

Feb. 21, 1967

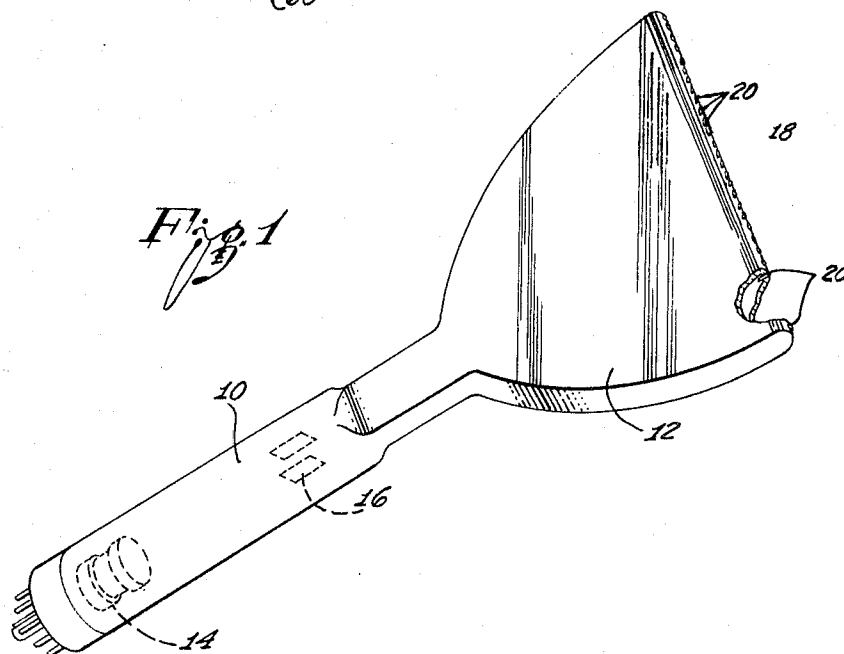
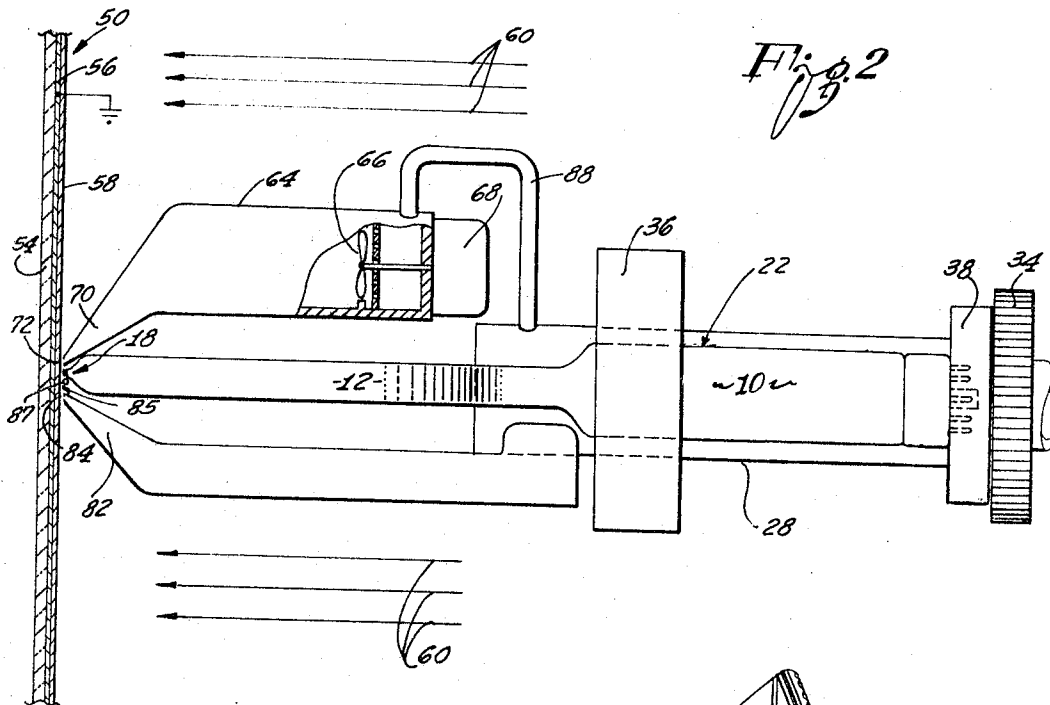
N. F. FYLER

3,305,872

CATHODE RAY TUBE APPARATUS FOR RECORDING AND DISPLAYING COLOR IMAGES

Filed Jan. 10, 1962

3 Sheets-Sheet 1



INVENTOR:
Norman F. Fyler

By Dee Palmer
Agent

Feb. 21, 1967

N. F. FYLER

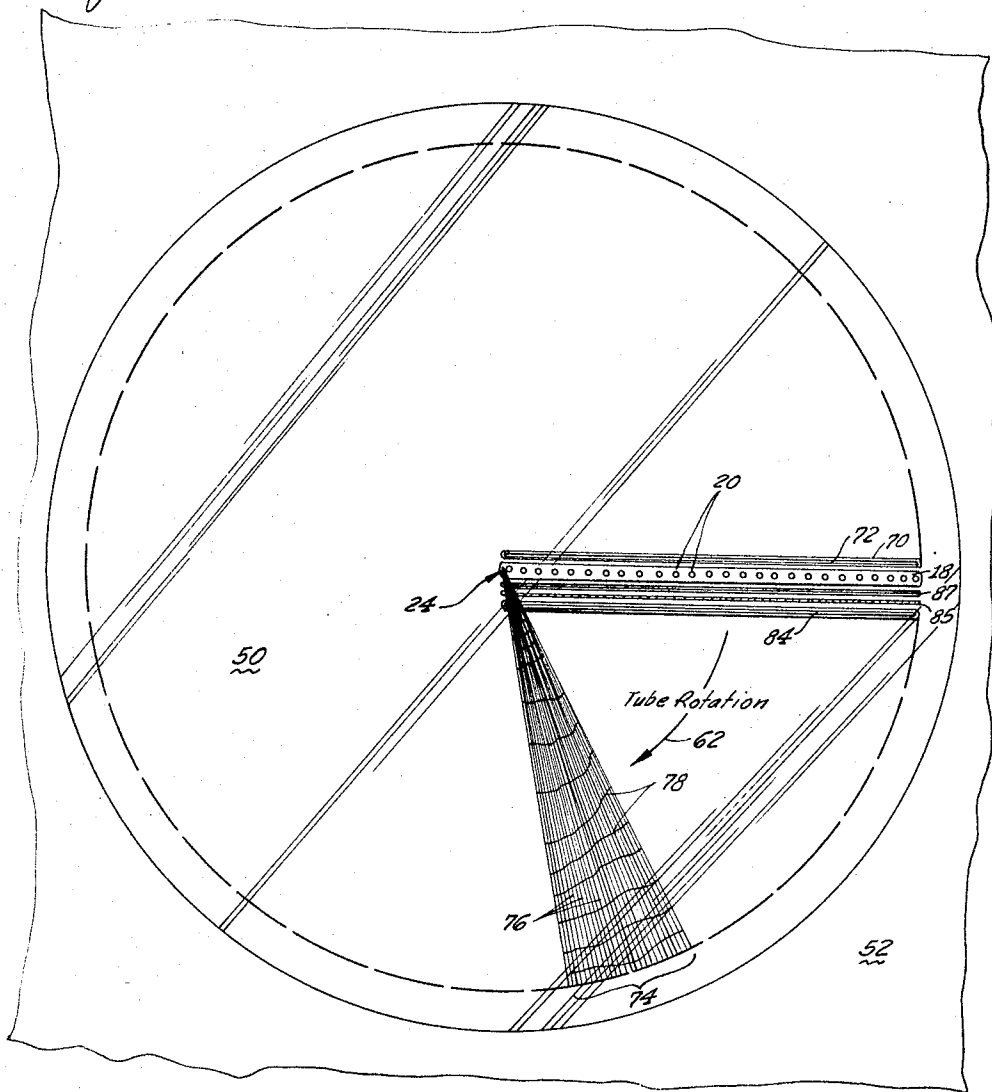
3,305,872

CATHODE RAY TUBE APPARATUS FOR RECORDING AND DISPLAYING COLOR IMAGES

Filed Jan. 10, 1962

3 Sheets-Sheet 2

Fig. 3



INVENTOR:
Norman F. Fyler

By *Richard J. Fentner*
Agent

Feb. 21, 1967

N. F. FYLER

3,305,872

CATHODE RAY TUBE APPARATUS FOR RECORDING AND DISPLAYING COLOR IMAGES

Filed Jan. 10, 1962

3 Sheets-Sheet 3

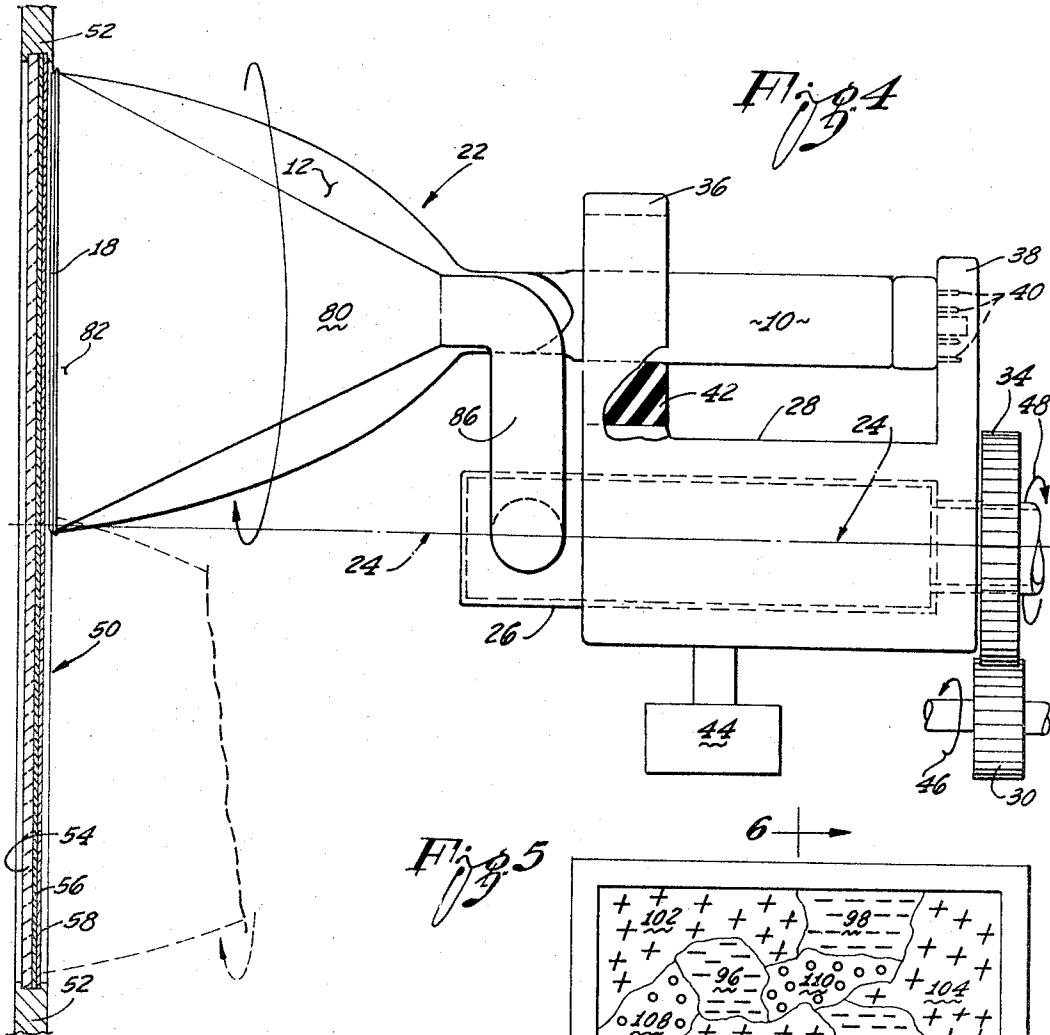


Fig. 3

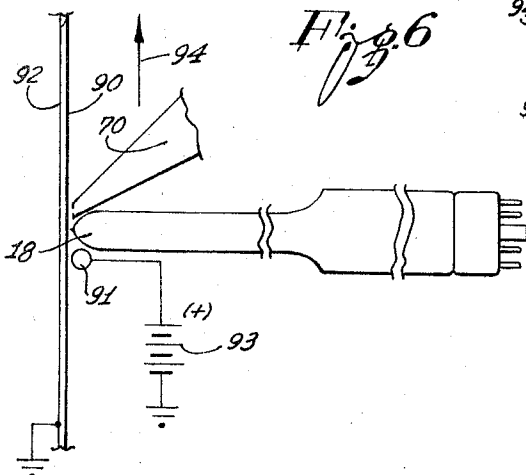


Fig. 6

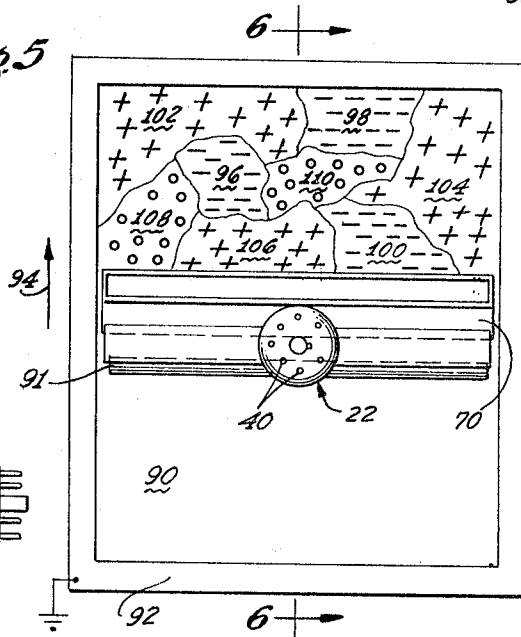


Fig. 5

INVENTOR:
Norman F. Fyler

By *Robert J. Fyler*
Agent

CATHODE RAY TUBE APPARATUS FOR RECORDING AND DISPLAYING COLOR IMAGES

Norman F. Fyler, Menlo Park, Calif., assignor to Litton Precision Products, Inc., a corporation of Delaware
Filed Jan. 10, 1962, Ser. No. 165,435
4 Claims. (Cl. 346-74)

This invention relates to apparatus and methods for producing images either of a permanent nature, such as those useful in the reproduction field, or of the changeable type in which the display may be continuously updated, as in the case of radar receivers, for example. More particularly, the invention is concerned with reproduction apparatus and methods using particulate material or powders for rendering visible latent electrical charge patterns as produced on dielectric surfaces.

The last mentioned principle is frequently used in dry processes reproduction machines such as duplicators for office use. However, among other shortcomings, this type of apparatus supplies copies exhibiting only one color. In spite of the fact that two-color or multi-color reproduction is highly desirable in many fields such as advertising and the graphic arts, no simple and efficient apparatus employing the dry printing process using charge patterns and powder, and resulting in prints having more than one single color has been developed up to the present time.

Accordingly, there is a definite need for two-color or multi-color reproduction facilities using the comparatively simple dry process employing powders applied and adhering to charge patterns on a dielectric medium. Therefore, and in one important aspect, the invention involves a dry process of this type resulting in two-colored or multi-colored images as a significant contribution to the reproduction art.

In another aspect, and with reference to display systems useful in radar receiving equipment or similar applications, the invention deals with a direct view display system using a cathode ray tube of special design in a novel arrangement and in connection with an especially designed viewing screen on which information is displayed so that it can readily be observed under bright ambient light conditions. Additionally, one of the more important principles of this invention, referring to reproduction in different colors, as described in more detail below, is successfully applied to and combined with display equipment, resulting in improved systems having both increased visibility and color.

Numerous systems for visually displaying information received in the form of video signals involve cathode ray tubes. One common form utilizes "long persistence" phosphor screens. These cathode ray tube systems suffer from a number of practical disadvantages. One of the more severe shortcomings of such screens resides in the fact that the images have a relatively low brightness, and cannot be steadily viewed under bright ambient light conditions, without adverse physiological effects. Furthermore, the long persistence phosphor has a relatively high initial light level which trails off rapidly to a very low level of light. This phenomenon causes eye fatigue and has other detrimental effects on the observer.

Some attempts have been made to enhance the visibility under bright ambient light conditions. The electrostatic storage tube and the "dark trace" cathode ray tube have been used with some degree of success. However, both of these devices also have serious limitations, so that a definite need for a more satisfactory display system suitable for direct view use under high level ambient light conditions continues to date. Numerous tests and attempts to develop existing arrangements have estab-

lished that the simultaneous use of different colors might result in improved radar and other visual display systems. Color could be utilized to add additional dimensions to the presentation, to discriminate between distinct informations of different nature by simultaneously displaying distinct colors, and furthermore to enhance contrasts on a screen; however, no satisfactory multi-color system has been developed up to the present time.

Accordingly, it is one of the more important objects of this invention to improve the reproduction of images in electrostatic reproduction systems, of both the display and the permanent reproduction types, by the addition of color effects.

It is a further object of the invention to provide a two-color or three-color system applicable to both display and permanent image processes and equipment.

It is a further object of the present invention to display information supplied for example from radar receiving systems or the like in such a manner that it can be viewed by an observer under high level ambient light conditions such as bright daylight.

It is another object of this invention to relieve the observer from continuous severe eyestrain which frequently occurs with conventional cathode ray tube display systems in which the tube is provided with a long persistence phosphor screen.

It is a further object of the present invention to intermittently display or record received information either as a two-tone image or with added color effects so that it may be either observed under direct view conditions or recorded by a fixing step for storing the information for an indefinite time.

In accordance with another object of this invention, information may be retained on the screen for any desired period of time, with new information superimposed on that previously recorded so that the track of an object such as a missile or an aircraft may conveniently be displayed.

It is a further important object of this invention to display received information in a multi-color system so that discrimination between different types of information may readily be accomplished, if desired; thus, different colors may be used for discriminating between information received at distinct periods of time; or, distinct contrasting colors may be employed simultaneously for distinguishing between friendly and enemy planes, moving and stationary targets, or the like.

A still further object of this invention is to provide a special display screen which permits the display of single color or multi-color information in connection with the display system described below in more detail and under such circumstances that it can be observed in bright daylight, projected on a wall screen, or recorded, if desired.

The systems of the present invention may advantageously use a recently developed cathode ray tube specially designed for the purpose of facsimile reproduction systems or the like. An improved cathode ray tube of this type is described in pending United States patent application Ser. No. 16,734, filed Mar. 22, 1960, now U.S. Patent No. 3,193,907, Norman F. Fyler, and the essential structure of such tube is described in the following paragraph.

It has been stated above that a conventional cathode ray tube includes a phosphor screen on which the electron beam impinges. The scanning motion of the electron beam is produced by changing electrostatic or magnetic fields, as is well known in the art, so that a detailed description of the deflection portion of the tube is unnecessary. The specific tube used in accordance with the present invention has no phosphor screen but is provided

3

with a faceplate which transmits electrical charges to discrete zones or elemental areas. For this purpose, the cathode ray tube is provided with a plurality of individual conductors, generally a great number of wire sections, which traverse the faceplate. The faceplate itself is made of highly insulating material and the individual wire conductors extending through it are physically separated and also electrically insulated from each other. While in the first developments of such faceplates the wires were flush with both the internal and external surfaces of the faceplate, the most recent designs of such tubes have provided improved operation with the wires extending through the faceplate and protruding slightly from both the internal and external surfaces of the faceplate. The advantages and the theoretical background of this type of faceplate are discussed in the above-mentioned copending application.

In accordance with the specific use in facsimile apparatus or the like, the individual wires imbedded in insulating material to form the faceplate of this type of cathode ray tube are placed in a linear arrangement, generally a small number of rows of very closely spaced wire conductors, to form a narrow elongated strip-shaped front face, as described in the above mentioned copending application. The electron beam performs a sweeping motion along the internal surface of the faceplate to impinge on the internal wire ends, applying to them negative charges changing in accordance with information received. These charges are transferred through the faceplate by the array of individual wires and deposited on a recording medium such as a dielectric film passed along the external surface of the faceplate. The charge pattern appearing on the recording medium is then rendered visible by any suitable known developing process.

As stated above, this type of cathode ray tube having an elongated, charge-transmissive faceplate is employed in one embodiment of the present invention in a novel arrangement for continuously displaying received information, suitably in connection with an appropriately designed screen, so that observations may be made under bright light conditions, or for reproducing images which may be fixed for permanent use or storage.

Referring now to one of the more important features of the invention, two-tone or two-color representation is achieved by producing a charge pattern which includes positively and negatively charged areas on a dielectric surface, and applying positively and negatively charged particulate materials or powders of different appearances or color to the surface, which may be a dielectric sheet on which the image is to be reproduced and fixed, or a display screen. As a result, each powder then adheres to areas charged to the opposite polarity than the powder itself. In other words, negatively charged powder adheres to positively charged areas, and vice versa. When using powders exhibiting different colors or otherwise having different appearances, such as different reflection characteristics, a two-color or two-tone image is obtained which may be temporarily displayed on a screen or fixed to become permanent.

In accordance with another feature of the invention, a further color is added in the form of that of the sheet or screen itself by providing electrically neutral areas in the applied charge pattern. In these areas, substantially no adhesion occurs and the color of the sheet or screen remains visible as an added color or shade.

A further feature involves the steps of first precharging the surface of the sheet or screen positively and substantially uniformly, and then superposing a negative charge pattern on the positively charged surface. As a result, negatively charged areas are obtained wherever the negative charge exceeds the positive precharge, while positive areas remains on all locations where the positive precharge prevails over the negative charge. Areas in which the charges cancel each other are neutral. Thus, areas to which substantially no powder adheres and which

4

therefore exhibit the above-mentioned third color also form part of the displayed or permanently fixed image.

In accordance with another important feature of the present invention, an assembly for visually displaying electrically transmitted signals representative of information includes a cathode ray tube, preferably of the type described and having a charge-transmissive faceplate, combined with a dielectric screen facing the faceplate, and provisions are made for producing relative sweeping motion between the faceplate and the screen so that the faceplate periodically sweeps over the screen surface. The assembly includes arrangements for rendering visible the charge pattern as applied to the screen during one period of the relative sweeping motion so that a direct view image appears on the screen, preferably using the two-color or three-color powder process mentioned above.

In accordance with a further feature, and in a preferred embodiment of the invention, the sweeping motion is obtained by rotating the cathode ray tube about an axis parallel with the tube axis and extending through one of the end points of the elongated strip-shaped faceplate. In this arrangement, the screen remains stationary, and it can be seen that when the faceplate executes a rotating sweeping movement covering a circular area on the screen by assuming successive radial positions within the circular screen area.

In accordance with another feature of this invention, the charge pattern is rendered visible by applying particulate material, preferably electrically charged pigmented powder or dust, to the screen, suitably immediately upon exposure of each radial area to the charge-transferring faceplate. As a result, when rotating the tube as described, and in accordance with a principle well known per se, the particles adhere to charged areas of the screen but do not adhere to areas which did not receive any charge. It can be seen that, after one complete cycle of rotation, the faceplate sweeps again over the same radial area of the screen, once during each cycle. When it is intended to display the continuous motion of an observed object, such as an aircraft, it may be desirable to display successive positions of such an object. It will be apparent that, by superimposing information received during successive cycles on that received during preceding cycles, the track of the object is displayed on the screen.

In accordance with another feature, and in order to satisfy the need for a different type of display process, a system in accordance with this invention preferably includes an "eraser" unit for removing, from each screen area, the particulate material applied to such area during a preceding cycle. Such eraser may be a vacuum cleaner type suction device, a brush, or the like, which sweeps over the screen immediately and directly in front of the faceplate, and which may include a discharging electrode or brush.

In an illustrative embodiment of the invention, the cathode ray tube with the elongated strip-shaped faceplate, the device for applying charged particulate material to the screen and the "eraser" form one unitary movable assembly. This assembly revolves to execute a sweeping motion in front of, and adjacent the stationary screen, so that along each radius of the circular screen area powder applied in the preceding cycle is removed, new charges are deposited in accordance with received signals, and the image is rendered visible by applying new particulate material to the area, with one step almost immediately following the preceding. Thus, an image will be displayed on the screen which continuously exhibits latest information since that of the preceding cycle is removed before new information is applied.

A further feature of the invention includes a multi-color display system especially suitable for use in connection with the display equipment employing a cathode ray tube having a strip-shaped charge-transmissive faceplate,

5

as described. Such multi-color system includes provisions for applying a positive precharge to the dielectric surface of the screen, and the charge is substantially uniformly distributed over the entire screen surface. Considering now that the screen has received such positive precharge, and negative signal charges are applied through the faceplate to the precharged screen, the charges may be balanced in such a manner that in areas, where a weak negative charge is applied, the stronger positive charge prevails. Other areas receiving a strong negative charge prevailing over the positive precharge will become negatively charged; where the charges of opposite polarity cancel each other, neutral zones are obtained on the screen. When applied to a screen having areas charged to different polarities, material which includes particles charged to carry one polarity and other particles charged to carry the other polarity, each particle adheres only to areas having a polarity opposite to that of its own charge. By using two types of powder of distinct color, with one type charged to assume one polarity exhibiting one color and the other type oppositely charged exhibiting another color, a two-color image is displayed on the screen. If neutral zones exist in addition to positively and negatively charged zones, substantially no powder will adhere to such neutral zones on the screen. If then, in accordance with another feature of the invention, the screen exhibits a color distinct from those of both powders, a further color is introduced into the system and a three-color image is obtained.

In accordance with a further feature of the invention, a screen especially useful for displaying information in a two-color or three-color system includes a base plate as a support and made of transparent material such as glass, a plastic known under the trade name "Lucite," or the like. An intermediate layer of transparent, electrically conductive material is applied to the supporting base plate. On the transparent conductive layer, there is applied a thin dielectric layer made of a suitable plastic such as that known under the trade name "Mylar." The dielectric plastic layer faces the rotating cathode ray tube, with which rotates a container holding the charged particulate material or materials, and with which also rotates the eraser unit. The transparent dielectric layer of the screen is generally connected to ground. Suitably, an electrode rotates with the faceplate and immediately in front of it for applying a positive potential to the screen surface as described below, for obtaining two-color or three-color images.

It will be apparent that even when using one single type of particulate material such as colored powder or dust, applying a charge to it enhances adhesion of the powder to the screen in charged areas.

Further features of the invention include provisions for agitating the particulate material in order to impart electrical charges to it, and circulation arrangements for passing the particulate material, when removed from the screen, through the eraser unit back to the container from which it is again applied to the screen. Considering that a cathode ray tube having an elongated strip-shaped faceplate is used which periodically sweeps over the screen in a rotational movement, the container and the eraser unit may suitably be of the vacuum cleaner type with elongated nozzles terminating in elongated slots arranged adjacent and parallel with the faceplate. When rotating, both slots, with the faceplate between them, sweep over a circular area of the screen with the eraser slot in the forward direction with respect to the direction of rotation. Thus, particulate material applied to the screen during the preceding cycle of the sweeping motion is removed immediately before new charges are applied and rendered visible by powder application.

More particularly, and in accordance with one specific feature of this invention, the powder applicator includes a container holding both types of particulate material. The materials are selected to assume, by their inherent

6

nature, when subjected to friction, respectively different polarities. Thus, pulverized rubber may be employed as the material which becomes negatively charged, and plastic powder such as polystyrene may serve as the positive counterpart. Other known positive and negative type powders may obviously be used. Both powders are present in one single container and subjected to turbulent motion, suitably by means of a fan or the like, driven by a motor. As a result, they assume the charges by friction with each other and also with the container walls; then they are applied to the dielectric surface. This may suitably be accomplished by expelling the powders from the container through a slot against the dielectric surface, which may be a display screen or a sheet on which the powder pattern is fixed in a subsequent step, as described below.

The novel features which are believed to be characteristic of the invention, both as to its organization and method of construction and operation, together with further objects and advantages thereof, will be better understood from the following description considered in connection with the accompanying drawing in which illustrative embodiments of the invention are disclosed, by way of example. It is to be expressly understood, however, that the drawing is for the purpose of illustration and description only and does not constitute a limitation of the invention.

In the drawing:

FIG. 1 is an isometric schematic view of a cathode ray tube having a charge-transmissive faceplate, useful in the present invention;

FIG. 2 is a schematic side view of one embodiment of a system in accordance with the invention for continuously displaying information on a screen;

FIG. 3 is a side view of FIG. 2;

FIG. 4 is a bottom view of FIG. 2;

FIG. 5 schematically illustrates a method for applying a charge pattern to a sheet; and

FIG. 6 is a sectional view along line 6-6 of FIG. 5.

Referring now to FIG. 1, a cathode ray tube useful in a system of the type disclosed herein includes an envelope having a tubular stem portion 10 and an enlarged flat front portion 12. The tubular portion 10 encloses an electron gun 14 and deflection plates 16, both of which form part of conventional cathode ray tubes and need not be further described herein. Conventional magnetic deflector arrangements could also be used. The electron beam produced by gun 14 is accelerated toward the elongated, strip-shaped faceplate 18 of the tube. In a conventional manner, a sweeping motion is imparted to the beam by means of deflection plates 16, and the beam intensity is representative of signals indicative of information to be displayed. The faceplate 18 forming the front enclosure of the tube is made of insulating material and has a great number of individual wire sections 20 embedded in it, with each wire section protruding at both the internal and external surfaces of faceplate 18, as shown. In the course of its sweeping motion, the electron beam impinges on the internally protruding ends of wire sections 20 and the negative charge impressed on the wires is transferred through the faceplate to appear at the external ends of the wires. As stated above, this type of cathode ray tube is known in the art and generally used for purposes of facsimile transmission or the like. When the tube is used in a conventional manner, the charges appearing at the external wire ends are deposited on a roll of a recording medium passed along the external surface of the faceplate.

FIGS. 2 through 4 schematically illustrate a display arrangement in accordance with the invention, using the cathode ray tube of FIG. 1 with a charge-transmissive strip-shaped faceplate in a novel arrangement. A cathode ray tube, generally designated 22 and including the tubular portion or stem 10 and an enlarged flat portion 12, is mounted for rotational motion about an imaginary axis 24

extending parallel with the tube axis and through one end point of its elongated faceplate 18. The supporting structure includes a hollow shaft 26 on which is mounted a tubular section 28 driven to rotate by means of gears 30 and 34. A pair of radially extending flanges 36 and 38 is secured to the tubular section 28 and supports the cathode ray tube 22 in a predetermined position with respect to rotation axis 24. Although numerous designs may be devised which result in a revolving motion of tube 22 and also provide for the necessary electrical connections, it has been found convenient to employ flange 38 in the manner shown in FIG. 4 in which the flange serves as a socket for the connector pins 40 of the tube. For convenience, all structural details including electrical connections such as those to the connector pins have been omitted in the drawing. The central section of the cylindrical tube stem 10 passes through the other flange 36 which suitably carries an annular insert 42 of resilient material to provide a shock-proof support for the tube. As shown in FIG. 4, a counterweight 44 may be secured to the tubular support section 28 at its side opposite the cathode ray tube to ensure smooth revolving motion of the entire assembly, as described to this point, when gear 30 is driven to rotate as indicated by arrow 46 to drive gear 34 in the direction indicated by arrow 48.

The faceplate of tube 22 describes a circular movement in a plane which is perpendicular to axis 24 and parallel to the plane of the screen 50. It can be seen that, with axis 24 intersecting the screen 50 at its center, faceplate 18 of cathode ray tube 22 covers a circular area on the screen by sweeping through successive radial positions. At this point it should be noted that it is desirable to maintain the protruding external wire ends of the faceplate as close as possible to the screen surface facing the tube, without actual contact between them. Generally, the clearance between the wire ends and the screen surface is about 0.001 inch to 0.003 inch.

The screen is a flat disc maintained in its position by a frame 52 which may conveniently form part of an enclosure or cabinet. It has been found convenient to mount the screen in a horizontal position with the cabinet enclosing the vertically arranged cathode ray tube so that a desk-type arrangement is obtained. Thus, the screen can readily be observed by an operator sitting or standing in front of it. It will be apparent that such vertical arrangement of the rotational portion is further advantageous to provide a smoothly balanced sweeping motion of the revolving assembly.

Referring now to the screen itself, it includes a base or supporting position in the shape of a circular disc 54 made of glass, "Lucite" or the like, supporting a transparent conductive intermediate layer 56, suitably including stannous chloride, and a transparent dielectric layer 58 which may be made of plastic material such as that known under the trade name "Mylar" or any other suitable polyester. As stated above, the conductive intermediate layer 56 is connected to ground. For multi-color display purposes, the grounded layer 56 and an additional electrode or brush sweeping over the screen surface cooperate to deposit a positive precharge on the screen, as is also explained below in connection with the powder applicator assembly. At this point, it should be noted that all three elements, the supporting disc 54 and layers 56 and 58, are preferably transparent so that the screen may be illuminated by light supplied from a source (not shown) and in the direction of arrows 60, FIG. 2, while the operator views the screen from the side opposite the tube. In connection with an arrangement in which the screen is mounted in the horizontal upper surface of a desk-like enclosure, the arrows 60 indicating the direction of light point in an upward direction, with sources of light arranged in the enclosure and surrounding the tube. Thus, the operator faces the screen from the left-hand side as shown in FIG. 2, and, as represented in

FIG. 3, with the faceplate 18 of the tube appearing behind the transparent screen.

It will be apparent from the foregoing that, when the cathode ray tube 22 is energized and at the same time is driven by gears 30 and 34 to revolve about axis 24, the faceplate 18 sweeps over a circular area of screen 50 by a rotational movement in the direction of arrow 62, as shown in FIG. 3. As signals are applied to the tube to change the beam intensity in accordance with information received, a charge pattern is deposited on the screen 50. In this movement, one complete revolution of 360° constitutes one cycle of this periodical sweeping motion.

The following now refers to the structure involved in rendering visible the charge pattern applied to the screen.

In addition to the tube itself, a container 64 holding particulate material such as fine dust or any suitable pulverized substance is mounted adjacent the tube on the supporting structure for the tube, to revolve with it. The container 64 is provided with a device for constantly agitating the powder contained in it, which may include a fan 66 driven by a motor 68 secured to the container, as schematically indicated in FIG. 2. As a matter of course, any other convenient means for agitating the powder particles may be used.

The end of the container pointing toward the screen is bent in such a manner that it terminates in an elongated flat portion forming a nozzle 70 having a slot-shaped aperture 72. The slot 72 extends adjacent and parallel with faceplate 18 of the cathode ray tube 22 and, since the container 64 is secured to rotate with the tube, the slot 72 follows the sweeping motion over the screen so that powder particles are blown under the action of the fan 66 and through slot 72 against the screen, immediately upon exposure of each radial screen area to the faceplate. It will be understood that the powder will adhere to areas having received a charge in accordance with information signals applied to the electron beam and an example of a treated area is illustrated in FIG. 3, however for a small angle designated 74. In this area, successive radial positions of the tube are indicated by radii 76, with lines 78 indicating zones to which a charge has been deposited so that adhering powder forms the image, as shown only in the angular area 74 of FIG. 3. It should be noted that by agitating the powder by means of fan 66, an electric charge is imparted to the powder. Furthermore, adhesion to the screen is improved by connecting the intermediate conductive layer 56 to ground.

As stated in the foregoing general description, by continuously superposing images applied during subsequent cycles of rotation result in a continuous track of a moving object such as an aircraft displayed on the screen. However, in most instances it is desired to merely display the latest information and it is for this purpose that the display system contemplated herein suitably includes an "eraser" unit for removing, at the beginning of each cycle, the powder which has been applied to one area of the screen during the preceding cycle. Although an element performing a wiping action on the screen may be used, it has been found convenient to employ a vacuum cleaner type arrangement, suitably in combination with a brush, which removes the powder by suction action, and such arrangement is included in the embodiment illustrated in FIGS. 2-4 of the drawing.

The eraser mechanism includes a container having a shape similar to that of the powder container 64, and designated by reference numeral 80. The bent portion of container 80 forming a nozzle 82, similar to nozzle 70 of container 64, is provided with a longitudinal slot 84 which also extends parallel and adjacent faceplate 18, however at the other side of the faceplate. Container 80 is also secured to the tube supporting structure to perform a sweeping motion with the tube and with the dust container 64. Slot 84 passes over the screen immediately ahead of the faceplate. An improved result is ob-

tained by the use of an elongated brush 85 secured to nozzle 82 alongside the slot 84 to loosen the powder from the screen so that it is readily picked up by the suction action of the eraser.

It has been mentioned that the supporting structure for the rotating assembly includes the tubular shaft 26. Since it is desirable for economic reasons to reuse the same powder during an extended period of time of operation, the embodiment illustrated in the drawing shows the vacuum cleaner type eraser container 80 connected by a conduit 86 (FIG. 4) to the internal space within the hollow shaft 26 and the hollow shaft 26 connected to the dust container 64 by another conduit 88 (FIG. 2). It will be apparent that, in operation, fan 66 driven by motor 68 will impart a circulating motion to the powder which then is expelled from container 64 through slot 72 toward the screen, picked up again by brush 85 and suction action through slot 84 of container 80, returned through conduit 86 into the hollow shaft 26, through conduit 88 and back into container 64. Considering that some loss of powder can practically not be avoided, additional powder may be supplied through the shaft 26, if desired. In cases in which circulation of the powder is not desired, an arrangement may readily be designed for continuously supplying new powder to container 64 and removing powder through the vacuum cleaner type eraser 80. Then, the eraser suitably includes a second motor-driven unit for performing the suction action required for removing powder from the screen.

As stated in the foregoing discussion, the cathode ray tube, the powder applying unit and the powder removing unit form a unitary assembly which revolves in the direction of arrow 62, FIG. 3. Since slot 84 and brush 85 of the eraser unit sweep over the circular screen area ahead of the faceplate, and the faceplate, in turn, sweeps ahead of slot 72 of the dust container 64, it will be seen that, once during each cycle of the circular sweeping motion, each radial area of the screen is cleaned or scavenged as a first operation, followed immediately by the deposition of a new charge in accordance with the signals as applied to it across the faceplate, which step is immediately followed by the application of new powder by the blowing action of fan 66 driving charged powder through slot 72 of container 64 against the screen. Thus, the rotating assembly, when passing any of the radial screen areas, removes from it the image displayed during the preceding cycle of sweeping motion and applies to it a new image which, in turn, remains until the unit passes through the same position in the course of the following cycle. Accordingly, the screen, as a whole, displays at any time and in a continuously changing manner the latest information which may be supplied from a radar receiving station performing a synchronized scanning motion over the sky.

The following now refers to the important feature mentioned above and involving display in at least two colors. A uniformly positive electric precharge, suitably in the range of about 300 to 600 volts, may be applied to the entire surface of layer 58 which faces the revolving assembly of the faceplate, the powder applicator and eraser. This may be accomplished by means of a roller 87 of conductive material mounted in any suitable fashion between the eraser unit and the faceplate and connected to the positive terminal of a voltage source (not shown). Roller 87 then acts as an electrode depositing a positive precharge on the screen surface when passing over it following the eraser unit and ahead of the faceplate, due to electrostatic induction, because the conductive transparent intermediate screen layer 56 is connected to ground, as shown in FIG. 2. A metal brush acting as the electrode for applying a positive precharge may be used instead of the roller electrode 87. The charges applied in accordance with the electron beam and through the charge-transmissive faceplate 18 by means of the individual wire sections 20 are of negative polarity. The

magnitudes of the positive precharge and the negative charges may be selected in such a manner that strongly negative charges applied through the faceplate prevail in some areas, whereas in other areas the positive, previously applied charge prevails over the weaker negative charges applied through the tube. Thus, positive and negative charges appear simultaneously on the screen and as a function of signal intensity applied to the tube. In order to discriminately display the different polarities of charged areas, powder container 64 may contain two distinct types of particulate material. One of these materials, when agitated by rotating fan 66, becomes positively charged and the other becomes negatively charged. A number of materials inherently exhibiting the property of assuming charges of one polarity or the other by friction when agitated are known in the art. Good results have been obtained when using pulverized hard rubber as the material which assumes a negative charge. Such hard rubber powder may be brown in appearance or have any other desired color. As the positive particulate material, isobutyl methacrylate, known under the trade name of "Lucite," has been used successfully. This material also may be colored in any desired manner by adding pigments to it as it is originally prepared and before pulverization.

It is now assumed that container 64 includes colored powdered rubber and Lucite, each of them exhibiting an appearance distinct from and suitably contrasting with that of the other. When motor 68 is energized to rotate fan 66, the powder content in container 64 is subjected to a turbulent movement whereby each of the two powder materials assumes an electrical charge of one polarity or the other, respectively, according to its nature. This is the result of friction as the particles are driven in turbulent motion against the container walls; friction between the particles may also contribute to this effect. When driven through the slot 72 toward the screen of which the surface includes positively and negatively charged areas, powder particles will be attracted toward and adhere to areas charged to the opposite polarity. As a result, a two-color image of the information represented by the intensity of signals is displayed on the screen and may be viewed across the transparent base plate 54 and layers 56 and 58 of the screen, while the screen is suitably illuminated by light falling on the screen in the direction of arrows 60, FIG. 2. In addition to the foregoing, some areas in which the positive precharge of the screen and the negative charge applied across the faceplate of the tube cancel each other, no final charge appears on the screen. Substantially no powder will adhere to such areas, so that an observing operator, when viewing the screen, will notice a third color in the system which is that of the screen or that of the light applied to the screen in the direction of arrows 60. Such arrangement results therefore in a three-color display system.

At this point it should be noted, that a pair of separate containers for the two different types of particulate material may be used, if desired. However, it has been found that, in practice, good results are obtained with a single container including both materials. Although it could be expected that in a mixture of two distinct powdered materials two opposite charges could not be developed within one container without particles of one and the other type combining with each other to neutralize their charges, the opposite has been found to be true. This surprising effect may be due to the strong natural tendency of the powders to assume the indicated charges, and to the turbulent motion to which the powder mixture is subjected, with the turbulent air keeping the particles separated from each other, at least during the process of expelling the mixed charged powder through slot 72.

It will be apparent that numerous possibilities exist for combining the multi-color process in different manners to obtain different effects. By way of example, alternate cycles of sweeping motion may be combined

with arrangements for alternately supplying powders carrying one or the other polarity and exhibiting different colors. Thus, after each cycle, another powder having a different color and charged to the opposite polarity is applied to the screen, during the subsequent cycle. In accordance with another alternative, a pair of tubes or several tubes may be used simultaneously, with each tube sweeping the screen along another radius. When employing two tubes, they may be arranged in such a manner that both radii form one diameter of the circle. In such arrangement, each of the tubes may cooperate with an equipment for applying and removing charged powder to and from the screen, each powder exhibiting a different polarity and color.

In the foregoing description, the visual display system has been illustrated by an embodiment in which the screen may be continuously viewed by an operator. However, it will be understood, that, in specific instances, equipment of the type contemplated herein may be provided with removable screens so that the information displayed on a screen may be retained for any desired time. Thus, the screen may be removed and subjected to any of the well-known fixing processes, for example, by heating the screen so that the powder combines with the dielectric layer 58 of suitably thermoplastic material or by applying a thin film of lacquer to the screen. Furthermore, a sensitized film may be secured to the screen in order to retain the information supplied after developing and fixing the exposed film. If desired, the image displayed on the screen may be transferred by an optical system in any suitable manner, for example, to a vertical wall-type display surface so that it can be viewed and observed simultaneously by a great number of persons.

The following now refers to the methods for reproducing on a sheet of dielectric material and rendering visible the obtained charge pattern in a system including at least two colors. The method is schematically illustrated in FIGS. 5 and 6 in which similar or identical elements are designated by the same reference numerals used in the previously discussed FIGS. 1-4.

The sheet 90 on which it is desired to reproduce an image may be made of any suitable dielectric material, such as paper, suitably coated with plastic material such as "Mylar." In the first place, a positive substantially uniform precharge is applied to the sheet. For this purpose, the sheet 90 is placed on a metal sheet 92 or backing plate connected to ground. The sheet 90 may have a conductive layer applied to the right-hand surface in FIGURE 5, instead of the separate backing plate 92. A roller-shaped electrode 91, similar to that designated by numeral 87 in FIG. 2, is mounted parallel and adjacent faceplate 18 of the tube and connected to the positive terminal of a voltage source 93, suitably of about 600 volts. As a result of this arrangement, a positive precharge is applied to the surface of sheet 90 facing the tube, by electrostatic induction. In FIGS. 5 and 6, the tube, designated by numeral 22, is assumed to be mounted in such a manner that it sweeps in a rectilinear motion over the sheet 90 when the sheet is passed in an upward direction, as indicated by arrows 94 in FIGS. 5 and 6, i.e., from the bottom to the top. The paper 90 may be provided with a conductive backing layer 92, or the paper 90 may be separate from a conductive roller or layer 92. In the course of the relative movement of the paper and the tube, the tube is located in a position in which its faceplate 18 constantly faces the sheet 90. In FIG. 5, there is also shown, in a purely schematically manner, a nozzle 70 forming part of a combined agitator and powder applicator substantially identical with that described in the figures discussed above. Since it is assumed that it is intended to apply a permanent image to the sheet, no eraser unit such as that shown in FIGS. 2-4 is required in connection with the present discussed arrangement of FIGS. 5 and 6.

In operation, it will be seen that the grounded sheet 92 and also conductive roller 91 assume the function of electrodes similar to that of the intermediate layer 56 of the screen and roller 87 of the display arrangement shown in FIGS. 2-4. As a result of the positive charge applied to the sheet 90 by roller electrode 91, a substantially uniformly distributed positive charge appears at the surface of sheet 90 positioned away from the grounded plate electrode 92. No charge is indicated in the lower portion of FIG. 5 in the lower surface of sheet 90, since the tube 22 or roller 91 has not yet swept over this area.

Since it is assumed that the sheet 90 has moved in an upward direction, so that faceplate 18 has swept over the upper half of sheet 90 in FIG. 5, a pattern of negative charges in accordance with received signals has been applied to this upper area. In this motion, the conductive backing sheet may be passed with the sheet 90, or else it may remain stationary.

With negative charges having been deposited by the passing faceplate 18, some areas, identified by minus symbols such as areas 96, 98 and 100, become negatively charged because it is assumed that the negative charges exceed the positive precharge previously applied. In other areas, designated 102, 104, 106, the positive precharge prevails over the applied negative charge. Although this must not necessarily be so, the charges may cancel each other in some remaining areas 108 and 110 which areas then exhibit no charge at all.

As discussed in connection with the assembly described in the previous figures, a powder applicator including a container holding positively and negatively charged particulate materials or powders, schematically indicated at 70, is mounted along and immediately above the faceplate 18. Thus, particulate matter of either polarity adheres to areas which are charged to the opposite polarity. When the powders exhibit colors distinct from each other and also different from that of the sheet, a three-color image is obtained in which areas designated 102, 104, and 106 may exhibit one color, which is that of the negatively charged powder, while areas 96, 98 and 100 appear in the color of the positively charged powder. Areas 108 and 110 having received substantially no powder at all remain unchanged and have the original color of the sheet. It is to be understood that the design formed by areas 96-110 has been selected for the purpose of illustration only. In practice, color reproduction of any type of image may be achieved, such as lettering or pictures.

When the faceplate 18 has terminated the sweeping motion over the entire sheet, the image may then be made permanent by any known fixing step such as spraying with a transparent lacquer. Alternatively, pulverized thermoplastic material may be used, or the sheet may be coated with thermoplastic material, as mentioned above. Then, the fixing step may include heating the sheet with the powder on it until the powder adheres to the sheet.

It should be mentioned that, although the steps of treating a sheet have been described in connection with FIG. 5 by a rectilinear motion of the faceplate over the sheet, a circular sweeping motion such as that described in connection with the display equipment may be employed. Furthermore, it will be understood that applying both the positive precharge and negative charge pattern may be accomplished by means other than those described in the foregoing discussion. By way of example, the negative charges may be deposited by means of one or more arrays of pointed electrodes without a tube envelope and performing an action similar to that of the wire sections 20 in the faceplate 18 of the cathode ray tube. Other types of appropriately shaped electrodes can readily be designed for this purpose. As stated in connection with the display arrangement, powders of different polarity and color may be applied one after another instead of being applied simultaneously, and it will be apparent that a great number of pulverized insulating material

added with pigments lends itself to the purpose disclosed herein.

At this point it should be noted, when running tests to determine optimum conditions, the appearance of positively charged areas surrounding strongly negative areas has been observed, regardless of whether the surrounding areas were precharged or not. It is believed that this phenomenon is the result of electrostatic induction within the dielectric sheet material. Such additionally occurring contrasting charges may advantageously be utilized for stressing an image by applying differently colored material resulting in adhesion to the surrounding area to accentuate a given outline, for example. This is accomplished, as described above, by the use of differently colored powders. It will be understood that the same phenomenon occurs with the arrangement including a transparent screen, as described in connection with FIGS. 2-4.

It has been found that an addition of iron filings assists in handling and applying a charge to the particulate material used as the charged powder.

It is to be understood that the above-described arrangements are illustrative of the application of the principles of the invention. Numerous other arrangements may be devised by those skilled in the art without departing from the spirit and scope of the invention. Thus, by way of example and not of limitation, the erasing action may be obtained by using a wiping mechanism of brushes exclusively, instead of the vacuum cleaner-type scavenger illustrated in the drawing. The brushes may also be electrically grounded metal fibers to overcome the charge pattern and to establish a reference voltage in preparation for the application of new charges. Although, in the embodiment illustrated in FIGS. 2-4, the tube is shown to revolve, with the screen being maintained stationary, the principles of the invention may be applied to a system with a moving screen; then the tube together with the powder applicator and eraser unit remain in a fixed position, as discussed in connection with a stationary sheet, FIGS. 5 and 6. An elongated metal brush may be used in the place of the roller-shaped electrodes 87 (FIGS. 2 and 3) and 91 (FIGS. 5 and 6). In this regard, as mentioned above, the dielectric sheet shown in FIGS. 5 and 6 may have a conductive backing layer serving as the grounded electrode, so that no separate backing plate 92 must be used. Furthermore, the particulate material may be applied to container 64 and removed through eraser unit 80 from a stationary supply and through the hollow shaft 26, which is suitably provided with two concentric conduits to separate from each other the inlet and outlet paths for the particulate materials. Then, connection to a stationary powder supply may be made in any convenient manner by means well known in the art. In such arrangement, a stationary blower may be substituted for the fan 66 and motor 68 shown in FIG. 2. As stated above, and for the purpose of simplification, all electrical connections have been omitted in the drawing. In practice, the rotating supporting structure including the hollow shaft 26 is provided with a multiple collector ring for connecting pins 40 of the tube with the corresponding receiving equipment and the circuitry providing the oscillating potential to produce the sweeping motion of the electron beam in the tube. Further collector rings are also provided for supplying current to motor 68 driving the agitating fan 66 and for another motor, if such motor is used, for driving another fan or a pump to activate the vacuum cleaner type-scavenger or eraser. It is also noted, with regard to the schematic showings of FIGS. 5 and 6, that conventional sheet feeding and other known powder application techniques may be employed and that details of these steps have therefore been omitted.

Accordingly, from the foregoing remarks, it is to be understood that the present invention is to be limited only by the spirit and scope of the appended claims.

What is claimed is:

1. In an assembly for visually and continuously displaying electrically transmitted signals representative of information which is subjected to changes:

a cathode ray tube having a substantially longitudinally extending faceplate, a plurality of individual wire sections embedded in and extending through the faceplate for transferring to the exterior surface of the faceplate electrical charges as they are impressed on the inner wire section ends by the impinging electron beam and in accordance with the signals applied to the tube,

a display screen cooperating with the tube, the screen comprising a transparent base plate, a conductive transparent intermediate layer and a transparent dielectric layer facing the faceplate for receiving said charges,

means for producing repeated relative sweeping motion of the tube and the screen, one with respect to the other, for periodically scanning the screen to apply a charge pattern to it, with each screen location receiving a charge in accordance with the signals received during each cycle of the sweeping motion,

means subject to an analogous sweeping motion for applying particulate material to each location of the screen once during each cycle and following exposure of the location to the faceplate for visually displaying, by adhesion of said material to the charged screen areas, an image of the charge pattern,

and means, also subject to an analogous sweeping motion, for removing the image formed by the particulate material from each location during each cycle immediately preceding subsequent exposure of the location to the faceplate, whereby said material is retained to represent a pattern image by adhering to each location on the screen for the duration of substantially one complete cycle of the sweeping motion.

2. In an assembly for visually and continuously displaying electrically transmitted signals representative of information which is subject to changes:

a cathode ray tube having a substantially longitudinally extending faceplate, a plurality of individual wire sections embedded in and extending through the faceplate for transferring electrical charges to the exterior surface of the faceplate as they are impressed on the inner wire ends by the impinging electron beam and in accordance with the signals applied to the tube,

a display screen cooperating with the tube, the screen comprising a transparent base plate, a conductive transparent intermediate layer and a transparent dielectric layer facing the faceplate for receiving said charges,

means for revolving the cathode ray tube with respect to the screen about an axis which is parallel but laterally offset with respect to the tube axis to produce a cyclic sweeping motion of the faceplate over the screen, the faceplate assuming successive radial positions to scan a circular area on the screen during each complete cycle of sweeping motion, whereby a charge pattern is applied to the screen, with each screen location receiving a charge in accordance with the signals received during each cycle of the sweeping motion,

a container holding particulate material and having a slot extending parallel with and adjacent the faceplate secured to the tube along one side of the faceplate to revolve with it for applying the particulate material to each location of the screen following its exposure to the faceplate for visually displaying, by adhesion of said material to the charged screen areas, an image of the charge pattern,

means for agitating the particulate material in the container to impress electrostatic charges on the particulate material by friction,

and means including a vacuum cleaner type unit having

a slot extending alongside the faceplate at the other side of the faceplate also mounted to revolve with the tube for removing, by suction, the image formed by the particulate material from each location substantially immediately preceding its subsequent exposure to the faceplate, whereby said material is retained to represent a pattern image at each location for the duration of substantially one complete cycle of the sweeping motion.

3. In an assembly for visually and continuously displaying electrically transmitted signals representative of information which is subject to changes:

a cathode ray tube having a substantially longitudinally extending faceplate, a plurality of individual wire sections embedded in and extending through the faceplate for transferring negative charges to the exterior surface of the faceplate as they are impressed on the inner wire section ends by the impinging electron beam and in accordance with signals applied to the tube,

a display screen cooperating with the tube, the screen comprising a transparent base plate, a transparent dielectric outer layer facing the faceplate for receiving said negative charges and a conductive transparent intermediate layer for connection to ground, means for revolving the cathode ray tube about an axis which is parallel but laterally offset with respect to the tube axis to produce a cyclic sweeping motion of the faceplate over the screen, the faceplate assuming successive radial positions to scan a circular area on the screen during each complete cycle of sweeping motion, whereby a charge pattern is applied to the screen,

an electrode mounted to revolve with and ahead of the tube for applying a positive precharge to the screen, with each screen location receiving, in accordance with the signals received during each cycle of the sweeping motion, a negative charge of sufficient magnitude to exceed that of the positive precharge in some of the screen areas, the positive precharge prevailing over the negative charge in other areas, with both charges cancelling each other in the remaining areas, to produce a latent charge pattern on the screen which comprises positive, negative and neutral areas,

a container coupled to the tube and subject to an analogous sweeping motion, the container holding a first, positively charged and a second, negatively charged particulate material, the container having an opening for applying the particulate materials to the screen, whereby each particulate material adheres to screen areas having a polarity opposite to that of the material, with substantially no particulate material adhering to the neutral screen areas, the first and second materials exhibiting visual appearances distinct from each other and also from that of the screen, the particulate materials being applied to each location of the screen once during each sweeping motion cycle and following its exposure to the faceplate for visually displaying on the screen an image of the charge pattern,

and means, also coupled to the tube and subject to an analogous sweeping motion for removing the image formed by the particulate materials from each location once during each cycle and immediately preceding subsequent exposure of the location to the precharging electrode and to the faceplate, whereby said materials are retained to represent a visible image of the charge pattern by adhering to oppositely charged screen locations for the duration of substantially one complete cycle of the sweeping motion.

4. In an assembly for visually and continuously displaying electrically transmitted signals representative of information which is subject to changes:

a cathode ray tube having a substantially longitudinally extending faceplate, a plurality of individual wire sec-

tions embedded in and extending through the faceplate for transferring electrical charges to the exterior surface of the faceplate as they are impressed on the inner wire ends by the impinging electron beam and in accordance with signals applied to the tube,

a display screen facing the faceplate to cooperate with the tube, the screen comprising a transparent base plate, a transparent dielectric layer facing the faceplate for receiving said charges, and a conductive transparent intermediate layer for connection to ground,

means for revolving the cathode ray tube about an axis parallel but offset with respect to the tube axis to produce a cyclic sweeping motion of the faceplate with respect to the screen, the faceplate assuming successive radial positions to sweep over a circular area of the screen during each complete cycle of the sweeping motion,

an electrode mounted to revolve with and ahead of the tube for applying a positive precharge to the screen, with each screen location receiving a negative charge in accordance with the signals received during each cycle of the sweeping motion, whereby the negative charges are superimposed onto the uniform positive precharge at the screen, the magnitude of negative charge exceeding that of the positive charge in some of the screen areas, the positive charge prevailing over the negative charge in other areas, with both charges cancelling each other in the remaining areas, to produce a latent charge pattern on the screen which comprises positive, negative, and neutral areas, a container mounted to revolve with and behind the tube, the container holding first and second particulate materials,

means including a fan for agitating the particulate material in the container to impress electrical charges on the particulate material, the container having a slot extending adjacent and parallel with the faceplate for applying the particulate material to the screen, whereby each particulate material adheres to screen areas having a polarity opposite to that of the material, with substantially no particulate material adhering to the neutral screen areas, the first and second particulate materials exhibiting visual appearances distinct from that of the other and also from that of the screen, the materials being applied to each location of the screen following its exposure to the faceplate for visually displaying on the screen a visible image of the charge pattern,

and means including a suction-operated eraser having a longitudinal slot extending adjacent and parallel with the faceplate also mounted to revolve with and ahead of the precharging electrode and the tube for removing, from each location, the image formed by the particulate materials substantially immediately preceding its exposure to the precharging electrode and the faceplate, whereby said materials are retained to represent a pattern image at each location for the duration of substantially one complete cycle of the sweeping motion.

References Cited by the Examiner

UNITED STATES PATENTS

2,143,844	1/1939	Daller	346—135
2,777,745	1/1957	McNaney	346—74
2,858,181	10/1958	Ortlieb	346—74
2,955,894	10/1960	Epstein	346—74
3,045,644	7/1962	Schwartz	346—74
3,181,172	4/1965	Boblett	346—135

BERNARD KONICK, *Primary Examiner.*

I. L. SRAGOW, R. M. JENNINGS, V. P. CANNEY,
Assistant Examiners.