potential difference of 16 kv. between the cathode and the conductive coating on window member 11e. Modulating input signals were supplied between the cathode and grid of the tube, in accordance with the teachings of the present application, to modulate the intensity of the electron beam emitted, and the resultant intensity modulated beam was swept across a Tesla target member of 8 inch diameter and 1/2 mil thickness by a deflection voltage synchronized with the incoming video signals.

Upon completion of the writing of the electrostatic charge distribution pattern on the target surface, the writing beam was shut off and the tube rotated 180° to cascade the charged particles across the reverse side of the target surface. The charged particles adhered to the reverse side of the target surface in those areas thereof having opposite charges thereon to produce a visible image of the electrostatic charge distribution pattern. In this connection, the use of white opaque Tesla material is very desirable since it provides a high contrast with the dark particles adhering thereto, thus increasing the visibility of the resultant display. The resultant visible display persisted in substantially the same form as originally prepared for a period of 168 hours, thus clearly indicating the ability of the target material to retain the discrete electrical charges thereon and hence to retain an image for an extended period of time.

To erase the display, the flood gun filament was operated at a potential of -1.4 kv. relative to the tube face plate 11e, and a potential of +50 volts was supplied to

the front half of clamp ring 17 to cause this ring to serve as a collector electrode for the secondary emission electrons, as discussed above. Complete erasure of the display was accomplished in 0.1 second and the adhering particles on the reverse side of the target surface were removed therefrom on dissipation of the electrostatic charge pattern.

The above information relative to the actual operation of the present invention clearly indicates the stability of the resultant image display. The present invention will have numerous applications where it is desired to produce a visible display of information which is transmitted in the form of electrical signals. By virtue of the fact that only a single scan of the electrostatic target surface by the modulated electron beam is required to produce an electrostatic charge distribution pattern suitable for producing a visible display in accordance with the teachings of the present invention, and further in view of the persistence and stability of the resultant display, the present invention will be useful in numerous data processing applications. For example, the present invention may be utilized to produce a visible display at one or more remote stations to which electrical signals, representing requested information, are sent from a central file in the form of video signals in response to an inquiry from such stations. Since only a single scan is required, a minimum amount of central storage file time is involved in transmitting the information to the remote viewing locations, thus freeing both the central file and the communication lines for transmission of information to other locations. Similarly, the stability of the display eliminates the need for repeated scanning of the target surface by the modulated electron beam, and permits the resultant display to remain for an extended period of time for study, photography, projection or other use.

What is claimed is:

1. Apparatus for forming a visible image from an electrical information-bearing signal comprising an evacuated envelope, a source of electrons in said envelope, a target member of electrical insulating material disposed at one end of said envelope, a plurality of electrically charged particles of small size disposed in a chamber on the opposite side of said target member from said electron source, means for directing said electrons in a beam toward said target member and for sweeping said beam across said target member, means for modulating the intensity of said directed beam as a function of said electrical signal as said beam sweeps across said target to produce an electrostatic charge distribution pattern on said target surface corresponding to said information, means for maintaining said charged particles in said chamber away from the influence of the electrostatic charge on said target during sweeping of said beam across said target, and means for cascading said charged particles from said chamber over said target member upon completion of said charging of said target to cause said particles to adhere to said charged areas of said target to produce a visible image of said charged areas.

2. Apparatus for forming a visible image from an electrical information-bearing signal comprising an evacuated envelope, said envelope having a transparent window at one end thereof, a source of electrons in said envelope, a target member of electrical insulating material disposed at said one end of said envelope and spaced from said transparent window to form a chamber, a plurality of electrically charged particles of small size disposed in said chamber between said target member and said window, means for directing said electrons in a beam toward said target member and for sweeping said beam across said target member, means for modulating the intensity of said directed beam as a function of said electrical signal as said beam sweeps across said target to produce an electrostatic charge distribution pattern on said target surface corresponding to said information, means for maintaining said charged particles in said chamber away

from the influence of the electrostatic charge on said target during sweeping of said beam across said target, means for cascading said charged particles in said chamber over said target member upon completion of said charging of said target to cause said particles to adhere to said charged areas of said target to produce a visible image of said charged areas, and means for removing said electrostatic charge distribution pattern from said target surface to remove said visible image.

3. Apparatus for forming a visible image from an electrical information-bearing signal comprising an evacuated envelope, said envelope having a transparent window at one end thereof, a source of electrons in said envelope, a target member of electrical insulating material disposed at said one end of said envelope and spaced from said transparent window to form a chamber, a plurality of electrically charged particles of small size disposed in the bottom of said chamber between said target member and said window, means for directing said electrons in a beam toward said target member and for sweeping said beam across said target member, means for modulating the intensity of said directed beam as a function of said electrical signal as said beam sweeps across said target to produce an electrostatic charge distribution pattern on said target surface corresponding to said information, means for maintaining said charged particles in said chamber away from the influence of the electrostatic charge on said target during sweeping of said beam across said target, means for rotating said envelope upon completion of said charging of said target for cascading said charged particles in the bottom of said chamber over said target member to cause said particles to adhere to said charged areas of said target to produce a visible image of said charged areas, and means for removing said electrostatic charge distribution pattern from said target surface to remove said visible image.

4. Apparatus for forming a visible image from an electrical information-bearing signal comprising an evacuated envelope, said envelope having a transparent window at one end thereof, a source of electrons in said envelope, a target member of electrical insulating material disposed at said one end of said envelope and spaced from said transparent window to form a chamber, a plurality of electrically charged particles of small size disposed in said chamber between said target member and said window, means for directing said electrons in a beam toward said target member and for sweeping said beam across said target member, means for modulating the intensity of said directed beam as a function of said electrical signal as said beam sweeps across said target to produce an electrostatic charge distribution pattern on said target surface corresponding to said information, means for maintaining said charged particles in said chamber away from the influence of the electrostatic charge on said target during sweeping of said beam across said target, and drive means connected to said envelope for moving said envelope upon completion of said charging of said target for cascading said charged particles from the bottom of said chamber over said target member to cause said particles to adhere to said charged areas of said target to produce a visible image of said charged areas.

5. Apparatus for forming a visible image from an electrical information-bearing signal comprising an evacuated envelope, said envelope having a transparent window at one end thereof, a source of electrons in said envelope, a target member of electrical insulating material disposed at said one end of said envelope and spaced from said transparent window to form a chamber, a plurality of electrically charged particles of small size disposed in the bottom of said chamber between said target member and said window, means for directing said electrons in a beam toward said target member and for sweeping said beam across said target member, means for modulating the intensity of said directed beam as a function of said electrical signal as said beam sweeps across said target to

produce an electrostatic charge distribution pattern on said target surface corresponding to said information, means for maintaining said charged particles in said chamber away from the influence of the electrostatic charge on said target during sweeping of said beam across said target, means for moving said target and said charged particles upon completion of said charging of said target for cascading said charged particles from the bottom of said chamber over said target member to cause said particles to adhere to said charged areas of said target to produce a visible image of said charged areas, and means

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for removing said electrostatic charge distribution pattern from said target surface to remove said visible image.

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