

Aug. 30, 1938.

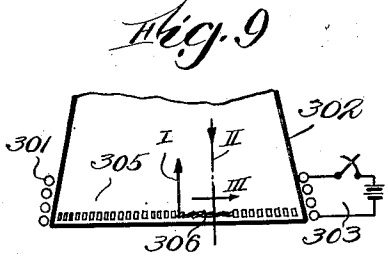
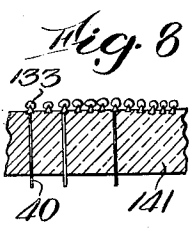
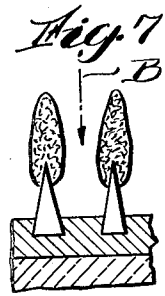
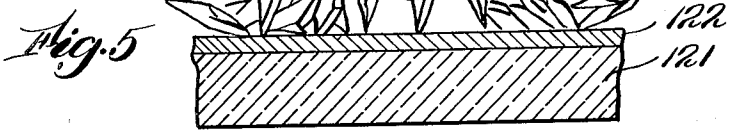
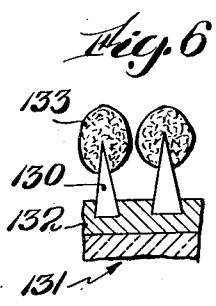
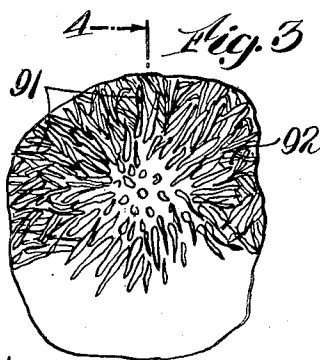
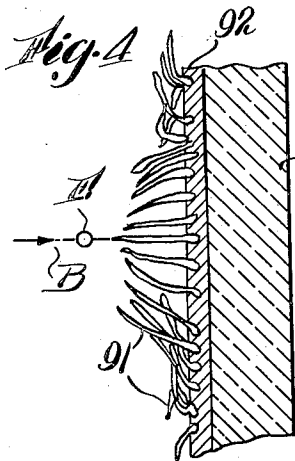
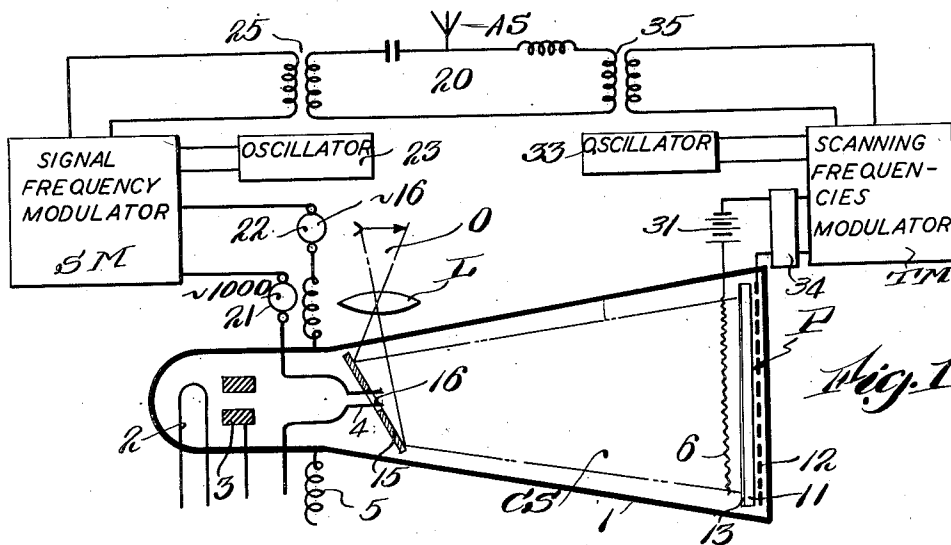
R. D. EATON

2,128,631

SYSTEM OF OPTICALLY REPRODUCING ELECTRIC IMPULSES

Filed Oct. 20, 1934

2 Sheets-Sheet 1



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SYSTEM OF OPTICALLY REPRODUCING ELECTRIC IMPULSES

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2 Sheets-Sheet 2

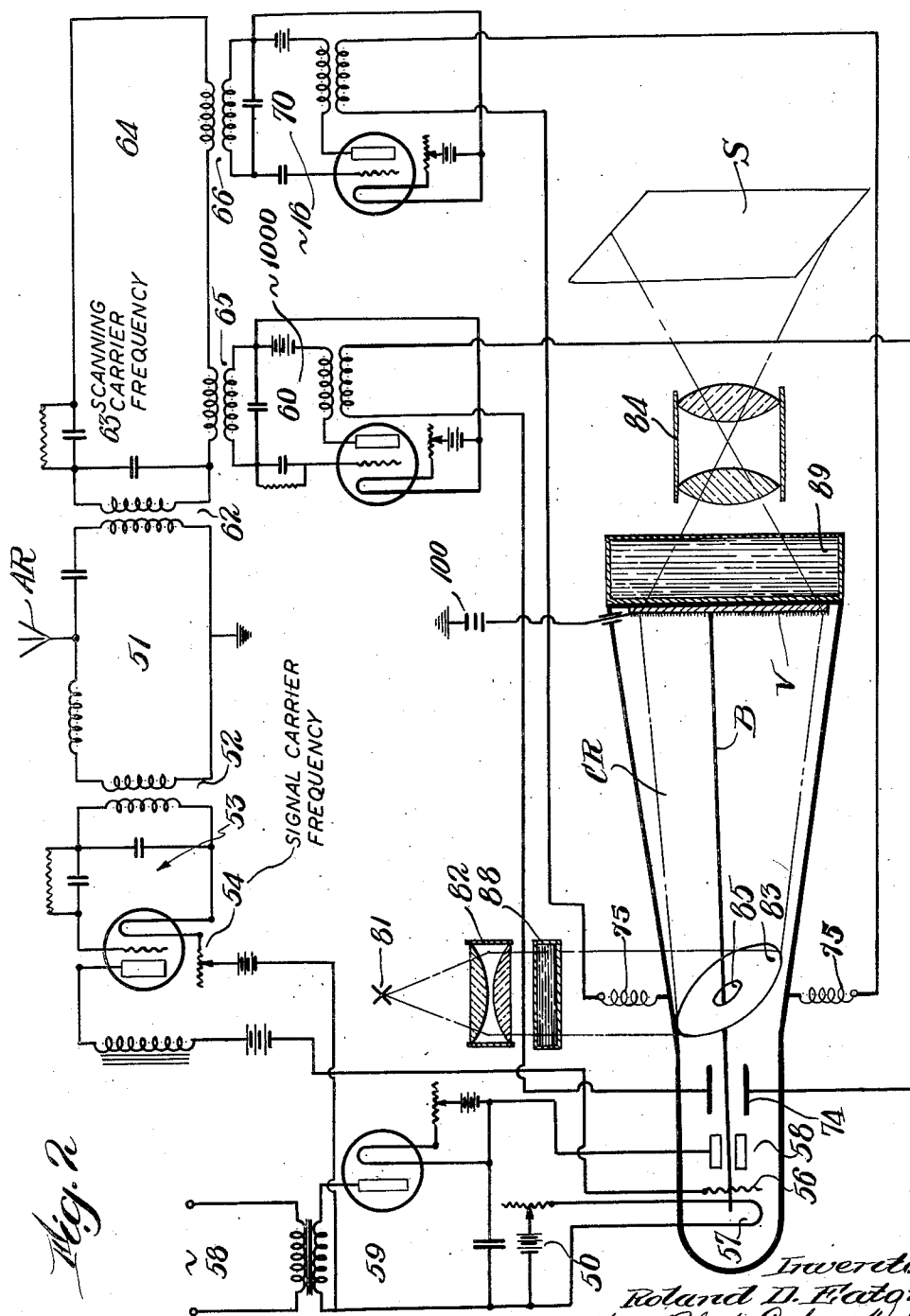


Fig. 2

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UNITED STATES PATENT OFFICE

2,128,631

SYSTEM OF OPTICALLY REPRODUCING
ELECTRIC IMPULSES

Roland D. Eaton, Cambridge, Mass., assignor, by direct and mesne assignments, of one-third to Jules A. Perrault and one-tenth to Charles H. Hawes, both of Boston, Mass., eighty-one fifteen-hundredths to Frank C. Stanton, Allston, Mass., one-sixth to Ida W. Glover, one one-hundred-fiftieth to Grace W. McGann, Providence, R. I., and nine fifteen-hundredths to Leo J. Logan, Marblehead, Mass.

Application October 20, 1934, Serial No. 749,140

8 Claims. (Cl. 178—7.5)

My invention is concerned, generally speaking, with the problem of optically reproducing electric impulses, and in one of its principal applications deals with this problem as encountered in converting incoming television signals into visible images.

Heretofore, one of the major difficulties in the art of television was the lack of sufficient light intensity of the reproduced picture. The other-wise most satisfactory reception arrangement employing cathode ray apparatus, of the type of the Braun oscillograph tubes, produces upon a face of a flask or tube, covered with fluorescent material, pictures yellowish green in color, which in itself is unsatisfactory. Further, the picture area is small, and the intensity of the visible rays emitted therefrom is too low to permit enlargement of the image by way of projection. The amount of light emitted from the fluorescent area of the vacuum tube, upon being struck by electrons, depends upon the intensity of the rays striking the fluorescent material as well as upon the properties of the latter. The electron energy of the rays can be increased to such an extent that, under certain circumstances, the heat produced by the electron impact might result in cracking the glass. But even with the highest practical electron intensity, the best available fluorescent material produces only a light intensity that is not sufficient to illuminate, through a projection lens system, an ordinary home movie screen.

It is, therefore, one of the principal objects of my invention to provide a method, and means, for reproducing at a receiving station the image of an object transmitted in the manner customary in the art of television, with a light intensity approaching that of modern motion picture apparatus.

In its more general aspect, my invention embraces the optical indication or detection of changes in electrical conditions by light whose intensity is to a large extent independent of the energy of the electric phenomenon to be detected.

Still another feature of the invention is the control of the intensity of any light beam by means of electron discharges, whereby the light intensity, as well as its rate of change, has a very high magnitude as compared with the controlling electron energy and its rate of change.

My invention also provides means for converting the present inefficient television apparatus employing cathode ray tubes reproducers into a much more satisfactory arrangement by comparatively minor, and inexpensive changes.

These, and other objects, aspects and features of my invention will be apparent from the following description of practical embodiments thereof illustrating its genus by way of example. The description refers to drawings in which:

Fig. 1 shows a conventional arrangement for sending television signals;

Fig. 2 is a television receiving circuit embodying in my invention;

Fig. 3 is a view of the light valve screen according to one embodiment of my invention;

Fig. 4 is a section on lines 4—4 of Fig. 3;

Fig. 5 is a section through a light valve screen according to another embodiment of my invention;

Figs. 6, 7, and 8 are sections through a light screen according to a third embodiment of my invention; and

Fig. 9 represents a modification of my invention employing a magnetic field.

The practical embodiment of my invention now to be described by way of example is part of a television equipment whose sending side may be of any conventional design, as for example shown in Fig. 1. Since this sending circuit is well known in the art, it is only schematically indicated as follows:

A cathode ray tube CS having an envelope 1, a hot cathode 2, and a tubular anode 3 is in addition equipped, like the familiar Braun oscillograph, with a pair of plates 4 suitable to establish an electric field, and coils 5 capable of maintaining a magnetic field parallel to the electric field of plates 4, the electrons emitted from cathode 2 passing through the opening of anode 3 through the fields of 4 and 5 towards the wide end of the tube. At that portion of the tube is arranged a grid 6 and behind it a composite plate P consisting of a layer of insulating material 11 covering a screen 12 made up of minute conducting dots of about 300 mesh. On the other side of insulating layer 11 is a stratum of alkali metal 13, for example caesium, or any other photoelectric material. The dots 12 are electrically interconnected.

Plates 4 and coils 5, respectively, are supplied with alternating currents generated at 21 and 22, these alternating currents having frequencies of 1000 and 16, respectively. The circuits of plates 4 and coils 5 are led to a scanning frequency modulator SM where their waves are impressed upon a radio frequency current generated by oscillator 23. Cathode 2 and anode 3 are in a high tension direct current circuit (not shown) supplied for example by a rectifier unit.

Cathode 2 is supplied with heating current from a suitable source (not shown). Dot screen 12 and grid 6 are in a circuit supplied with unidirectional potential, for example from a battery 31, and the signal impulses formed in this circuit are supplied to a television signal modulator TM where they are impressed upon a second radio frequency current supplied by oscillator 33. By means of transformers 25 and 35 the two carrier waves coming from modulators SM and TM, respectively, are supplied to an oscillating circuit 20 to which the sending antenna AS is connected. It will be understood that various amplification and other auxiliary devices are provided in this circuit of which only the essentials have been described. The cathode tube C contains an inclined mirror 15 which reflects a light beam, coming through lens system L from object O, towards grid 6 and plate P.

In order to broadcast a reproduction of the moving object O, it is projected by lens L towards the face of the cathode ray tube and focused upon the photoelectric layer 13 of composite plate P.

The mirror 15 reflecting this light has a central opening 16 through which the electrons emitted from the hot cathode 2 can pass on to grid 6 and plate P. Normally, that is without light impinging upon 16 and P, the circuit containing these elements is interrupted at P, and causes modulator TM substantially to neutralize the carrier oscillations generated at 33, which, under such conditions, are therefore not transmitted by antenna AS.

Oscillators or generators 21 and 22, delivering currents of frequencies 1000 and 16, respectively, cause an alternating electric field of frequency 1000 to be set up between plates 4 and an alternating magnetic field, parallel to the electric field and of frequency 16, to be set up by coils 5.

The electric field between plates 4 causes the cathode ray beam passing through anode 3 to be swung across plate P, and back, one thousand times per second, whereas the magnetic field swings the beam, at right angles to the first movement, 16 times a second, the two fields accomplishing in this well known manner a scanning movement, the beam covering every point of the area of plate P within $\frac{1}{2}$ of a second.

In modulator SM, the currents generated at 21 and 22 are impressed upon the carrier wave produced by oscillator 23, and the modulated carrier, suitably amplified, is radiated by antenna AS, thus constantly transmitting the scanning frequencies of plates 4 and coils 5.

The light rays of the beam bearing the image of object O and focused on plate P cause the photoelectric material 13 to emit electrons at intensities varying at each point proportionally with the light intensity of the optical image, at these points. The grid 6, and dot plate 12 form in effect condensers whose dielectric constant depends upon this photoelectric emission from layer 13. Hence, the cathode ray beam scanning these individual condensers will produce current changes in the circuit containing grid 6 and composite plate P.

These small current changes are appropriately amplified at 34 and at modulator TM impressed upon the radio frequency wave generated by oscillator 33. Coupling transformer 35 transmits the radio frequency wave to antenna AS, this wave being therefore modulated by the television signal current amplified at 34, which is in turn governed, as explained above, by the intensity of

the optical image at the spot at which the cathode ray is directed at any particular moment. In this manner, antenna AS transmits a television signal controlled by the scanning movement of a cathode ray, and at the same time the frequencies which control the scanning.

The receiving circuit, including my new light valve device as applied to television, will now be explained with reference to Fig. 2, the circuit which controls the intensity and movement of the beam of the reception cathode ray tube being in itself well known, so that the description thereof can be reduced to the essential features.

An oscillating circuit 51 is connected to receiving antenna AR resonant to the two carrier frequencies provided by the oscillator circuits 23 and 33 of the sending arrangement shown in Fig. 1. Through transformer 52 and filter 53 and suitable amplifying equipment (not shown) the modulated carrier wave from 33 of Fig. 1 is transmitted to detector triode 54, whose anode circuit includes control grid 56 and cathode 57 of receiver cathode ray tube CR.

Tube CR, like tube CS, has a hot cathode 57 and a tubular anode 58. The cathode 57 is supplied with heating current, for example from a battery 50, whereas the anode-cathode circuit is supplied with suitable high voltage unidirectional current, for example from alternating current source 58 through rectifier 59.

Circuit 51 is further connected, through transformer 62 and filter 63 which selects the carrier wave originating in oscillator circuit 23 of Fig. 1 to circuit 64 containing in series primaries 65 and 66. These primaries are parts of detector and amplification arrangements 60 and 70 which select, separate and detect the two scanning frequencies originating at oscillator circuits 21 and 22 of the sender shown in Fig. 1. The plate circuit of detector 60, selecting the current of frequency 1000, includes the plates 74 of tube CR, whereas the plate circuit of detector 70, selecting the current of frequency 16, includes coils 75 of tube CR. Plates 74 produce an electric field of frequency 1000, whereas coils 74 produce a magnetic field, codirectional with the electric field, of frequency 60, these fields being in synchronism with the fields produced by plates 4 and coils 5, respectively, of Fig. 1.

The optical equipment of the receiver includes a strong source of light, for example arc 81, a condenser 82 which illuminates light valve screen by means of a mirror 83 within the tube, and a lens system 84 for projecting the transparency on valve screen V on surface S.

Optical system 82 is separated from the cathode tube by heat absorbing cell 88 which may, for example, be filled with 1% copper sulphate solution, or with circulated and cooled liquid. Screen V is preferably cooled by means of a water jacket 89.

Mirror 83 has a central perforation 85 permitting the cathode ray beam B coming through anode 58 to pass to screen V, whereby, since the fields of plates 4 and 74, and coils 5 and 75, respectively, are in synchronism, the cathode ray beam of tube CR moves in exactly the same manner as the scanning beam of sender tube CS.

The electron beams are concentrated on plate P (Fig. 1) and screen V (Fig. 2), respectively, by means well known in the art, for example auxiliary electrodes.

It will now be evident that the cathode ray beams always point at corresponding portions of sending area P and receiving screen V, respec-

tively. Moreover, the intensity of the electron beam B in the receiving tube is at all times maintained proportional to the light intensity of the optical image of O focused on P, at the place where the sending beam impinges. This is accomplished with the aid of grid 56, whose potential is controlled by the signaling wave detected at 54 as above described.

According to my invention, the varying intensity of the electron beam B moving over screen V controls the transparency of that screen at the point where it impinges in a manner which will now be described in detail. Screen V has the function of normally preventing the passage of light, but becoming transparent at portions subjected to the effect of an electric field, or an impinging electron current. In the present embodiment of this broad principle forming the basis of my invention, I utilize the effect of an electric field upon particles attached to a base and capable of changing their shape or position according to the varying intensity of the electric field in which they are located.

It is a well known fact that the hairs of persons or animals stand up under electrically charged objects, for example in a shop where machines are driven by leather or fabric belts. This phenomenon is due to the fact that electrons emitted from the belt (which may have a considerable potential) form a charge on the hairs and the skin, so that an electric field exists between hairs and belt. As well known, bodies tend to move along the lines of force of an electric field, and since the hairs are attached at one end, they straighten out in the direction of the field, provided the intensity of the latter is sufficient to overcome the weight, stiffness and inertia of the hairs. If the field is not very strong, the hairs will be only partly erected and not straightened out entirely in the direction of the field.

Referring now to Figs. 3 and 4, according to one modification of my invention, I use hairs 91 embedded in a layer 92, preferably of semi-conducting material, applied to a glass plate 93. There are various ways of obtaining a screen of this type, one of which is to arrange suitable fibers (for example fine animal hair) in a layer, to contact one surface of this layer with stratum 92 in tacky condition, to let the stratum harden and finally to shear the free ends of the fibers, for example in an electric field.

Under normal conditions, as shown in the marginal portions of Figs. 3 and 4, the hairs assume irregular positions, essentially parallel or at least oblique to plate 93, and therefore obstructing the passage of light through the screen. When the electrons E forming cathode ray beam B strike a hair or a bundle of hairs, the hair, or a few hairs forming the bundle, are erected, as shown in Figs. 3 and 4, in the direction of the electric field which is also the direction of the cathode ray beam and of the light coming from mirror 83. The movement of the hair depends upon the intensity of the cathode ray beam; the weaker the field and the less pronounced the erecting effect, so that the transparency of the point where the cathode ray strikes screen V will depend upon the intensity of the beam. This intensity again is controlled by grid 56 and hence by the light intensity of the corresponding point of plate P of the sending tube (Fig. 1). Fig. 4 clearly shows this effect, the hairs immediately adjacent to the beam B appearing as dots and therefore uncovering their interstices for the

passage of light, whereas the rest of the hairs over the entire screen V are irregularly positioned and therefore form a substantially opaque surface.

It is apparent that intensity and position of the light beam passing from arc 81 and mirror 83 through the transparent point of screen V corresponds to position and intensity of the optical image on plate P of the receiver at the point where P is struck by the scanning cathode ray beam in tube CS.

The lens 84 receives the light passing through V and focuses it on projection screen S, forming on the latter a moving picture of object O (Fig. 1).

It will now be apparent that my invention makes the size and intensity of the final picture independent of the receiving surface proper of the cathode tube CR, my cathode ray controlled light valve screen V having essentially the effect of the transparency in a normal projection apparatus with light source 81, optic system 82-84 and projection screen S.

I found that the structure of screen V can be made sufficiently minute to provide a definition as fine as that possible with the silver grain of present motion picture positive film, since hairs of a diameter of the magnitude of these grains are available.

The flexibility of the particular fiber used should be taken into account by observing that each hair erects and collapses thirty-two times per second. Considering the mass of a hair of dimensions practical for use on screen V, this frequency of vibration is sufficiently slow to allow a wide margin for selecting a suitable fiber which will be able easily to follow these vibrations.

The hairs should be sufficiently long so that their angle of flexure or amplitude of vibration is small as compared with the effective light obscuring length of the bent hair. This eliminates the danger of breakage of fibers due to the continuous vibration.

Any danger of a burning of the hairs is effectively eliminated by the provisions of cooling devices 88 and 89, above described.

It is necessary that each hair, once charged, is again discharged immediately upon the passing of the cathode ray beam, in order to restore opacity of the screen and to be ready for the next approach of the beam. The charge of the fibers is, therefore, carried away by connecting layer 92 to ground, as indicated at 100 in Fig. 2. The time of discharge can be controlled by a resistance in series with each hair, or, preferably, by controlling the conductivity of the fiber by dipping it in a salt solution and measuring the resistance of the treated hair, changing the solution until the desired conductivity and discharge period is obtained. The conductivity of the fiber must not be too high since in that case leakage occurs between the hairs, which distorts the image due to a spreading of the effect of the cathode ray beam.

The opening 85 in mirror 83 is comparatively very small (shown exaggerated in Fig. 2) and, since the mirror is not in focus, acts merely as a "stop" or diaphragm slightly diminishing the amount of light reaching screen V, but not distorting the gradation of the picture.

It will be observed that the use of my new light valve screen is not limited to television but that motion pictures, maps and similar objects can be transmitted, especially since, by control-

ling the conductivity of the screen, images can be maintained as long as desired.

Instead of using fibers as light valve elements of my screen, other elements, as crystals, drops of liquids, or colloids or indeed any elements that orientate themselves in an electric field can be used for absorbing light in amounts controlled by an electron discharge beam.

For example, as shown in Fig. 5, more or less opaque needle crystals 120 are evenly distributed over a horizontal screen 121. The weight of the crystals is so balanced with respect to the force of the electric field, that the latter can erect the crystals but is not strong enough to bring them entirely out of contact with the screen. The effect of the cathode ray beam is indicated in Fig. 5 where crystals 125 are positioned substantially in the direction of beam B, whereas the surrounding crystals assume irregular positions, thus obstructing the passage of light. Layer 122 is semi-conductive, similar to stratum 92 of Fig. 4.

Instead of crystals, amorphous materials, as particles of talcum, glass, organic matter, bakelites, etc., may be used.

As indicated above, when this embodiment of my invention is used, screen V is arranged horizontally, and it will be obvious that the light beam emerging therefrom will have to be directed into horizontal direction by means of a mirror or prism.

According to still another embodiment of my invention, shown in Figs. 6 and 7, I use fine metallic needle points 130 embedded in semi-conductive layer 132 supported by screen 131. To each point is applied a droplet of liquid 133 which may be colored, gray or clear. Normally, the droplets are substantially spherical, as shown in Fig. 6, whereas, under the influence of beam B, they elongate as shown in Fig. 7. It will be evident that the spherical droplets of Fig. 6 substantially obstruct the passage of light, whereas the elongated elements of Fig. 7 uncover the interstices between the needles and effectively increase the transparency of the screen.

Colloids and various viscous fluids may be used for the droplets, and their surface tension is selected with a view to ensure their retention upon the needle points as well as proper balance with the elongating force of the electric field.

Instead of supporting the needle points in semi-conductive layer 132 of Figs. 6 and 7, they may be passed through the glass support as shown at 140 and 141 of Fig. 8. In this case, the conductivity of the screen elements can be controlled with particular certainty and independently of the supporting layer, and they may be arranged either inside or outside the tube.

In still another phase, my invention utilizes not only the electric fields caused by the electron movement in the cathode beam but also the magnetic fields accompanying them. The electric field corresponding to the electron beam is parallel to the latter, whereas the lines of the associated magnetic field are located in planes perpendicular to the beam. Hence, if the screen particles consist of a diamagnetic substance, as glass, carbon, graphite, antimony, boric acid, most organic liquids, and others, the effect of the magnetic field will aid the lifting action of the electric field as above described, because, as well known, bodies of diamagnetic substances tend to locate their longest dimension across a magnetic field.

On the other hand, if the light valve particles

consist of paramagnetic substances (which tend to set the longest dimension parallel to the magnetic field) as iron, nickel, cobalt or salts of these metals, the magnetic field which accompanies the electron beam can be utilized as follows:

Referring now to Fig. 9, 301 is a coil surrounding the screen end of cathode ray tube 302 otherwise similar to that shown in Fig. 2. Coil 301 is supplied with direct current, as indicated at 303 and sets up a magnetic field of direction I. In this field the paramagnetic elements will assume positions 305, hence offer to the light coming from mirror 83 (Fig. 2) a minimum obstruction so long as this field exists alone. If a cathode ray plays over the screen, its electric field II and its magnetic field III tend to counteract field I. The magnetic field is negligibly small since the effective current in the cathode ray beam amounts to hardly more than one milli-ampere. The electrostatic field, however, is of considerable magnitude since it depends upon the tube voltage. If the field produced by coil 301 is properly balanced with the effect of the electron beam, the particles are tilted at degrees proportionate with the intensity of the beam, as indicated at 306. Hence, the area immediately surrounding the point upon which the cathode ray beam is focused will obstruct the passage of light, producing an effect which has to that of the previously discussed embodiment the relation of negative photographic record to positive record. If the screen is in this case used horizontally, the elements need not be embedded, but their weight may be used to balance the force of magnetic field I.

It is understood that my invention can be modified in other respects, and permits of many constructive changes according to practical requirements of particular application thereof, the underlying principle being always the rearrangement of elements of a screen under the controlled influence of elementary electric fields, whereby the transparency of the screen is changed according to the distribution of the fields over the screen, so that the latter can be reproduced by projection similar to a conventional photographic transparency.

It should be understood that the present disclosure is for the purpose of illustration only and that this invention includes all modifications and equivalents which fall within the scope of the appended claims.

I claim:

1. A device of the character described comprising a substantially unbroken transparent base of high resistance material, minute elements distributed over said base and normally conditioned to assume positions in which they absorb substantially uniformly over said base light impinging thereon, means for normally maintaining said elements in an electric condition maintaining said position, and means for setting up an electronic beam causing an elementary electric field to move over said base, said field changing said electric condition and said position of said elements with respect to said base.

2. A device of the character described comprising a substantially unbroken transparent base of high resistance material, minute elements distributed over said base and normally conditioned to absorb a substantial amount of light impinging thereon, means for normally maintaining said elements in substantially uncharged condition, and means for setting up an electronic beam causing an elementary electric

field to move over said base, said field changing the electric condition of said elements causing them to change their position with respect to said base in accordance with picture signals applied to said beam.

3. A device of the character described comprising a substantially unbroken transparent base of high resistance material, elongate particles distributed over said base contacting it with one of their respective ends, and normally conditioned to assume positions in which they absorb substantially uniformly over said base light impinging thereon, means for normally maintaining said particles in an electric condition maintaining said position, and means for setting up an electronic beam causing an elementary electric field to move over said base, said field changing said electric condition and said position of said particles with respect to said base.

4. A device of the character described comprising a substantially unbroken transparent base of high resistance material, liquid droplets distributed over said base and normally conditioned to assume shapes in which they absorb substantially uniformly over said base light impinging thereon, means for normally maintaining said droplets in an electric condition maintaining said shape, and means for setting up an electronic beam causing an elementary electric field to move over said base, said field changing said electric condition and said shape of said droplets with respect to said base.

5. A device of the character described comprising a stratum of high resistance material, minute magnetic particles distributed over said base and normally conditioned to assume positions in which they absorb substantially uniformly over said base light impinging thereon, means for normally maintaining said particles in an electric condition maintaining said position, means for setting up an electronic beam causing an elementary electric field to move over said base, said field changing said electric condition and said position of said elements with respect to said base, and means for establishing a substantially uniform electromagnetic field perpendicular to said screen and controlling the posi-

tions of said particles in cooperation with said changing elementary electric field.

6. A device of the character described comprising an electron discharge apparatus of the Braun oscillator tube type with hot cathode, beam intensity control grid, beam focusing means, beam moving means and a beam projection surface; a screen on said surface intersecting the general direction of said beam and comprising a semi-conductive stratum and elementary particles in contact with said surface and movable relatively thereto under the influence of said beam; means for applying a selected potential to said layer; a light source; means including a reflector within said discharge apparatus for directing light from said source towards said screen; an exhibition surface; and lens means for projecting upon said exhibition surface said light passing through said screen as controlled by said particles.

7. Apparatus according to claim 6 further characterized in that said particles are magnetic, and by means for establishing a substantially uniform electromagnetic field perpendicular to said screen which controls the positions of said particles in cooperation with the changing elementary field established by said beam.

8. A cathode ray tube comprising an evacuated vessel having a transparent wall portion, at said wall portion a substantially uniformly transparent, and dielectric light valve screen with normally uncharged elementary particles adapted to change their light obstructing effect by varying their positions under the influence of the directional force exerted by a varying electric field, a cathode emitting an electron beam of variable intensity directed substantially perpendicular towards said screen, means for moving said beam and therefore the field corresponding thereto over said screen, a light source, and a reflector in the path of, and having an aperture for, said beam for directing light from said source towards said screen substantially codirectional with said beam for optically reproducing said screen as modified by the changing effect of said particles under the influence of said field.

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