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CATHODE RAY TUBE

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My invention relates to television receiving tubes and systems and particularly to systems incorporating tubes of the cathode ray light valve type.

In certain types of cathode ray light valves utilizing the electron beam of a cathode ray tube to control the orientation of particles in a liquid to provide a valve action on light from an auxiliary light source such as disclosed in my copending application Serial No. 256,833 filed February 17, 1939, have been proposed, but have not been altogether feasible because of the inability of the structure to utilize the control action of the beam to the fullest advantage, so that the effect of the electron beam in controlling the light from the auxiliary source has been inadequate. Other difficulties have been encountered because the structure scanned by the electron beam and responding thereto would not rapidly return to a condition of equilibrium to be in a condition to be rescanned. In this type of tube the discharge of the target or scanned structure to an equilibrium value is produced by using a scanning beam of electrons having a velocity higher than the velocity necessary to produce greater than unity secondary electron emission from the scanned structure. Such a method may not discharge the target rapidly enough for modern television arrangements and the target should preferably have uniform secondary electron emitting properties over its scanned surface. In practice it is hard to provide such a surface, and even then the half tones of the projected light on the viewing screen are somewhat limited in range.

The principal object of my invention is to provide a television receiving system incorporating a tube of the cathode ray light valve type wherein the time response is quicker and the half tones are of greater range under the operating conditions imposed by modern television transmitting systems. It is also an object to provide a device and system which is responsive to the control action of a modulated cathode ray beam to a greater degree than heretofore. It is a further object to provide an improved television receiving system and a method of operation wherein the above difficulties with the prior art devices are overcome.

In accordance with my invention I provide a light valve of the cathode ray beam type having an electrically polarizing light absorbing medium with means to swing the potential of the scanned target surface above and below the potential impressed on the surface by scanning. More particularly, I periodically vary the potential impressed at the boundaries of the light absorbing medium with respect to the cathode ray beam accelerating potential so that the cathode ray beam is effective in changing the potential of the scanned surface during a subsequent scan.

I provide a convenient way of varying this potential by the use of switching means, to change the potential on electrodes on either side of the light absorbing medium with respect to the beam accelerating anode, the switching being effected during the periods between frame scanning. These and still other objects, features, and advantages of my invention will become apparent and will at once suggest themselves to those skilled in the art from the following description taken in connection with the accompanying drawing in which:

Figure 1 is a view in cross section of a cathode ray light valve or tube and picture projection system embodying my invention;

Figure 2 is a pair of curves indicating the secondary electron emission characteristics of certain of the electrode structure shown in Figure 1;

Figure 3 is a schematic representation of certain of the tube structure shown in Figure 1 to illustrate certain aspects of the operation of my device; and

Figure 4 is a partial view of a modified tube structure which may be used in my system.

Referring to Figure 1 which illustrates my tube and system, the cathode ray tube or light valve includes a highly evacuated envelope or bulb 1 of cylindrical shape with a tubular arm or neck section enclosing a conventional electron gun. The cylindrical portion of the bulb 1 is provided at one end thereof with a window 2 of optically uniform material such as glass so that light from a substantially constant intensity light source 3 may be formed into parallel rays of light by the lens system 4 and projected through the cylindrical portion of the bulb 1. The opposite end of the cylindrical portion of the tube is provided with a closure, likewise of optically transparent material which will hereinafter be referred to as the target 5 being positioned so as to be scanned by an electron beam originating from the gun structure in the neck of the bulb 1.

The electron gun assembly is of the conventional type and comprises a cathode 6 from which an electron stream may be drawn, a control electrode 7, and a first anode 8 maintained positive with respect to the cathode 6. The electron stream leaving the first anode 8 is accelerated and concentrated into an electron scanning beam focused on the surface of the target 5 facing the electron gun by a second anode 9 which is preferably a conductive coating on the inner surface of the envelope 1 over a portion of the neck section and also over a portion of the inner surface of the cylindrical section. The first anode 8 and the second anode 9 are maintained at the desired positive potentials with respect to the cathode 6 by a potential source such as the battery 10. The control electrode 7 is maintained slightly negative with respect to the cathode 6 by the biasing

battery 11 connected between the control electrode and the cathode in series with a source of control potential or a video receiver 12 such as used in conventional television receiving systems. Adjacent the end of the first anode 8 farthest removed from the control electrode 7 I provide means for sweeping the electron beam over the target 5. For this purpose I have shown the deflection coils H and V for deflecting the electron beam in mutually perpendicular directions such as in a horizontal and a vertical direction respectively, the period of vertical scanning being greater than the period of horizontal scanning by a factor determined by the number of horizontal lines desired. The coils are supplied with the proper currents for sweeping the beam over the target 5 by conventional horizontal and vertical sweep oscillators, that supplying the coils H being suitably controlled for keystone compensation as well known in the art since the plane of the target 5 is at an angle with respect to the longitudinal axis of the electron gun. It is understood that conventional deflection plates may be substituted for either one or both of the deflection coils if desired.

The target 5 is composed of high electrical resistance material having the desired quality of being optically transparent and is sealed to the bulb 1 by the use of an intermediate vitreous material as described in my above copending application. I have found it necessary to provide a physically rugged target of material having the desired characteristics but which is nevertheless sufficiently thin to meet the operating requirements of my device. In the preferred modifications of my device I prefer mica as a target material because even when sufficiently thin, such as a few thousandths of an inch, it is sufficiently strong to withstand normal hydrostatic and vapor pressures.

I provide a container or reservoir 13 positioned exterior to the envelope or bulb 1 and adjacent the target 5, the target 5 preferably forming one wall of the container. In the wall of the reservoir 13 and opposite the target 5 I provide a window 14 of glass or other transparent material axially aligned with the target 5 and also with the window 2 so that light from the light source 3 may be projected through the cylindrical section of the bulb 1 and the reservoir 13 and focused on a distant light intercepting or viewing screen 15 by the lens system 16. The target 5 and window 14 constitute in effect a double wall for the envelope or bulb 1. The distance between the adjacent surfaces of the target 5 and the window 14 is not critical although it should be small. Preferably this distance should be substantially equal to the diameter of the electron beam from the electron gun. I have made satisfactory tubes of this type where this distance was less than one millimeter. On one surface of the reservoir window 14, preferably the outside surface thereof, I provide a substantially transparent electrically conductive electrode 17, preferably an exceedingly thin film of metal, such as gold or platinum, which may be sputtered, condensed from the vapor phase, or otherwise applied as well known to those familiar with the art of making thin conductive films. While I have shown the electrode 17 on the outside surface of the window 14, it may be deposited on the opposite or inside surface and still meet the requirements of my device.

Within the reservoir 13 I provide a suspending medium or liquid 18 carrying in suspension a great number of light intercepting or absorbing

particles 19, which may be oriented to vary the light transmitting character of the device. The characteristics and functions of the liquid 18 and the particles 19 will be considered more fully below. Between the target 5 and the window 14, I provide a mechanical agitator such as a sheet of mica or other transparent material (not shown) which is maintained in motion during operation of the device.

I make the target 5 of such a material that when bombarded by energy such as by a beam of electrons of relatively low velocity the charge produced thereon is negative whereas when bombarded with higher velocity electrons the charge developed thereon is positive in that more secondary electrons are liberated from the target than there are arriving primary electrons, the material also having the property that under still higher velocity electron bombardment fewer secondary electrons are produced than there are arriving electrons. The electron beam produced and focused on the target 5 by the electron gun is modulated in intensity by the control electrode 7. The intensity of the beam over a period of one vertical sweep of the beam may be utilized to produce a picture produced in a manner well known in the art but instead of the picture being rendered visible by the cooperation of a fluorescent material deposited on the target the electrons produce an electrostatic image of the picture, which electrostatic image varies in intensity of charge from area to area in accordance with the light and shade areas from which the signals applied to the control electrode 7 were derived. The electrostatic image on the target 5 orients the particles 19 in the suspension in a manner to be described and thus permits varying amounts of light from the source 3 to pass through the suspension and be focused upon the viewing screen 15, the energy of the viewed picture being controlled but not generated by the electron beam.

As shown in considerable detail in my copending application the suspending medium or liquid 18 contained in the reservoir 13 may be any liquid having the desired characteristics as regards electrical resistance, transparency, vapor pressure and viscosity. Thus the suspending medium preferably has very high electrical resistance and transparency and low vapor pressure and viscosity. Liquids including n-amyl-sebacate, ethyl-hexyl-phthalate, ethyl-hexylacetate, and tetrabromoethane are satisfactory. Particles of graphite of a size somewhat larger than colloidal, or commercial aluminum foil having a thickness less than $\frac{1}{2}$ micron, the foil being sub-divided into particles that are very thin compared to their other dimensions may be used. The ratio of the areas of the particles normal to the light-rays passing through the light valve in the deoriented and oriented condition should be as large as possible. This ratio may be termed the shape factor of the particle when taken with respect to the interposed particle area in the two conditions. I have found that with particles of any average shape factor the change in light transmission of the suspension with the application of the field and the efficiency with which the light is controlled may be varied in a predictable manner by changing the number of particles contained in a unit volume of the suspending medium. Thus, for television purposes, for example, maximum contrast of the optical image projected as a picture on the viewing screen 15 can be adjusted to the desired value

when the light valve is constructed and the average brightness of the picture can be adjusted at any time by changing the intensity of the light source 3.

In accordance with my invention I provide means to suddenly change the potential adjacent the scanned surface of the target 5 with respect to the electrode 17 at a rate commensurate with the rate of frame scanning. I thus provide means to capacitively swing scanned elements of the target 5 from a high potential to a low potential with respect to the second anode 5 which is maintained at the high potential.

Referring to Figure 1 I provide an electrode 20 preferably as a band of metal on the wall of the envelope 1 between the second anode 9 and the target 5. The electrodes 17 and 20 are connected through a rotating commutator 21 having a conducting section 22 and an insulating section 23 to the second anode 9. These electrodes are also connected to a point 24 of the battery 10 which point is negative with respect to the second anode 9 potential. This connection is made through a high resistance 25 of 8 to 12 megohms to allow the charge applied to the electrodes 17 and 20 upon rotation of the commutator to leak off. The value of this resistance should be such that the charge leaks off in the time between frame scanings of the beam, that is during the vertical return time. The use of the resistance 25 may be avoided by using a double contacting commutator to switch the electrodes 17 and 20 first to second anode potential and then to a lower potential between alternate frame scanings. While I have shown a simple commutator arrangement for rapidly changing the potential of the electrodes 17 and 20 with respect to the second anode 9 it is obvious that the commutator may be replaced with a thermionic vacuum tube oscillator of the square wave generating type.

In operation the potential applied to the second anode may be approximately 7000 volts positive with respect to the cathode 6, and the point 24 on the battery 10 may be 5000 volts positive with respect to the cathode 6. While I prefer to operate the electrodes 17 and 20 during alternate scanning periods at second anode potential and at a potential negative with respect to second anode potential, I have found that the system will work equally as well if this potential is positive with respect to the second anode. The choice of the lower potential simplifies the power supply requirements.

The selection of the tube or light valve potentials will become apparent upon consideration of Figure 2, wherein the curves represent the emission of secondary electrons from the scanned surface of the target 5 as ordinants for values of the second anode potential as abscissae. I have found that it is somewhat difficult to provide a target of material having uniform secondary electron emitting properties over its entire surface, but in my system and method of operation it is not necessary that the entire target surface have the same secondary emitting properties and I have therefore shown two curves in Figure 2 representative of two portions of the target surface, although it is understood that the various areas of the target may vary in secondary electron emitting properties over wide limits. Referring again to Figure 2 and to the curve shown in full outline, the line A represents unity secondary electron emission, a condition which exists when the secondary electron emission from the target is equivalent in quantity to the number

of primary electrons impinging on the target. It will be observed that at second anode potential below the point marked B on the curve, the ratio of secondary electrons to primary electrons is less than unity, whereas for second anode potentials between the points B and C the secondary emission is greater than unity and for higher potentials than that represented by point C this ratio is again less than unity. It may, therefore, be observed that the curve in full outline crosses the line A at two points, B and C. The points B and C will therefore be referred to as first and second cross-over respectively. For mica the first and second cross-over points are approximately 100 and 3000 volts respectively as shown. In selecting potentials such as the 5000 and 7000 volts referred to above, it is evident that these potentials have been selected as being higher than the highest second cross-over potential of any point or area of the target 5, and the difference of these potentials should be less than the second cross-over potential minus the first cross-over potential. Thus, this difference of potential should not exceed 2900 volts in the example considered.

Referring again to Figure 1, the potential of the electrodes 17 and 20 is substantially that of the second anode 9 when the circuit through the commutator 21 is closed through the conducting segment 22. When, however, due to rotation of the commutator 21, the circuit between the electrode 20 and the battery 10 is interrupted by the insulating segment 23, the potential of these electrodes quickly assumes the potential of the point 24 on the battery 10 which, at the values given above, is 5000 volts, the second anode being at 7000 volts with respect to the cathode 6. Obviously, the type of commutator or other device used to vary the potential of the electrodes 17 and 20 may be of any type designed to accomplish the desired results with respect to amplitude, potential and phase of the potential which is desired. I have found, however, that the time during which the circuit is closed should be substantially equal to the time during which the circuit is open through the commutator 21 so that the potential applied between the electrodes 17 and 20 and the second anode 9 is of the square wave type. I have also found that the circuit through the commutator 21 should be opened or closed immediately before the target is vertically scanned and that the reverse occur immediately before the next vertical scan. The reversals should therefore take place between the periods of vertical frame scanning, that is, during the time required between the end of one vertical frame and the beginning of the next vertical frame. Thus, for receiving television signals transmitted under the present RMA system of transmission using 30 frames per second, the speed of a commutator having a contact over 180° of its periphery should be 15 revolutions per second, since the circuit is completed and broken twice for each revolution. It is therefore desirable to synchronize the speed of the commutator with the frame synchronizing circuits of the video receiver 12, although this is not necessary, since I have found that this speed may be varied over quite wide limits provided moving bar patterns may be tolerated.

I have found that by applying a substantially square wave shape potential variation between the second anode 9 and the electrodes 17 and 20 it is possible to obtain very good half-tones in the recreated picture with low beam currents

of the order of 10 microamperes average current over a frame period. With my device and system disclosed in my above-referenced copending application wherein the electrode 20 was not used and the transparent electrode 17 was connected directly to the second anode, an average electron beam current of approximately 75 microamperes was necessary for proper operation using my previous method of secondary electron discharge of the scanned areas. Using my new system of varying the potential applied to the electrodes 17 and 20, much lower average beam current is required for the reproduction of a changing picture, resulting in the current range for half-tone reproduction of both repetitive and changing pictures being the same so that the valve is capable of much higher half-tone response.

The method of operation yielding actuation of the valve at low beam currents is explained by referring to the following table and to Figure 3, which shows a fragmentary cross-section of a portion of the light valve in Figure 1.

Cycle	Operation	D	E	F	G	Potential difference across suspension
0	Before 1st scan	7,000	7,000	7,000	7,000	0
1	First scan	6,000	6,200	6,800	7,000	+600
	Polarization	6,000	6,500	6,500	7,000	0
	Impulse downward	4,000	4,500	4,500	5,000	0
2	Second scan	3,000	3,700	4,300	5,000	+600
	Polarization	3,000	4,000	4,000	5,000	0
	Impulse upward	5,000	6,000	6,000	7,000	0
3	Third scan	4,000	5,200	5,800	7,000	+600
	Polarization	4,000	5,500	5,500	7,000	0
	Impulse downward	2,000	3,500	3,500	5,000	0
4	Fourth scan	3,000	4,300	3,700	5,000	-600
	Polarization	3,000	4,000	4,000	5,000	0
	Impulse upward	5,000	6,000	6,000	7,000	0
5	Fifth scan	4,000	5,200	5,800	7,000	+600
	Polarization	4,000	5,500	5,500	7,000	0
	Impulse downward	2,000	3,500	3,500	5,000	0
6	Sixth scan	3,000	4,300	3,700	5,000	-600
	Polarization	3,000	4,000	4,000	5,000	0
	Impulse upward	5,000	6,000	6,000	7,000	0

The columns of the above table headed D, E, F, and G show voltages assumed by an elemental area of the surfaces D, E, F and G when an area of the target is scanned, and refer to the corresponding designations of these surfaces in Figure 3. The terms "impulse upward" and "impulse downward" refer to the changes of potential impressed on the semi-transparent conducting electrode 17, on the electrode 20, and, by capacitive coupling, on the scanned surface of the wall 5, by the use of the commutator 21. It is assumed that the target 5 is scanned over the surface D with an unmodulated beam to produce a repetitive raster. It is likewise assumed that the second anode 9 is held at 7000 volts and that the potential on the electrodes 17 and 20 is alternately changed from 7000 to 5000 and from 5000 to 7000 volts between successive frame periods of scanning. Thus, the electrodes 17 and 20 are held at 7000 volts during one scan, 5000 volts during the next, 7000 volts during the third etc., by rotating the commutator 21 which is synchronized with the vertical scanning frequency. It is further assumed that the secondary emission second cross-over point of the target 5 is at an electron velocity of 3000 volts as shown by the full line curve in Figure 2 and that the electron beam from the cathode 6 is of such intensity as to change the potential of the scanned element, under con-

sideration in the above table, by 1000 volts. It is also further assumed that 20% of the potential difference generated by scanning the surface D imposed across the target 5, the suspension 18 and the wall 14 occurs across each wall and that the suspension opposite a scanned element polarizes completely before the next time this element is scanned. This leaves 60% of the potential difference available for activating the particles in the suspension. These assumptions of 20% and 60% refer to any new field superimposed upon the fields present due to the charge distribution obtained before the application of the new field. Thus in the first scan of cycle 1 as shown by the above table, 60% of the change in potential is across the fluid and 20% is across each wall. Thus if D falls 1000 volts, E falls 80% of this, or 800 volts, F falls 20%, or 200 volts. After "impulse downward" at the end of the first cycle, the charge distribution places 1000 volts across the whole valve, but none across the suspension, due to leakage. The second scan (cycle 2) reduces the potential of the surface D by 1000 volts more, and it is assumed that 20% of this change appears across each wall and 60% across the suspension. Hence E falls 80% of the potential difference caused by scanning, or 800 volts (from 4500 to 3700), while F falls 20% of this same potential, or 200 volts, or from 4500 to 4300 volts. In all subsequent rapid changes due to scanning, which changes the field across the valve as a whole, 20% of the change appears across each wall and 60% across the liquid suspension. These assumptions are reasonable since I have found that changes in any of the assumptions will, in general, result in no essential change in the mode of operation.

Referring to the above table, the potentials tabulated below the surfaces of the walls are for an element bombarded early in the vertical scanning period. Before the first scan and with the commutator 21 closed to complete the circuit through the segment 22, all wall potentials are that of the second anode, namely, 7000 volts due to leakage, and the potential difference across the suspension 18 is zero. The electron beam from the cathode 6 then strikes the element or area under consideration and since the beam velocity is above that corresponding to the secondary emission second cross-over point, the bombarded element falls in potential by 1000 volts. The resulting field is distributed across the valve, a potential difference of 600 volts (the sign arbitrarily taken to be positive) appearing across the suspension, and the suspended particles are oriented. Since the suspension 18 is not a perfect electrical insulator, this potential difference across the suspension disappears due to electrical leakage, this action being termed electrical polarization of the suspension. Therefore, during the remainder of the first vertical scan, the suspension opposite the area under consideration polarizes and all of the potential difference appears across the wall of the target 5 and across the window 14. During this period of polarization the particles in suspension have become oriented and deoriented again by whatever means are employed for the latter purpose, such as the sheet of mica between the target 5 and wall 14 referred to above. The electrical leakage has been referred to above as "electrical polarization" because electrical leakage of the suspension results in electrical polarization. This is true since the leakage results in a transfer of charge to the surfaces of the suspension, hence to the inside

surfaces E and F of the walls 5 and 14. This distribution of bound charges at the interfaces, notwithstanding the charges on the outside of the walls, results in a zero field across the suspension. It is a real charge distribution, for if the charges on the outside of the walls were removed, the charges on the inside of the walls would result in a field across the suspension. A change in the charge on the surface E, which occurs at every scan, upsets the balanced charge distribution and causes a field to reappear across the suspension. Due to leakage, the charge is again dissipated until the charge distribution is such as to result in zero field across the suspension. As soon as the charge on the surface D of the wall 5 is changed to produce a field across the suspension, a current flows in the suspension, due to leakage, and the polarization changes, giving a new charge distribution again resulting in no field across the suspension. Beginning with the third cycle, this current flows in opposite directions in alternate cycles and the process is repeated indefinitely. The electron beam is preferably blanked out during the return time various methods for such blanking being well known in the art and during this return time the commutator 21 breaks the contact between the electrodes 17 and 20 and the second anode, and the charge on these electrodes is rapidly dissipated through the resistor 25, and the electrodes 17 and 20 assume the potential of the point 24 on the battery 10, this potential being, as indicated above, 2000 volts less than that applied to the second anode. The combination of capacitive coupling to the electrode 20 and to the surface on which the electrode 17 is deposited carries all of the areas of all the walls of the valve down in potential. It is assumed that these walls are carried down 2000 volts, although departures from this uniformity of potential change will not alter the essentials of the operation of the device.

The next cycle of operation begins with the rescanning of the element under consideration which is again reduced in potential, this time to the assumed second cross-over point of the target 5, or to 3000 volts. This new change in potential is distributed across the valve, again resulting in 600 volts being developed across the suspension. Polarization follows and the cycle is completed with the upward potential change of the electrodes 17 and 20 due to the closing of the commutator following the second scan. In the third cycle the potential across the valve is again 600 volts in the same direction as in the first and second cycles and no new step is introduced except that the recently scanned element is now caused to swing below the second cross-over point. In the fourth cycle the scanned area is changed upwardly in potential to 3000 volts, since the secondary emission ratio is now greater than unity and for the first time the field across the suspension is reversed, resulting in a potential difference across the suspension of minus 600 volts. The fifth and sixth cycles are repetitions of the third and fourth respectively, and subsequent cycles repeat in pairs.

It will be apparent from the above explanation that the potential developed across the suspension is alternating in direction. This feature is of considerable importance in that the particles in suspension are not always caused to migrate in the same direction. The sticking of the particles to the inner walls of the valve is much less with this capacitive mode of operation than when all of the electrodes are maintained at a fixed po-

tential, and where the beam charges the surface of the target 5 down in potential at each scanning, as disclosed in my copending application referred to above. It will likewise be observed from the above table that the potential across the valve never falls to zero, but this is immaterial since the suspended particles respond only to the potential across the suspension which falls to zero between successive horizontal scanings.

While I have disclosed the transparent electrode 17 as being on the outside surface of the window 14 and I have shown this positioning in the above mode of operation, I have found that the valve works equally as well with this electrode on the opposite surface of the window 14. This latter arrangement is to be preferred where it is necessary to have the window 14 of considerable thickness to withstand atmospheric pressure such as when the area of the target 5 is considerable.

I have indicated that the use of a square wave potential change between the electrodes 17 and 20 with respect to the second anode 9 is preferable. Thus, it should be pointed out that the use of a sine wave of alternating potential will not satisfy the requirements of my system. Thus, if the scanning be assumed to be 30 frames per second, a 15-cycle sine wave will leave the beginning and end areas of the target, in sequence of scanning, unactuated. In addition, a 30-cycle sine wave or any multiple will leave the scanned area under consideration at the same potential given to this scanned area during the previous scanning cycle, since the potential on the electrode 20 would return to the same amplitude and the same phase. Hence, the beam can apply no new impulse to the area under consideration. Odd multiples of 15-cycle sine wave potentials would have reversed amplitudes in alternating vertical frames and would again leave the nodal points unactuated. Finally, sine wave frequencies incommensurate with 30 cycles per second would result in drifting bar patterns.

With different values of second anode potential the wall potentials of the valve during the cycles of operation before equilibrium is established, such as before the fourth cycle in the above table, will be somewhat different from those given above, but the potential of the scanned target and the potential difference across the suspension will soon assume the above tabulated values. Furthermore, after the first few cycles, essentially the same equilibrium will be reached whether the area under consideration is at the beginning, during or at the end of the vertical frame scanning, since the polarization and the potential difference across the suspension due to scanning are essentially independent of the absolute values of the potentials and are unaffected by the sudden change produced by commutation.

If the beam current is strong enough to charge the scanned area down to the second cross-over potential from the higher of the two potentials applied to the electrodes 17 and 20, a newly scanned area which might be expected to be at second anode potential initially would be changed by 4000 volts during the odd-numbered cycles, but by only 2000 volts during the even-numbered cycles shown in the above table resulting in a serious asymmetry. However, for half-tone reproduction the beam current is adjusted to charge the surface by the desired number of volts and if the potential of electrode 20 is always above that of the second cross-over point by more than

the maximum desired voltage swing, this asymmetry disappears. Therefore, the voltage swing of the electrodes 17 and 20 with respect to second anode potential should be at least as great and preferably greater than the maximum potential change to be impressed on the target 5 by scanning, but must be less than the beam velocity in volts corresponding to the second cross-over point of the scanned target surface because if this potential change is greater than this beam velocity the target would be below cathode potential.

In the unusual case in which an actuation of the same magnitude is to be developed at a given point on alternate frames only, the tabulations given in the above table will not apply strictly. Thus, in a television system, assume that the picture to be translated on the viewing screen 15 is that of a white picket fence which is being panoramed by the transmitting camera at a rate such that an identical image of a picket appears in alternate scanning frames and is effective over the same area of the viewing screen. For this condition of operation, an area left by the beam at 3000 volts, for example, would be carried capacitively to either 5000 volts or 1000 volts and back to 3000 volts prior to the next scanning. Upon the next scanning the beam would find the area under consideration at the second cross-over point and could not alter its potential. This condition of operation, however, would occur very infrequently so that this difficulty may be neglected.

In assuming conditions of operation above it was assumed that the scanning rate was 30 cycles per second non-interlaced wherein the change of potential occurs at the end of the frame period. For interlaced scanning either of the single or multiple type, the change in potential should occur at the end of the frame period rather than following each field.

As pointed out above, my system and method of operation are not dependent upon the uniformity of the target 5 with respect to the second cross-over point. This feature of my invention will become apparent upon consideration of the following table where it is assumed that the second cross-over point of one portion of the target is 3000 volts and of another portion is 4000 volts and that the potential of the electrodes 17 and 20 is varied between 5000 and 7000 volts, the electron beam being of such intensity as to charge the surface of the target by 1000 volts.

Operation	Second crossing point 3,000 v.	Second crossing point 4,000 v.
Start.....	7,000	7,000
1st scan.....	6,000	6,000
Potential dropped 2,000 v.....	4,000	4,000
2nd scan.....	3,000	4,000
Potential raised 2,000 v.....	5,000	6,000
3rd scan.....	4,000	5,000
Potential dropped 2,000 v.....	2,000	3,000
4th scan.....	3,000	4,000
Potential raised 2,000 v.....	5,000	6,000
5th scan.....	4,000	5,000
Potential dropped 2,000 v.....	2,000	3,000
6th scan.....	3,000	4,000
Potential raised 2,000 v.....	5,000	6,000
7th scan.....	4,000	5,000
Potential dropped 2,000 v.....	2,000	3,000
8th scan.....	3,000	4,000

It will be seen from the above table that beginning with the third scan, that is, the beginning of the third frame period, 1000 volts difference of potential of alternating direction for

subsequent scans is applied to both areas having different second cross-over points. With the exception of the second scan of the area having the higher second cross-over point, 1000 volts is applied to each area during the earlier scans as well. Thus, a repetitive highlight would be developed equally well on the two areas of widely different secondary emission second crossing points. With respect to newly scanned areas, the full potential difference of 1000 volts would be applied to either area for successive scans as long as the minimum second anode potential is above the highest second cross-over point by at least the maximum change in potential to be developed by scanning.

I have found in the operation of the system described above that secondary electrons liberated from the scanned areas of the target are collected by other areas which are to be scanned and that this collection of secondary electrons may vary the amount to which the areas may be charged down by the beam. Thus, a potential difference across the valve may not appear at certain areas for every scan but only at alternating scans. I have found that this difficulty can be overcome by providing means to withdraw secondary electrons from the scanned surface of the target 5. For this purpose I provide a wire mesh grid 26 in place of the electrode 20 as shown in Figure 4. Replacing the electrode 20 with the wire mesh electrode 26, is desirable inasmuch as it is possible to obtain a closely adjacent spacing between the electrode 26 and the target 5, this closer spacing preventing spurious effects produced by non-uniform collection of secondary electrons over the surface of the target 5. To prevent defocusing and change in deflection sensitivity of the beam I provide a second wire mesh electrode 27 between the second anode 9 and the wire mesh electrode 26. It is understood, of course, that the connections of the device shown in Figure 4 are similar to those shown in Figure 1 except that the electrode 27 is maintained at second anode potential.

While I prefer to scan the target 5 with a beam from an electron gun as shown in Figure 1, this gun structure may be replaced by a photocathode which is scanned with a beam of light to provide a scanning electron beam which is directed toward and focused upon the target 5. My system is likewise applicable to a tube wherein the inner surface of the window 2 is provided with a photocathode insensitive to the light from the source 3 but sensitive to monochromatic light such as infra red so that the electron scanning beam may be generated by scanning the photocathode on the window 2 with an infra red light beam. Furthermore, my system is not limited for use with a device having a liquid suspension but is equally applicable to any device in which the light intercepting medium becomes electrically polarized, such as of the type described by Zworykin, U. S. Patent 2,025,143, which uses a material characterized by the fact that the same is normally opaque, but upon being exposed to or struck by a cathode ray beam at any spot or region thereon will become transparent to light in more or less degree in accordance with the intensity of the beam. Since these various modifications will become apparent from the above description, it is believed unnecessary to illustrate these particular arrangements, but that the same will be obvious to those skilled in the art to which my invention is directed.

While I have indicated the preferred embodi-

ments of my invention of which I am now aware, I have also indicated only one specific application for which my invention may be employed and it will be apparent that my invention is by no means limited to the exact forms illustrated or the use indicated but that many variations may be made in the particular structure used and the purpose for which it is employed without departing from the scope of my invention as set forth in the appended claims.

What I claim is:

1. In a system for television reception, a cathode ray light valve having a double end wall, a suspension of substantially flat light intercepting particles adapted to be aligned by an electrostatic field in an electrically polarizable liquid carrier between said double wall, an electron source exposed to the inner surface of said double wall and an associated anode within said valve to generate an electron beam, means between the anode and said source to vary the intensity of said beam, means to scan the beam over the said inner surface of said double wall in mutually perpendicular frame and line directions to develop electrostatic charges proportional in intensity to the intensity of said beam and vary the light intercepting properties of said suspension by alignment of said particles, an electrode between said anode and the inner surface of said double wall, means to impress a difference of potential on the said anode with respect to said electrode and the outer surface of said double wall, and means operative following completion of alternate frame scansions of said inner surface to remove the said difference of potential periodically and periodically maintain the outer surface of said double wall and said electrode at the potential of the said anode to thereby vary the potential of the scanned inner surface of said wall, means to project light through said double wall and said suspension, and means to intercept the light passing therethrough.

2. In a system for television reception a cathode ray tube having two closely adjacent light transmitting end walls, an electron gun including an anode within said tube and exposed to the inner surface of one wall to generate an electron beam of variable intensity, a suspension of light intercepting substantially flat particles in a liquid carrier between said walls, means to scan said beam in two mutually perpendicular directions over the said inner surface of one wall to produce thereon an electrostatic image representative of the intensity of said beam, the period of duration of scanning in one direction being greater than the period in the other direction, a pair of electrodes, one on either side of said suspension and adjacent said walls, means to apply a difference of potential of constant magnitude between said pair of electrodes and the said anode of said gun and switching means to electrically connect together said pair of electrodes and said anode immediately following completion of the alternate periods of scanning which are of the longer duration.

3. In a system for television reception a cathode ray tube having a light transmitting double end wall, means including an anode within said tube to generate an electron beam of variable intensity, a suspension of light intercepting particles capable of being oriented in an electrostatic field in a liquid carrier between said double wall, means to scan the inner surface of one wall of said double wall in two mutually perpendicular directions with said electron beam to produce

thereon an electrostatic image having a charge distribution representative of the intensity of said beam, means including an electrode adjacent the other wall of said double end wall to impress an electrostatic field across said suspension, said field corresponding in spatial intensity to said electrostatic image, means to apply a difference of potential of constant magnitude between said anode and said electrode immediately following completion of alternate periods of scanning in one of said directions whereby the light transmitting properties of the said suspension may be varied in accordance with the intensity of said beam.

4. In a system for television reception, a cathode ray tube having a light transmitting target of a material which liberates fewer secondary electrons than incident electrons when bombarded with a high velocity cathode ray beam, a container joined to said tube, said container having a light transmitting window opposite and axially aligned with said target, a suspension of light absorbing particles in an electrically polarizable liquid medium in said container and between said target and said window, means including an electron source and an anode within said tube to generate an electron beam, a source of potential connected between said cathode and said anode of sufficient magnitude to accelerate said beam to a velocity in excess of that required to liberate secondary electrons at the secondary emission second cross-over of said target, a pair of electrodes, one of which is between said anode and said target the other of which is on the opposite side of said suspension from said target, means connected between said anode and said pair of electrodes to periodically and substantially instantaneously change the potential on said electrodes from the potential of said anode to a potential differing from that of said anode by an amount less than the difference in potential between said electron source and the secondary emission second cross-over of said target, means to vary the intensity of said beam, and means to scan said beam over said target synchronously with the periodic change of potential on said electrodes to vary the light transmitting properties of said suspension in accordance with the intensity of said beam.

5. In a system for television reception, a substantially constant intensity light source, a light receiving screen opposite said source, a cathode ray tube having an electrically polarizing light absorbing medium in the path of light from said source to said screen, said medium being adapted to transmit light when subjected to an electrostatic charge field, means including an electron source, an anode maintained positive with respect to said source to develop an electron beam, means to sweep said beam in line and frame sequence over an area adjacent said medium and a pair of electrically connected electrodes, one of said electrodes positioned on either side of said medium to subject said medium to a succession of electrostatic charge fields corresponding in charge distribution to the light and shade of elemental areas of an optical image, an electrical circuit including electrical switching means connected between said electrodes and said anode to alternately connect said electrodes and said anode together and then during intervening alternate connections to connect said electrodes to a source of constant potential of different magnitude with respect to said anode and means to operate said switching means syn-

chronously with and following each complete frame scanning sequence.

6. In a system for television reception, a substantially constant source of light, a light receiving viewing screen exposed to said source, a cathode ray tube having a mica target between said source and said screen, a container joined to said tube, said container having a light transmitting window opposite and in alignment with said mica target, a suspension of light absorbing particles in a liquid carrier in said container and between said target and said window, means within said tube to generate an electron beam, means to vary the intensity of said beam, an anode connected to a source of potential sufficient to accelerate said beam to a volt velocity considerably in excess of the secondary emission

5 second cross-over of said target, means to scan said beam over said target in vertical and horizontal directions, the period of vertical scanning being of longer duration than the period of horizontal scanning, an electrode exposed to said beam and another electrode on the opposite side of said suspension, electrical switching means to connect said electrodes to said anode during alternate periods of vertical scanning, and means 10 to maintain a constant difference of potential between said electrodes and said anode during the intervening periods of vertical scanning to vary the light transmitting properties of said suspension in accordance with the intensity of 15 said beam.

JOHN S. DONAL, Jr.