ELECTRICAL STORAGE SYSTEM

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FIG. 2.

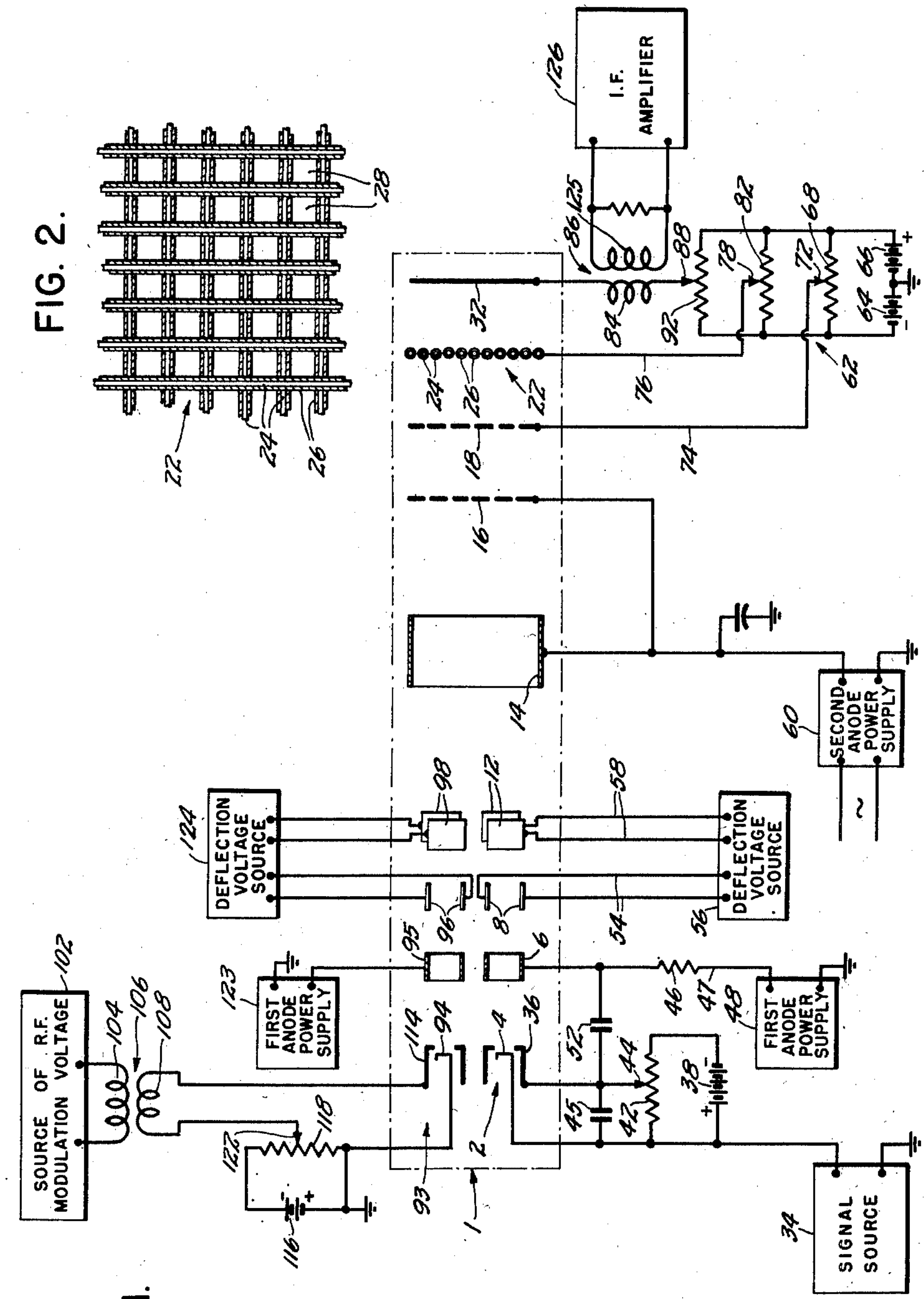

FIG. 1.

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FIG. 3.

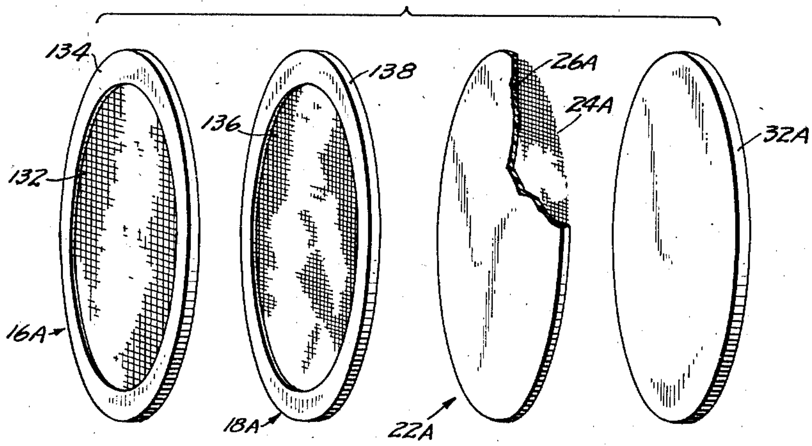
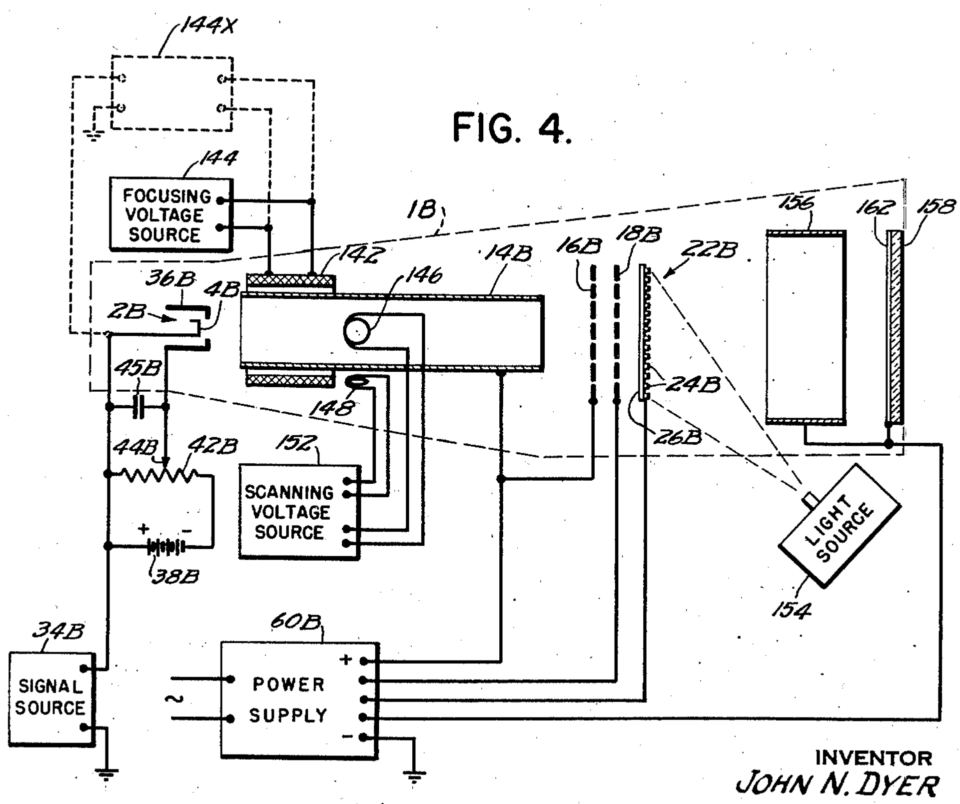


FIG. 4.



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ELECTRICAL STORAGE SYSTEM

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FIG. 8.

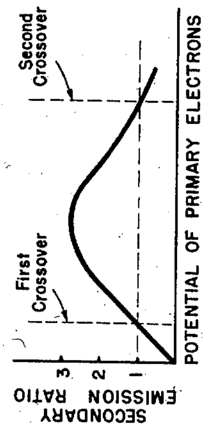
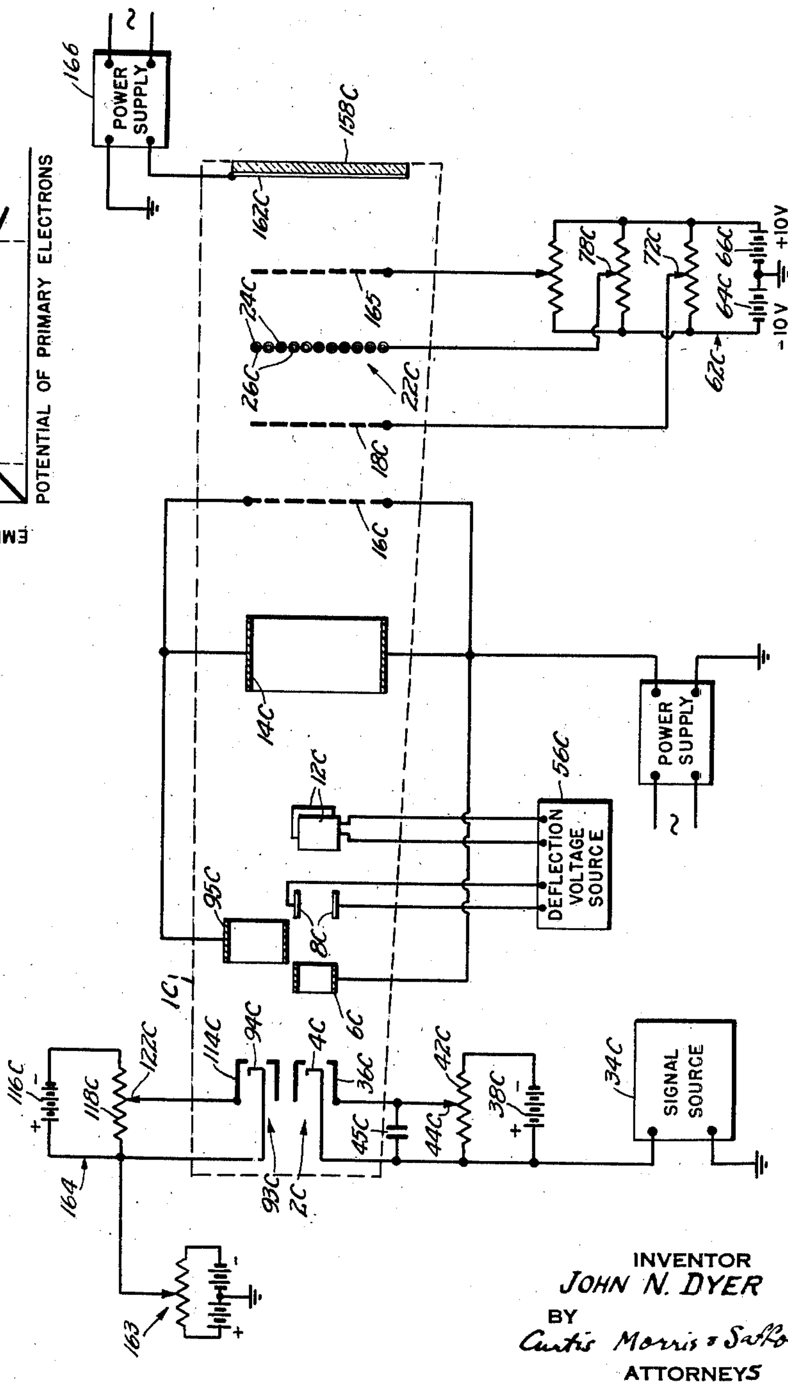


FIG. 5.



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ELECTRICAL STORAGE SYSTEM

Filed Oct. 19, 1949 4 Sheets-Sheet 4

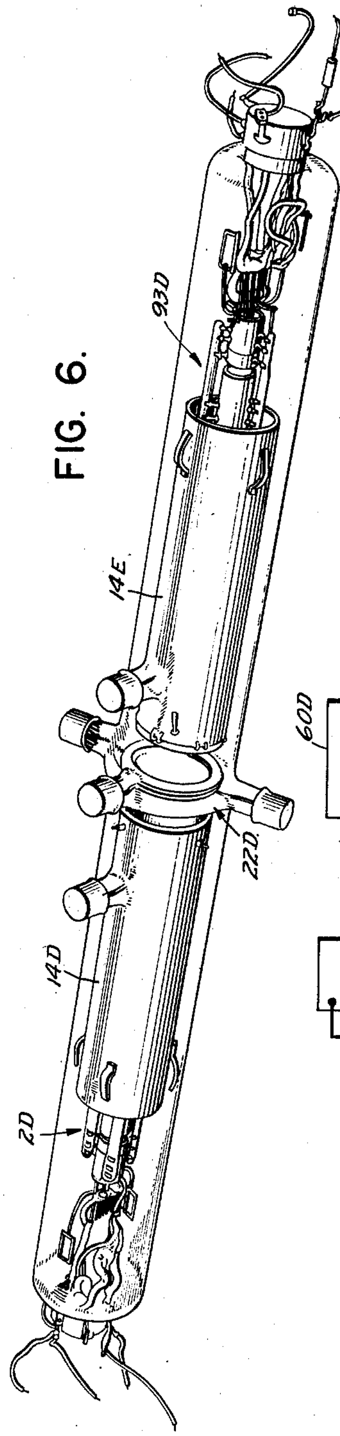

FIG. 6.

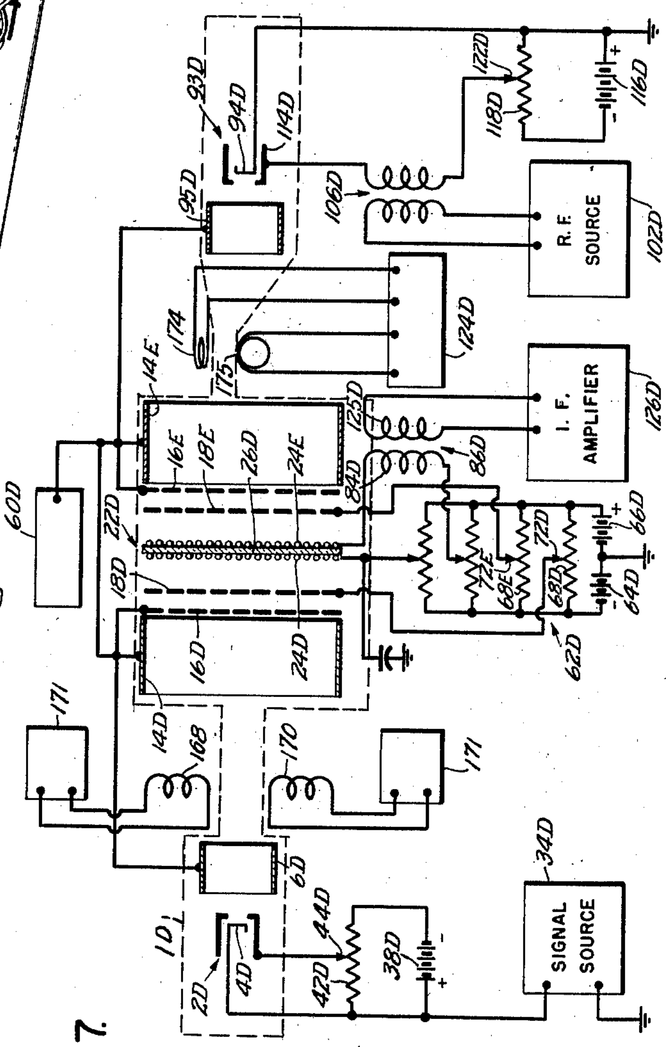

FIG. 7.

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2,821,653

Patented Jan. 28, 1958

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2,821,653

ELECTRICAL STORAGE SYSTEM

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Application October 19, 1949, Serial No. 122,350

24 Claims. (Cl. 315—11)

This is a description of an invention in the field of electronics and pertains to methods and apparatus for storing and reproducing information. In apparatus of this type, the information which is to be stored is first converted into an electrical signal which then is stored in the form of distributed electrical charges. In reproducing the information, these charges control an electrical current and produce therein characteristics corresponding to the information contained in the original signal.

The manner in which electrical information can be "remembered," that is, stored and subsequently reproduced, can be explained further by considering, as an example, one form of storage tube, or memory tube as they are sometimes called, in which a beam of electrons, called the "writing" beam, is arranged to strike the surface of a sheet of insulating material. Whenever the electron beam strikes the insulating material a negative charge of electricity will be built up by the electrons deposited at the point where the beam strikes, and will remain until removed by some external mechanism or until it gradually "leaks" from the insulating material. If this "writing" electron beam is swept, or scanned, across the surface of the insulating material while the electrical signal corresponding to the information to be stored is used to turn the beam "on" or "off" in accordance with that information, a static pattern of electrical charges will be left on the insulating material. This pattern can be used to control, in any of several ways, a "reading" electron beam which subsequently scans the same path. Such apparatus can be made continuous in operation by cyclically scanning the entire surface of the insulating material in much the same manner that the electron beam scans the picture area in a television receiver.

However, unless special precautions are observed with the arrangement just described, each element or unit area of the storage surface will carry only "yes" or "no" information, that is, each element is either charged or not charged. It has been found difficult to control the actual amount of charge on each unit area so that continuous gradations of value can be represented, that is, so that the gradations of the charges along the scanning path will accurately correspond to gradations in the information to be stored.

This difficulty in retaining gradations of value is caused in part by the integration of the charges left by the writing beam as it repeatedly scans the storage surface, that is, each successive sweep of the writing beam continues to deposit additional charges on each partially charged unit area so that the charge on each of these areas eventually builds up to a maximum or saturation value, resulting in loss of the original intermediate values. For example, suppose that the beam as it sweeps by a first unit area of the storage surface is at full intensity, and as it sweeps past a second unit area, the electron beam is at a lower intensity corresponding to an intermediate value of the information to be stored. Assume that the intensity of the electron beam as it sweeps by the first unit area is such that the storage surface at the first unit area is charged just to saturation, that is, to the greatest negative potential which it can acquire from that particular writing beam. As the writing beam sweeps by the second point its intensity is reduced in accordance with the new value of information and, accordingly, the second unit area is charged to a lesser value so that the relative charges at the two points on the surface correspond to the relative values of the information to be stored. If the storage tube is to retain intermediate values, the relative values of these charges must be maintained as the information is repeatedly "rewritten" on the storage surface. However, if the time required for the electron beam to complete its cyclical scanning path and return to the second unit area is less than the time required for the charge at the second unit area to be completely removed, by leakage or other means, then some charge remains on this second unit area. This "left-over" charge on the second unit area is in addition to the amount of charge which will be deposited on the second unit area by the beam as it makes its second sweep. Thus, the charge on the second unit area will be built up beyond the desired value; and with each subsequent scan, this area will be charged to a higher and higher potential. Eventually it will reach saturation level, at which time it will have the same effect on the reading beam of electrons as the first unit area which has been retained at saturation level throughout the repeated scanning operations. If, for example, the information to be stored represents a visual scene in which there are gradations of shading ranging from black to white, this building of the charges on the storage surface results in loss of the half-tones, or gradations in shading, and produces a full-tone scene in which each element of the scene is substantially either black or white.

This difficulty cannot be entirely overcome by the use of short discharge times for the storage surface, because, for many applications, such a rapid decay of the stored information would defeat the very purpose of the storage system. Moreover, even though the half-tone values can be reproduced, at least to some extent, by the use of a method of operation wherein the charge pattern is entirely re-established on each new writing such that all residual charges are removed either just before or as the new charge is stored, such a method prevents the retention of any of the previous charge pattern. In this case if the device were used for storing pictures of aircraft movements such as are obtained on a radar display device, it would not be possible to show the direction of motion of the aircraft by leaving a "trail" behind it as it moves. In addition, if such a device were used to store information that is by its nature intermittent, it would be found that if the signal happened not to be present during the writing process, whatever charge was still left on the storage surface from the previous writing period, would be removed entirely and the continuity of the storage process would be broken. These reasons show why, for many applications, a rapid decay of the stored information or the re-establishment of the stored charge completely on each successive writing may not be desirable.

The level to which a particular unit area of the storage surface is charged depends upon the characteristics of the storage furnace, the intensity of the electron beam, the velocity, that is, the energy level, of the approaching electrons, and the length of time for which the electron beam is directed at the particular unit area. The maximum level to which the unit area can be charged, that is, the saturation level, is independent of the intensity of the electron beam, it merely requiring a shorter or longer time to reach saturation. However, this ultimate saturation level is a direct function of the velocity of the electrons in the approaching beam. The velocity of an electron in free space is a direct function of the voltage which accelerated the electron and, accordingly, the velocity of an electron can be expressed in terms of voltage, thus the charge on the storage surface continues to build up until the voltage or potential of this charge is that which corresponds to the velocity of the approaching electrons before they are slowed by the charge existing on the storage surface, at which time the charge on the storage surface will repel the approaching electrons with sufficient force to prevent them from striking the storage surface. Accordingly, the present invention provides for a storage tube in which the velocity of a relatively low-velocity electron beam is controlled in accordance with the information to be stored, so that the maximum charge at any point on the storage surface can never exceed the value which is representative of the particular information to be stored at that point, irrespective of how many times the information is re-written on the storage surface.

Although velocity modulation per se of electron beams has been proposed by others, I am not aware of any arrangement whereby the velocity of the approaching electrons limits the ultimate level of charge on the storage surface so as to retain the intermediate signal values without the use of a rapid decay time or the use of a system which completely re-establishes the charge pattern on each successive writing. Thus, one aspect of the present invention is directed to methods and apparatus whereby electrical information can be stored and subsequently reproduced with the original relative gradations in signal values, that is, without loss of gradations in the signal values.

The system described in the above illustrative example, in which each unit area of the storage surface carries either a saturation charge or no charge, in effect records information in two co-ordinates, whereas the present invention effectively adds an additional co-ordinate thereby increasing the amount of useful information that can be stored.

As an example of the utility of the present invention, consider a continuously scanning radar system in which the targets are presented visually on a cathode-ray tube. Usually one component of motion of the scanning beam of the cathode-ray tube is synchronized with the pulse rate of the radar system and is relatively rapid, but the other component of scanning motion often is synchronized with the movement of the radar antenna system and, therefore, is at a relatively slow rate so that a relatively long period of time is required to scan the entire picture display area, and a long persistence phosphor must be used for the viewing screen of the cathode-ray tube. Because of this long scanning period, the average excitation of the phosphor is low and the fluorescent pattern is dim so that it can be observed clearly only in semi-darkness, that is, when the viewing screen is shielded from other sources of illumination.

The brillance or average excitation of the screen of the cathode-ray tube can be increased by storing the information from the radar system on an insulating storage surface and then rapidly scanning this surface with the reading beam. The electrical signals picked up by the reading beam can be applied to a conventional cathode-ray tube with a short persistence screen and, because this screen is scanned at a rapid rate, sufficiently high to minimize flicker, the average excitation will be much higher and the display pattern can be observed satisfactorily under ordinary conditions.

However, conventional storage tubes are not satisfactory for such an application because of the loss of half-tone values, that is, targets originally visible through echoes caused by rain or other interfering signals would be lost by the integration occurring within the storage tube. The present invention provides for control of the integration characteristics of the storage tube so that the brighter image can be produced and the half-tone values preserved. Such integration control is possible because the writing beam is velocity modulated in accordance with the successive instantaneous values that are to be preserved. The ultimate charge at any point on the storage surface is therefore limited by the signal value rather than by inherent tube characteristics.

In such a display brightening system, the scanning rate of the reading beam conveniently can be at the same rate that is employed in conventional television scanning systems, and the information collected originally by the relatively slowly moving antenna can be handled subsequently by ordinary television circuits. This results in important operating advantages in addition to the more brilliant visual display. For example, ordinary television links already in existence can be used to relay or distribute the radar information, and information such as maps or other data, translated into corresponding electrical signals, by conventional television equipment, can be superimposed readily upon the radar pattern. It is apparent that corresponding advantages of the present invention can also be obtained in connection with many other types of data capable of being presented by a cathode-ray tube.

It is apparent that the storage tube can be operated in the reverse manner, that is, data collected by a rapidly scanning system can be stored and reproduced subsequently by a slower scanning system. For example, suppose it is desired to transmit information, picked up by a conventional television camera, over networks which have insufficient bandwidth to transmit the original data. A storage tube, constructed and operated in accordance with the present invention, in which the reading beam scans the storage surface at a rate low enough that it can be handled by the particular transmission channel, will permit the reproduction of a useful image at the receiver, although it is apparent that rapidly changing scenes may not be transmitted clearly.

Earlier type memory tubes in which information is stored accurately in only two co-ordinates have been found useful in electronic computer systems, which can operate at extremely high rates of speed, because the information is stored electrically rather than mechanically. It is obvious that the additional co-ordinate provided by the present invention will further enhance the utility of such memory tubes in this field.

The signal level reproduction characteristics (the retention of half-tones or relative signal values) provided by the present invention are particularly useful in a storage tube in which the stored information is presented visually on the face of the envelope of the storage tube. For example, such a display-type, or directly-viewed, storage tube can be incorporated in a television receiver to increase the brightness of the received image.

In one embodiment of the present invention, a directly-viewed storage tube is provided in which the information is "written" on an insulating storage surface by a scanning arrangement operated in synchronism with the television signals. A flooding-type reading beam, that is, a uniform beam of electrons coextensive in cross section with the storage surface, passes through the storage surface, which is arranged to permit the passage of electrons and to act somewhat in the manner of a control grid in an ordinary tube, and each elemental area of the cross section of the flooding-type reading beam is controlled independently in accordance with the charge on the corresponding elemental area of the storage surface. This reading beam of electrons is then accelerated and strikes the fluorescent screen at the end of the tube to reproduce the image. Thus, all of the bright portions of the fluorescent screen are continuously energized, whereas in a conventional television picture tube only a single element of the screen is energized at any one time. The resulting increase in brilliance is particularly desirable in optical projection television systems where it is difficult to obtain a sufficiently bright fluorescent screen to illuminate adequately the larger optical viewing screen on which the television picture is projected.

Thus, in accordance with the present invention, a storage tube is provided whereby information can be stored and subsequently reproduced without loss of the relative signal values and which may be utilized in a variety of ways in many different applications. One aspect of the invention is directed to an improved storage tube in which electrical information is written on a storage surface by a velocity-modulated electron beam and is not re-written on any element of the surface by subsequent scans of the beam unless the potential on that particular element of the storage surface is less than that which would be produced by the writing beam at the time it re-scans the same point. Thus, if the input signal has remained unchanged during successive cyclical scans the writing beam will merely replace the electrons which have been removed from the storage surface since the previous scanning operation. In the preferred embodiment, this is accomplished by controlling the velocity of a low-speed scanning beam in accordance with the amplitude, or some other characteristic, of the signal that is to be stored. Accordingly, one aspect of the invention is directed to a storage tube in which the writing beam is velocity-modulated to prevent excessive integration of the information on the storage surface.

Another aspect is directed to such a storage tube in which the reading beam is modulated to provide an output signal having an inherent carrier frequency so that the reading and writing beam currents can be separated. Still another aspect of the invention is directed to control of the integration characteristics; for example, so that limited integration can be provided to permit the use of storage tubes in radar systems without loss of relative signal values or material reduction in the maximum radar range.

These and other aspects, advantages, and objects of the invention, relating to types of construction, processes, and modes of operation, will be in part pointed out in, and in part apparent from, the following description considered in conjunction with the accompanying drawings in which:

Figure 1 shows, diagrammatically, a scanning-converter storage tube and associated circuits embodying the invention;

Figure 2 is an enlarged sectional view of a portion of the storage electrode of the tube shown in Figure 1;

Figure 3 shows a series of electrodes suitable for use in the storage tube of Figure 1 with a somewhat differently constructed storage electrode;

Figure 4 illustrates a second embodiment of the invention wherein the stored image is reproduced visually on a fluorescent surface at the end of the storage tube;

Figure 5 illustrates another embodiment of a directly-viewed storage tube;

Figure 6 is a perspective view of a double-ended scanning-converter type storage tube;

Figure 7 represents, diagrammatically, the construction of the tube shown in Figure 6 and associated circuits; and

Figure 8 is a secondary emission curve of a storage surface.

A storage tube may take any of several forms depending upon the particular function which it is to perform and the characteristics of the apparatus with which it is to be used. In one form, called a scanning-converter, the storage tube delivers an electrical signal which can be presented visually on conventional cathode-ray equipment or which can be used for control purposes in auxiliary electrical apparatus. Because this tube uses separate beams of electrons for writing and reading, the output signal can have a different scanning rate, and even a different scanning sequence, from the input signal. For example, the tube can be used to convert a slowly scanning system, as in radar, to a rapidly scanning system, as in television, and to convert data originally presented in terms of polar coordinates into rectangular co-ordinate form. Such a tube can be used also to convert interlaced scanning patterns to consecutive scanning patterns and to convert patterns having a given number of lines per frame to patterns of a different number of lines.

In another form, called the storage-display tube, the signals are reproduced as a visual display on the end of the same envelope which houses the storage surface. Such tubes are useful to brighten a cathode-ray image, so that it can be observed under daylight conditions or projected with increased brilliance on a larger screen. Such tubes also are useful in photographing and presenting other data capable of being presented on a cathode-ray tube.

THE SCANNING CONVERTER (Fig. 1)

Information storage

In the scanning converter tube, indicated diagrammatically and generally at **1**, the writing beam of electrons originates in a conventional cathode-ray "gun" assembly, generally indicated at **2**, including a cathode **4** which is heated by the usual heater arrangement. This heater, as well as certain other conventional storage or cathode-ray tube components, has been omitted from the diagrammatic showings of this application in order to simplify the drawings and description, the requisite techniques and structures being well known in the art.

The electrons emitted by the cathode **4** are focused into a sharp beam by a cylindrical focusing anode structure, indicated diagrammatically at **6**. This electron beam then is deflected horizontally and vertically to produce the scanning motion, by electrostatic fields produced by vertical deflecting plates **8** and horizontal deflecting plates **12** to which suitable scanning voltages are applied. The electron beam is accelerated (toward the right, as viewed in Figure 1) by an accelerating anode **14**, which may be a conductive coating on the interior of the glass wall of the tube **1**, and a conductive screen **16** arranged so that the electron beam can pass through its meshes. The electron beam after passing through the accelerating screen **16** is decelerated by the field of a second screen **18**, which is maintained at a potential near that of the cathode **4**, usually within two hundred volts.

The information is stored in the form of distributed electrical charges on a target, generally indicated at **22**, which is positioned near the decelerating electrode **18**. The target **22** includes a conductive screen **24** (see also Figure 2) each wire of which is surrounded by a thin layer **26** of insulating material on which the electrons are deposited. Electrons which pass through the open meshes of the decelerating electrode **18** may strike the insulating storage surface **26** of the target **22** and build up a static negative charge, or they may pass through the meshes **28** of the target to a collector electrode **32** positioned immediately behind the target. Whether a particular electron will strike the storage surface or will pass through one of its meshes to the collector electrode **32**, depends upon the velocity of the electron and the amount of charge on the storage surface adjacent the point at which the electron approaches the surface. For example, assume an electron beam to be directed with a constant velocity toward a given portion of the storage surface **26**, which is initially at the same potential as the cathode. Initially, these electrons will strike the storage surface **26** and build up an increasingly negative charge, but as soon as the charged surface reaches a critical potential, depending upon the velocity of the approaching electrons, no more electrons will strike the surface and the beam will be deflected or repelled and pass through the meshes 28 of the target 22 or return to electrodes 16 or 18. Subsequently, only enough electrons will strike the insulating storage surface 26 to replace those that are lost through leakage or other causes.

If the velocity, that is, the energy level, of the approaching electrons is increased, as by increasing the voltage difference between cathode 4 and target 22, an additional number of electrons will strike the storage surface 26 building up a greater negative charge, subsequent to which the electrons will again be deflected from the storage surface.

If the velocity or energy level of the approaching electrons is reduced, no additional electrons will strike the insulating surface 26 and the electrons that are lost by leakage, or otherwise, will not be replaced until the potential on the storage surface 26 has dropped to a value corresponding to the new velocity of the approaching electrons.

In this embodiment, the writing electron beam repeatedly scans the storage surface, while the information to be stored controls the velocity of the electrons approaching the surface. The storage surface 26, therefore, assumes a potential distribution corresponding to the information to be stored.

In order to provide such velocity modulation, the signal which is to be stored, derived from a suitable source indicated in block form at 34, is connected between the cathode 4 and ground. Although a relatively high accelerating voltage, say 1000 volts, is used, only a low potential signal, say 10 volts, is required to produce adequate velocity modulation, and in any event the signal voltage is chosen to be below the first cross-over of the insulating storage surface 26. This will be apparent from a brief explanation of the secondary emission characteristics of an insulating surface (Figure 8). If a relatively low velocity electron strikes such a surface, it remains on the surface, at least for a short length of time depending upon the conductivity of the insulating material, and produces a negative charge at that point, but if the electron is traveling at sufficiently high velocity when it strikes the insulating surface it will produce "secondary emission," that is, it will cause one or more secondary electrons to be emitted from the surface, thus, producing a positive charge on the surface at that point. With still higher impact velocities the number of secondary electrons for each primary (impacting) electron decreases and eventually at very high velocities less secondary electrons will be emitted than there are primary electrons striking the surface, so that the surface will again acquire a negative charge. A curve showing the ratio of secondary electrons to primary electrons with change in the velocity of the primary electrons striking the surface is shown in Figure 8. Thus, when the velocity of the primary or impinging electrons is below the first cross-over point, where the ratio of secondary to primary electrons is unity as the curve is rising, or when the velocity of the primary electrons is above the second cross-over point, where the ratio of secondary to primary electrons is again unity as the curve descends, the insulating surface will acquire a negative charge. At electron velocities between the first and second cross-over points, the surface will acquire a positive charge because more than one secondary electron will be emitted for each one striking the surface.

In order to maintain the electron beam at constant intensity, that is, constant magnitude, a control grid assembly 36 is maintained at a constant potential, relatively to the cathode 4, by means of a battery 38, or other suitable voltage source, and a potentiometer 42. The positive terminal of battery 38 is connected to the cathode 4 and to one end of the potentiometer 42; the negative terminal of this battery is connected to the opposite end of the potentiometer 42. The adjustable contact 44 of the potentiometer 42 is connected to the control grid 36 and permits manual adjustment of the intensity of the electron beam. A condenser 45 is connected between the cathode 4 and the control grid 36 to keep them both at the same signal potential.

The focusing anodes 6 are constructed and operate in the conventional manner to direct the electrons into a relatively sharply focused beam. Positive voltage for the focusing circuit is provided through a resistor 46 and a lead 47 which is connected to the positive terminal of a conventional first-anode power supply, indicated diagrammatically at 48, the negative terminal of which is connected to ground. A condenser 52 is connected between the anode 6 and the grid 36 to maintain the anode 6 at the same signal level as the grid-cathode circuit to further insure against intensity modulation of the electron beam.

In order to produce the desired vertical scanning motion, the two deflecting electrodes 8, positioned respectively above and below the electron path, are connected by leads 54 to a conventional deflection voltage source, indicated diagrammatically at 56, which provides the voltages required to move the electron beam vertically in the desired manner.

To provide the simultaneous horizontal scanning of the electron beam, the two horizontal deflecting plates 12, positioned respectively on opposite sides of the electron beam, are connected by leads 58 to the same deflection voltage source 56, which is arranged also to supply suitable horizontal deflecting voltages. The operation of the deflection voltage source 56 can be controlled, for example, in the conventional manner by synchronizing voltages forming part of the input signal. Such focusing and scanning arrangements are well known and therefore have not been described in detail.

The accelerating anode 14 and screen 16 are connected to the positive terminal of a second-anode power supply 60, so that the electrons in the beam are accelerated to a velocity corresponding to the voltage existing between the accelerating members 14 and 16 and the cathode 4. This accelerating voltage is modulated by the signal from source 34 so that it varies in magnitude in accordance with the information initially contained in the amplitude of the input signal from source 34. The velocity of the electrons in the writing beam is a function of the magnitude of this accelerating voltage, so that the information to be stored is translated into corresponding variations in the velocity of the writing electron beam.

The potential on the decelerating screen 18 is provided by a voltage source, generally and diagrammatically indicated at 62. Two batteries 64 and 66, or other suitable voltage sources, are connected as shown, the negative terminal of battery 66 and the positive terminal of the battery 64 being connected to ground. The positive terminal of battery 66 is conected to one end of a potentiometer 68, and the negative end of battery 64 is connected to the opposite end of this potentiometer. The adjustable contact 72 of the potentiometer 68 is connected by a lead 74 to the decelerating electrode 18. With this arrangement, the voltage of electrode 18 may be set at ground potential or made either positive or negative with respect to ground depending upon the particular operating characteristics which are desired.

The conductive screen 24 of target 22 is connected by a lead 76 to the adjustable contact 78 of a potentiometer 82, which is connected in parallel with the potentiometer 68. This arrangement permits adjustment of the potential of the screen 24, with respect to ground, and provides a return path for the electrons which leak from the insulating material 26 to the conductive screen 24.

The collector electrode 32, which may, for example, be a metal plate, is connected through a primary winding 84 of a transformer, generally indicated at 86, whose purpose will be explained later, to an adjustable contact 88 of a potentiometer 92, which is connected in parallel with potentiometers **82** and **68**, to provide an adjustable voltage for the collector electrode **32** and a return path for the collected electrons. This electrode is usually operated at a small positive potential with respect to ground.

Thus, the velocity of the electrons in the writing beam is controlled in accordance with the amplitude of the signal voltage delivered by source **34** and a distribution of charges is built up on the target **22** which corresponds to the information to be stored. Because the low-velocity writing beam which approaches the target **22** is controlled by variations in velocity, rather than intensity, information once "written" on the target **22** is not rewritten unless the potential of the stored charge is less than the corresponding electron potential of the approaching beam, and even then the stored charge is built up only to this electron potential and does not represent merely the sum of the new and old charges. However, a certain amount of integration, or adding, of the charges often is desirable. For example, in a radar system it is desirable to integrate all of the pulse signals reflected by a single target during a single sweep of the antenna. By adjusting the intensity of the electron beam with respect to the capacity of the storage surface, the extent of the integration time can be set to produce the desired signal addition without integrating the signals resulting from subsequent antenna sweeps.

In order to reconvert this stored information to an electrical signal, the target **22** is utilized as a control grid to control the intensity of a separate reading beam.

Information reproduction (Fig. 1)

The reading beam of electrons originates in a second conventional cathode-ray "gun" assembly, generally indicated at **93**. The electrons are emitted by a cathode **94** and formed into a sharply focused beam by means of focusing anodes, indicated diagrammatically at **95**, and pass between vertical deflecting plates **96** and horizontal deflecting plates **98**. The same high voltage accelerating electrode or coating **14** and screen **16** can be utilized to accelerate the reading beam of electrons as are used for the writing beam, or if desired, separate accelerating elements can be provided. The reading beam of electrons passes through and is decelerated by the decelerating electrode **18**, so that the electrons approach the targe **22** with reduced velocity.

The reading beam of electrons is controlled, in grid fashion, by the target **22**. Those electrons which approach the target **22** at a given velocity will pass through those portions of the storage surface which are not charged, or which are charged below a given potential, and a decreasing proportion of the electrons will pass through as the voltage on the target **22** is increased in the negative direction. The electrons which pass through the meshes **28** of target **22** strike the collector electrode **32**. The output signal is taken from the collector electrode **32**, but because the electrons from the writing beam strike this same electrode, means must be provided for distinguishing between electrons which originated with the writing beam from those which formed a portion of the reading beam.

In order that the output circuit can distinguish those electrons originating in the reading beam and thus provide the desired output signal, the reading beam is amplitude modulated at a suitable constant frequency. It has been found advantageous to modulate the reading beam at a frequency such that a conventional I. F. amplifier can be coupled directly to the output circuit. To this end a source of constant-frequency modulation voltage, for example 10 megacycles, indicated in block form at **102**, is coupled to a primary winding **104** of a transformer, generally indicated at **106**, the secondary **108** of which is connected between a control-grid assembly **114** and its bias-supply circuit.

Bias voltage for the control grid **114** is provided by means of a battery **116**, the positive terminal of which is connected to ground and to one end of a potentiometer **118**. The negative end of battery **116** is connected to the opposite end of potentiometer **118**, the adjustable contact **122** of which is connected through the transformer winding **108** to the control grid **114**.

The focusing anode **95** is connected to a first-anode power supply, indicated diagrammatically at **123**. The vertical and horizontal deflecting electrodes **96** and **98** are connected to a suitable source of deflection voltage, indicated in block form at **124**, and which may include associated apparatus such as circuits for developing suitable synchronizing pulses for use in connection with the reproduced signal.

The scanning rate for the reading beam may be the same as, or different from, the scanning rate utilized in the writing beam. However, for most applications of this particular type of tube, the scanning rate of the reading beam is different from that of the writing beam. It is apparent, also, that the two beams can be operated simultaneously, or for particular applications it may be desirable to operate the reading and writing systems alternately. This, of course, can be accomplished by applying suitable control voltages to the grid assemblies **36** and **114**.

The proportion of the electrons in the reading beam which pass through the target **22** will be a function of the charge on the particular unit area of the target being scanned, and these electrons will be collected by the collector electrode **32**. The number of electrons which pass through the target **22** also will be a function of the intensity of the approaching electrons; these electrons are amplitude modulated at a radio frequency by the source **102**, so that the intensity of the reading electron beam striking electrode **32** also will vary periodically in accordance with the voltage from the source **102**. Accordingly, that portion of the signal current flowing from electrode **32** to ground that is produced by the reading beam is separated, from the current caused by the writing beam, by means of the transformer **86**, the secondary **125** of which is coupled directly to a tuned I. F. amplifier, indicated in block form at **126**. This amplifier is, of course, tuned to the same frequency as the modulation source **102**, and its output signal can be detected or utilized in any desired manner.

It is apparent that the storage characteristics of the tube will depend in part upon the decay time of the storage surface of the target **22**, that is, the rate at which electrons leak from the insulating material **26** to the conductive screen **24**, or are otherwise removed from the storage surface. This decay time, therefore, is adjusted in accordance with the particular application of the tube by controlling the conductivity and the thickness of the insulating material that covers the screen **24**.

The storage characteristics also depend upon the integration characteristics of the tube. The upper limit of charge at a particular unit area on the storage surface **26**, the saturation level, depends upon the velocity of the approaching electron beam, but a finite time interval is required to build the charge up to this saturation voltage, which corresponds to the velocity of the electron beam. It is apparent that if the intensity of the electron beam is high, the charging period, that is, the duration of integration on the storage surface, will be short. It is apparent also that this charging rate will be influenced by the area of the beam and the thickness of the insulating material **26** which coats the screen **24**. In practice the capacity of the screen **24** and the intensity of the electron beam are selected so that the desired build-up or integration period is produced. For example, when used with a typical slow-scanning radar system it is desirable that the tube should integrate the signals which are received during the passage of the radar beam across the target, but that on subsequent scans of the radar beam across the target, the signal impressed on the storage tube should not be written unless it exceeds the value of the signal remaining from the previous scan. Thus, the signal is not written as the sum of the new and the old signals; the storage tube does not keep on adding signals until some saturation level is reached, as could happen in the case of a fixed target if conventional storage tubes were employed, but rather the signal controls the brightness of the display in such a way that the output signal is a true reproduction of the relative intensities of the successive components of the radar signal. However, the pulses expected to be returned during the time the antenna moves one beam-width must be added if the maximum range of the radar system is to be realized.

It is apparent that with the mode of operation just described, both the writing and reading beams may tend to increase the negative charge on the storage surface, and with particular operating modes it may be desirable to operate the reading beam with a much lower intensity than the writing beam and with normal leakage currents through the storage surface several times larger than the reading beam current. However, the velocity of the reading beam with respect to the voltages on the insulating surface **26** and screen **24** of the target **22** can be chosen if desired so that the reading beam never can strike the insulating surface **26**, although it can be drawn through the meshes **28** in the screen where permitted by the signal. It is, however, not necessarily undesirable to permit a portion of the reading beam to strike the insulating surface, as it will act only to bias the insulator to a particular voltage.

Although the tube has been shown with electrostatic focusing and deflection, either or both of these functions can be performed in other known ways, for example, with electromagnetic fields.

In one particular tube, of the type just described, the storage target **22** consists of a nickel screen having 400 meshes per linear inch, each conductor of the nickel screen being covered with a film of silicon dioxide or other suitable insulating material having a thickness of about 0.0005-inch.

It is apparent that the storage target **22** can be formed in various ways depending upon the particular use to which the tube is to be put. For example, it can be formed of a sheet of insulating material with the conductive screen positioned adjacent the insulating surface. This construction is feasible because thin sheets of insulating material may be sufficiently porous or transparent to permit the electrons to pass through the insulating material to strike the collector electrode.

Figure 3 shows, in perspective, four electrodes such as might be used in the tube shown in Figure 1. An accelerating electrode, generally indicated at **16A**, comprises a relatively coarse screen **132**, with, say, 100 meshes to the linear inch, which is supported by an outer ring **134** of insulating material. A decelerating electrode, generally indicated at **18A**, comprises a somewhat finer mesh screen **136**, say, 200 mesh, supported on an insulating mounting ring **138**. A target, generally indicated at **22A**, is constructed somewhat differently from that shown in Figure 1, in that it comprises a fine conductive screen **24A**, say 400 mesh, secured to one side of a thin sheet of porous insulating material **26A**, A collector electrode **32A** comprises a disk of conductive metal. In practice, these electrodes are positioned very close together and may be pre-assembled into one compact unit, the electrodes being separated from each other by insulating rings such as **134** and **138**.

DISPLAY-TYPE STORAGE TUBE (FIGURE 4)

In this type tube, the image which is stored within the tube is also displayed visually on a fluorescent screen on the face of the same tube. One important advantage of such a directly-viewed tube is that a bright picture can be obtained without the use of a separate display tube, but other advantages are inherent depending upon the particular construction of the tube and the use which is made of it. For example, the tube is useful in research work for observing various experimental phenomena, the integration characteristics of the storage surface being regulated to produce the desired addition effects, which can be accomplished without the loss of the half-tone values.

As in the embodiment of Figure 1, the writing beam originates in a "gun" assembly, generally indicated at **2B**. The electrons are emitted by a heated cathode **4B** which is connected to a signal source, indicated in block form at **34B**, which provides an electrical signal carrying the information eventually to be displayed in visual form, the signal from source **34B** being used to control the instantaneous velocity of the electrons in the writing beam.

The intensity of the writing beam is controlled by a grid assembly **36B**, which is connected through a potentiometer **42B** to a battery **38B**, all substantially as described in connection with Figure 1.

In this embodiment, the electrons emerging from cathode **4B** are formed into a relatively sharply focused beam by means of a magnetic field produced by a conventional electromagnetic focusing coil, indicated diagrammatically at **142**, current being supplied to this coil from a conventional power supply, indicated in block form at **144**.

Deflection of the writing beam is accomplished in this embodiment by suitable magnetic fields produced by conventional deflecting coils **146** and **148** which are connected to a suitable source of scanning voltage, indicated in block form at **152**. An accelerating anode **14B** and screen **16B** are provided, as in the first embodiment, for accelerating the electron beam, suitable voltages being provided by a power supply **60B**. The electrons, after passing through screen **16B**, are decelerated by decelerating electrode **18B**, which is maintained at a potential near that of the cathode **4B** by means of the power supply **48B**.

A storage target **22B** is positioned adjacent the decelerating electrode **18B** and comprises a layer **26B** of insulating material, the back of which is coated with parallel, spaced, conductive strips **24B** of metal, or other suitable material.

Whether the writing electrons at any instant strike the insulating layer **26B** of the storage target **22B** depends upon the instantaneous velocity of the electron beam and the charge on the surface of insulator **26B** at the particular area at which the electron beam is directed.

The parallel strips **24B** are closely spaced and, for example, can be produced by vaporizing metal onto the thin layer **26B** of insulating material. These metal strips are rendered photo-emissive by treatment with caesium compounds, or other suitable materials, so that when light strikes this surface, electrons are emitted. In order to produce such emission the entire activated side of target **22B** is illuminated from an ultra-violet light source, indicated in block form at **154**. The number of electrons which escape from the photo-emissive surface at each unit area is a function of the charge on the insulating surface adjacent that point.

Thus, the target which stores the charges also provides a source of reading electrons which are emitted with an intensity distribution corresponding to the relative distribution of charges on the storage surface **26B**. These reading electrons are accelerated by conventional means, illustrated diagrammatically as an accelerating anode **156** connected to a suitable potential source derived from power supply **60B**. Focusing means can be provided for the electrons emitted by target **22B**, or the distance between the target and the final anode **162** can be made sufficiently small that dispersion of the electrons does not occur to appreciable extent. In the latter case an additional mesh may be added to act as a screen grid and prevent the positive field intensity at the target **22** from being excessively high.

At the end of the tube the inner surface of the glass wall **158** of the tube is coated with fluorescent material and with a thin layer of aluminum 162, which also serves as the final anode, as in conventional television picture tubes, which also is connected to the power supply 60B.

Thus, the reading beam of the display portion of the tube does not require any scanning mechanism, and the excitation of illuminated portions of the viewing screen are excited continuously, rather than intermittently as in the case of a scanning display system.

Figure 5 shows another embodiment of the display type storage tube. In this embodiment, the writing beam is produced in substantially the same manner as in Figure 1, the writing electron beam originating in a "gun" assembly, generally indicated at 2C. Electrons are emitted by a heated cathode 4C to which a varying voltage is applied, in accordance with the information to be displayed visually, by means of a signal source 34C. The electrons subsequently are focused and deflected by electrodes 6C, 8C and 12C, in conventional manner. Acceleration voltage for the electrons is provided by accelerating electrodes 14C and 16C, arranged substantially as in Figure 1. The electrons are decelerated by a decelerating electrode 18C, so that the electrons approach a target, generally indicated at 22C, with a reduced velocity corresponding to the instantaneous amplitude of the voltage delivered by the signal source 34C. The target 22C can be constructed in a manner similar to that shown in Figure 1, and in which the meshes formed by the conductive screen 24C, coated with insulating material 26C, are either open or filled with a layer of insulating material sufficiently thin or porous that it is substantially transparent to the flow of electrons.

In order to provide a visual display of the charge-pattern on the target 22C, a flooding beam is produced by a gun assembly, generally indicated at 93C. A cathode 94C, connected to ground through an adjustable bias supply, generally indicated at 163, emits the electrons which are formed into a suitable uniform beam such that substantially the entire target 22C is uniformly and simultaneously illuminated by the electron beam. A conventional control grid assembly 114C is connected to ground through an adjustable bias supply, generally indicated at 164. Suitable focusing electrodes are indicated diagrammatically at 95C.

The target 22C controls, in grid-like fashion, the electron density at different points in the cross section of the flooding beam in accordance with the distribution of charges on the storage surface.

In this directly-viewed tube, the collector electrode 32 of the embodiment shown in Figure 1 is replaced by a screen 165 which controls the distribution of the accelerating potential in the vicinity of the storage surface.

The electrons which are permitted to pass through the target 22C are accelerated by high voltage, for example, 10,000 volts, which can be applied directly to an aluminized fluorescent screen 162C, from a power supply indicated in block form at 166. This fluorescent surface comprises a suitable coating directly on the end 158C of the glass envelope which houses the tube structure. With this arrangement, cathode-ray displays, which ordinarily would be presented with low intensity, can be increased in brilliance so that they can be observed comfortably under daylight conditions or utilized as the light source for optical projection systems.

DOUBLE-ENDED SCANNING CONVERTER (FIGURES 6 AND 7)

Figure 6 illustrates a double-ended scanning converter tube in which the reading and writing beams are produced at opposite ends of the tube, each being directed toward the center of the tube where they strike opposite sides of the storage target to produce the desired storage and reproduction of the signal.

This type of construction is convenient because it permits the two electron beams to be easily controlled separately and reduces the likelihood of interaction between the reading and writing circuits. Electrons for the writing beam are emitted by a heated cathode 4D (Figure 7) which is coupled to a suitable signal source 34D as described in the earlier embodiments. The electrons are focused and accelerated by electrodes 6D, 14D, and 16D. Suitable, radar type, deflecting coils 168 and 170 are provided, which are connected to conventional sources 171 of deflecting voltages. After acceleration, the electrons of the writing beam are decelerated by a decelerating electrode 18D, connected to a voltage source 62D, similar to that of Figure 1.

In this embodiment, the storage electrode 22D comprises a thin layer of insulating material 26D coated on opposite sides with conductive screens 24D and 24E, respectively. The conductive screen 24D is maintained at a potential near that of the cathode by means of the voltage source 62D. The velocity modulated electrons from the writing beam impinge on the surface 26D and produce an electron distribution pattern in accordance with the modulation signal from source 34D.

The electrons of the reading beam originate at cathode 94D which is positioned at the opposite end of the tube and is connected directly to ground. The electrons in this reading beam are intensity-modulated by means of a suitable R.-F. voltage generator, indicated in block form at 102D, which is coupled through a transformer, generally indicated at 106D, to a control grid assembly 114D. These electrons are focused and accelerated by a conventional arrangement of electrodes 95D, 14E, and a screen 16E which is positioned over the end of the cylindrical tube which forms the accelerating anode 14E.

The deflection of this reading beam is controlled by conventional television-type deflection coils, illustrated diagrammatically at 174 and 175, which are provided with suitable deflection voltages from a source, indicated in block form at 124D. The proportion of the electrons of this reading beam which strike the storage electrode 22D and are collected by the screen 24E depends upon the charge on the storage surface at the particular point at which the beam is directed and, accordingly, the current that flows through primary winding 84D of transformer 86D to ground is a measure of such charge distribution. This current also depends upon the amplitude of the modulating voltage applied to the control grid assembly 114D so that this frequency component is present in the current through the transformer winding 84D. The voltage induced in the secondary winding 125D of this transformer is coupled to the input circuit of an I. F. amplifier 126D, which is tuned to the frequency of the R.-F. voltage source 102D.

The present invention provides a method for producing a charged pattern on an insulating surface where the charges are deposited in proportion to the input signal to the tube. For most applications it is desirable that this charge pattern be made to disappear at a suitable rate after it has been used to control the output signal of the tube. Such a decay can be accomplished by means, known to those skilled in the art, such as by permitting a controlled leakage of the charge to a grounded electrode, by bombarding the surface with positive ions, or by bombarding the surface with electrons with sufficient velocity to be over the first cross-over in the secondary emission characteristic.

With the various embodiments of the invention, there may be a small defocusing effect caused by the velocity modulation of the beam. For most applications this defocusing is not sufficiently severe to be objectionable; however with particular embodiments or when the invention is applied in a certain manner, the defocusing effect may be more severe, or the slight defocusing may be objectionable. Under such circumstances the focusing field can be modulated in accordance with the magnitude of the input signal. Such an arrangement is shown in Figure 4, wherein an alternative focusing voltage source is shown in broken outline at **144X**. This voltage source is similar in all respects to the conventional voltage source **144** except that it is connected to the input signal from signal source **34B** and is arranged to modulate the current through focusing coil **142**, in accordance with the input signal values, to such extent that the focusing of the writing electron beam remains constant. Further details of circuits for accomplishing this result will be apparent to those skilled in the art. For other applications, defocusing can be substantially prevented by maintaining the high velocity of the electron beam until it reaches a point physically so close to the storage surface that when the beam is decelerated there is little opportunity for it to become defocused.

It is apparent that various modes of operation of the described embodiments are possible and there are, in fact, at least four different modes of operation for the reading portion of the tube and there are usually at least two writing modes for each reading mode. For example, with reference to the embodiment shown in Figure 7, in one mode of operation the storage electrode is operated near the first cross-over potential and the adjacent electrode **18E**, on the reading side, is at a higher potential than the storage electrode.

For some applications, it may be desirable to operate the tube in such manner that the electrons in the reading beam never strike the storage target, the storage surface acting in effect like the control grid of conventional thermionic amplifier tubes. In other modes the insulator may have a transient current drawn while trying to reach zero current equilibrium state, and for such modes the secondary emission properties of both the target insulator and target screen are of importance.

The particular mode of operation that is selected will depend upon the particular application for which the tube is being used and upon the construction of the tube itself. The reading side of the tube can be operated either above or below the first cross-over, the selection of a suitable mode of operation being well within the skill of engineers familiar with this field.

It is apparent also that other means can be used to obtain the velocity modulation. For example, the velocity modulation potential can be applied between the decelerating grid and ground as well as between the cathode and ground as shown.

In this specification and the accompanying drawings, I have shown and described a preferred embodiment of my invention and various modifications thereof; but it is to be understood that these are not intended to be exhaustive nor limiting of the invention, but are given for purposes of illustration in order that others skilled in the art may fully understand the invention and the principles thereof and the manner of applying it in practical use so that they can modify and adapt it in various forms, each as may be best suited to the conditions of a particular use.

I claim:

1. The method of storing electrical information in the form of distributed electrical charges comprising the steps of forming a beam of electrons, accelerating said beam of electrons, deflecting said beam so as to cause it to repeatedly scan an insulating storage surface, decelerating said electrons, controlling the energy level of said electrons in said beam as it strikes each unit area of said surface in accordance with the information to be stored at said unit area of said surface, and building up the electrical charges distributed at each unit area of the surface by said repeated scanning until the amount of charge at each respective unit area is proportional to the energy level of the electrons in said beam as it strikes said respective unit area.

2. The method of storing electrical information in the form of distributed electrical charges comprising the steps of heating an electron-emitting surface to produce free electrons, forming said electrons into a sharply focused beam, increasing and subsequently decreasing the energy level of said electrons forming said beam, deflecting said beam so as to cause it to repeatedly scan a storage surface, and varying the energy level of said electrons of said beam as it strikes each unit area of said surface in accordance with the information to be stored at each unit area of said surface, and building up the electrical charges distributed at each unit area of the surface by said repeated scanning until the amount of charge at each respective unit area is proportional to the energy level of the electrons in said beam as it strikes said respective unit area.

3. The method of storing electrical information in the form of distributed electrical charges comprising the steps of emitting electrons, accelerating said electrons, forming said electrons into a beam, periodically deflecting said beam, decelerating said beam, controlling the energy level of said electrons in said beam in accordance with the instantaneous magnitude of a control voltage, causing said beam periodically to approach successive unit areas of an insulating surface, and by the periodic approach of said beam building up the amount of electrical charge at each successive unit area of said surface until the amount of charge at each successive unit area is proportional to the energy level of the electrons in the beam as it approaches each successive unit area and prevents further charge from building up at each successive unit area.

4. The method of storing electrical information comprising the steps of forming a first electron beam having a velocity below the first cross-over point of a predetermined storage surface, controlling the velocity of said first beam in accordance with the information to be stored, directing said first beam to impinge on a storage surface, forming a second electron beam, periodically increasing and decreasing the intensity of said second beam at a constant radio-frequency rate, and directing said second electron beam adjacent said storage surface thereby controlling said second beam in accordance with the charge on said surface.

5. The method of storing electrical information comprising the steps of forming a first electron beam, accelerating and subsequently decelerating said beam, controlling the velocity of said first beam in accordance with the information to be stored, directing said first beam to impinge with repetition on a series of regions of a perforated storage surface, removing the charges from said regions at a rate substantially slower than the repetition rate of the impingement of the first beam on any one of said regions so that the amounts of charge built up on successive regions of the surface are proportional to the velocities of the beam as it impinges on said regions forming a second electron beam, directing said second beam to pass through said perforations of said surface past said regions whereby said storage surface acts as a control grid to regulate the intensity of said second beam as a function of the charges on said regions of said storage surface.

6. The method of visually displaying information represented by an electrical signal comprising the steps of forming a first sharply-focused electron beam having a velocity potential less than the first cross-over point of a predetermined storage surface, controlling the energy level of electrons in said first beam as a function of the instantaneous values of said electrical signal, directing said first beam toward said storage surface, continually deflecting said first beam to periodically scan a plurality of regions of said storage surface, removing the charges from said regions at a rate sufficiently low that a substantial portion of the charge deposited by said first beam on each region remains until the beam again scans the region so that the charges deposited on each region are integrated and yet the energy level of the approaching electrons in the first beam as it scans each region limits the total amount of charge deposited on that region regardless of the intensity of the first beam, forming a second flooding beam of electrons, directing said second beam to impinge on a fluorescent screen, and simultaneously con-

trolling the intensity of each unit cross-sectional area of said second beam as a function of the integrated electrical charges on the corresponding regions of said storage surface produced by said first electron beam.

7. The method of visually displaying information represented by an electrical signal comprising the steps of forming a first sharply-focused electron beam, accelerating said electrons in said first beam to a sequence of different velocities, each velocity in said sequence being a function of the successive instantaneous values of said electrical signal, decelerating said electron beam, so that all of the electrons in said first beam have velocities less than the cross-over point of a predetermined perforate storage surface periodically deflecting said first beam and directing it to scan insulating portions of said perforate storage surface, removing the charges from said portions at a rate sufficiently low that substantial amounts of the charge deposited by said first beam on said portions during each scan can remain until the beam again scans the portions so that the charges deposited on each successive portion are built up to amounts proportional to the successive velocities of the electrons in said first beam, forming a second electron beam, directing said second beam toward said storage surface, controlling the proportion of electrons of said second beam passing through said perforations as a function of the charges on the corresponding portions of said surface, and directing the electrons passing through said perforations to impinge on a fluorescent screen.

8. In a system for storing information represented by an electrical signal, the combination comprising an electron emitter, elements producing a first electron-controlling focusing field for forming electrons emitted by said emitter into a beam, means producing a second electron-controlling accelerating field for accelerating said electron beam, a control circuit coupled to said signal for producing an electrical field of varying intensity for controlling the instantaneous velocity of said beam as a function of the magnitude of said signal, electrode means producing an electrical decelerating field for reducing the velocity of said electron beam, a storage surface positioned to intercept said electron beam, said decelerating field reducing the velocities of the electrons in said beam below the cross-over point of said surface, beam deflection means arranged to sweep said beam cyclically over a plurality of regions of said surface, and high resistance conduction path means near said regions arranged to remove from said regions the charges deposited by said beam, the rate of charge removal being slow relative to the repetition rate of said beam deflection means, whereby the charge on each respective region builds up to a value proportional to the instantaneous velocity of the beam as it scans that region.

9. In a system for storing information represented by an electrical signal, the combination comprising an insulating storage surface, an electron emitter, means forming electrons from said emitter into a beam, means for accelerating said electrons to a velocity exceeding the first cross-over point of said surface, a circuit connected to said signal and to said last said means for producing an electrical field of varying intensity for controlling the velocity of said beam as a function of the magnitude of said signal, scanning means for periodically scanning the beam over said surface, and means for reducing the velocity of said electrons to a value below said cross-over point of said surface, said insulating storage surface having a slow charge leakage rate relative to the scanning period and being positioned to acquire an electrical charge distribution, the variations in value of the charges on various regions of said surface being a function of the variations in velocity of said beam.

10. In a system for storing information represented by an electrical signal, the combination comprising a storage surface, an electron emitter, a first velocity control electrode for controlling the velocity of electrons from said emitter, a voltage supply circuit connected to said signal and to said first velocity control electrode and under the control of said signal for producing a varying voltage between said emitter and said electrode so as to cause said electrons to assume various velocities as a function of the magnitudes of said signal, a second velocity control electrode for reducing the velocities of said electrons below the cross-over point of said surface, said storage surface being positioned to be approached by said electrons, and means periodically deflecting said electrons toward various regions of said surface, said surface having means for removing the electrons deposited thereon at a rate substantially slower than the rate at which said periodic deflection occurs, whereby the electrons deposited on said regions build up to amounts proportional to the respective velocities of the electrons approaching said regions.

11. A storage tube comprising an electron emitter for emitting free electrons, a focusing circuit for focusing said electrons into a beam, an accelerating electrode, a storage target, said target including a wire screen and an insulating coating surrounding each of said wires and having open meshes to permit electrons to pass therethrough, a decelerating electrode positioned between said target and said accelerating electrode, and a circuit for maintaining said decelerating electrode at a potential near that of said emitter.

12. In a system for storing information represented by an electrical signal, the combination comprising an electron emitter, a focusing field for forming the emitted electrons into a beam, a first velocity control electrode for controlling the velocity of electrons from said emitter, a voltage supply circuit connected between said emitter and said electrode and under the control of said signal for producing a varying voltage between said emitter and said electrode corresponding with the variations in said signal so as to cause said electrons to assume a velocity which is a function of the magnitudes of said signal, a second velocity control electrode for reducing the velocity of said electron beam, a storage surface positioned to be approached by said electrons thereby to assume a potential which is a function of the velocity of said electrons, and circuit means for varying the intensity of said focusing field as a function of said information signal.

13. The method of effectively storing information in three co-ordinates on an electrical storage structure having a plurality of electrical storage regions comprising the steps of forming a beam of electrons, directing said beam toward said structure and periodically deflecting said beam in two co-ordinates repeatedly to approach said storage regions in a first predetermined sequence, producing variations in the velocities of the electrons in said beam as a function of the information to be stored and repeating said variations in a second predetermined sequence in accordance with said first predetermined sequence and controlling all of said velocities to hold them below the first cross-over point of said structure as the electrons approach said regions, removing from said regions the electrons deposited by said beam, said removal being at a rate substantially slow compared with the periodic deflections of said beam, whereby a substantial fraction of the electrons deposited on any region during one approach of said beam remains on said region until the succeeding approach of said beam, whereby the variations in the values of the charges built up on said storage regions by the repeated approaches of said beam correspond with the variations in the velocities of the electrons in said beam, thereby to provide a third co-ordinate of the information.

14. The method of storing information as electrical charges on an insulating storage surface and of preserving half-tone characteristics of the information comprising the steps of repeatedly scanning said surface with an electron beam, producing variations in the velocities of the electrons in said beam as they approach said surface as a function of the information to be stored while maintain-

ing all of said velocities below the first cross-over point of said surface, and integrating the charges deposited on the respective regions of said surface by the repeated scanning, whereby the velocities of the approaching electrons limit the ultimate level of charge built up on the various regions of the storage surface, thereby to preserve half-tone characteristics of the information.

15. A storage tube comprising an electron emitter for emitting free electrons, a focusing circuit for focusing said electrons into a beam, an accelerating circuit including electrode spaced from said emitter and a source of accelerating voltage connected to said electrode for accelerating said electrons, a storage target including a plurality of insulating regions and electrically conductive means near said regions, a decelerating electrode positioned between said target and said accelerating electrode, and a circuit for maintaining said decelerating electrode at a potential near to that of the emitter, thereby to slow the electrons in said beam below the first cross-over point of said storage target.

16. A storage tube comprising an electron emitter for emitting free electrons, a focusing circuit for focusing said electrons into a beam, an accelerating circuit including electrode spaced from said emitter and a source of accelerating voltage connected to said electrode for accelerating said electrons, a signal source connected into said accelerating circuit for varying the instantaneous values of the velocity of the electrons, a storage target including a plurality of insulating regions and electrically conductive means near said regions, a decelerating electrode positioned between said target and said accelerating electrode, and a circuit for maintaining said decelerating electrode at a potential to slow electrons in said beam below the first cross-over point of said storage target.

17. In a system for storing information represented by an electrical signal, the combination which comprises means for producing an electron scanning beam including an electron-emissive cathode, an accelerating electrode and focussing means, a storage target comprising a conductive screen and an insulating surface in contact therewith, deflection means for deflecting said scanning beam over said storage target in a two-dimensional repetitive scanning pattern, means for modulating the velocity of the electrons in said scanning beam in accordance with said electrical signal, and means for maintaining the impact velocity on said storage target of electrons in said scanning beam below substantially the first cross-over of the secondary emission characteristic of said insulating surface, whereby a charge pattern may be produced on said storage target corresponding to the information to be stored, the decay time-constant of said storage target being substantially longer than the period of repetition of said two-dimensional scanning pattern.

18. In a system for storing information represented by an elecrtical signal, the combination which comprises means for producing an electron scanning beam including an electron-emissive cathode, an accelerating electrode and focussing means, a storage target including a surface of insulating material, deflection means for deflecting said scanning beam over said storage target, means for modulating the velocity of the electrons in said scanning beam in accordance with said electrical signal, and decelerating electrode means positioned near said storage target to decelerate the electrons in said scanning beam below the velocity corresponding to substantially the first cross-over of the secondary emission characteristic of said insulating material, whereby a charge pattern may be produced on said storage target corresponding to the information to be stored.

19. In a system for storing information represented by an electrical signal, the combination which comprises means for producing an electron scanning beam including an electron-emissive cathode, an accelerating electrode and focussing means, a storage target including a surface of insulating material, deflection means for deflecting said scanning beam over said storage target, means for modulating the velocity of the electrons in said scanning beam in accordance with said electrical signal, means for maintaining the impact velocity on said storage target of electrons in said scanning beam below substantially the first cross-over of the secondary-emission characteristic of said insulating surface, whereby a charge pattern may be produced on said storage target corresponding to the information to be stored, means including a second electron-emissive cathode for producing a second electron beam, said second electron beam being directed toward said storage target for reproducing information under the control of the charge pattern on said storage target, and means for maintaining the potential of said second cathode near the potential of the cathode of said scanning beam.

20. In a system for storing information represented by an electrical signal, the combination which comprises means for producing an electron scanning beam including an electron-emissive cathode, an accelerating electrode and focussing means, a storage target including a surface of insulating material, deflection means for deflecting said scanning beam over said storage target, means for modulating the velocity of the electrons in said scanning beam in accordance with said electrical signal, decelerating electrode means positioned near said storage target to decelerate the electrons in said scanning beam below the velocity corresponding to substantially the first cross-over of the secondary-emission characteristic of said insulating material, whereby a charge pattern may be produced on said storage target corresponding to the information to be stored, means including a second electron-emissive cathode for producing a second electron beam, said second electron beam being directed toward said storage target for reproducing information under the control of the charge pattern on said storage target, and means maintaining the potential of said second cathode near the potential of the cathode of said scanning beam.

21. In a system for storing information represented by an electrical signal, the combination which comprises means for producing an electron scanning beam including an electron emissive cathode, an accelerating electrode and focussing means, a storage target including a surface of insulating material, deflection means for deflecting said scanning beam over said storage target, means for varying the potential of said cathode in the negative direction from a reference potential in accordance with variations in said electrical signal to thereby modulate the velocity of the electrons in said scanning beam, means for maintaining the impact velocity on said storage target of electrons in said scanning beam below substantially the first cross-over of the secondary-emission characteristic of said insulating surface, whereby a charge pattern may be produced on said storage target corresponding to the information to be stored, means including a second electron-emissive cathode for producing a second electron beam, said second electron beam being directed toward said storage target for reproducing information under the control of the charge pattern on said storage target, and means for maintaining the potential of said second cathode substantially at said reference potential.

22. In a system for storing information represented by an electrical signal, the combination which comprises means for producing an electron scanning beam including an electron-emissive cathode, an accelerating electrode and focussing means, a storage target including a surface of insulating material, deflection means for deflecting said scanning beam over said storage target, means for modulating the velocity of the electrons in said scanning beam in accordance with said electrical signal, whereby a charge pattern may be produced on said storage target corresponding to the information to be stored, and means re-

sponsive to said electrical signal for varying the field produced by said focussing means as said electrical signal varies to thereby reduce defocussing of said scanning beam.

23. In a system for storing information represented by an electrical signal, the combination which comprises means for producing an electron scanning beam including an electron-emissive cathode, an accelerating electrode and focussing means, a storage target comprising a conductive screen and an insulating surface in contact therewith, deflection means for deflecting said scanning beam over said storage target in a two-dimensional repetitive scanning pattern, means for modulating the velocity of the electrons in said scanning beam in accordance with said electrical signal, means for maintaining the impact velocity on said storage target of electrons in said scanning beam below substantially the first cross-over of the secondary-emission characteristic of said insulating surface, whereby a charge pattern may be produced on said storage target corresponding to the information to be stored, the decay time-constant of said storage target being substantially longer than the period of repetition of said two-dimensional scanning pattern, means including a second electron-emissive cathode for producing a second electron beam, said second electron beam being directed toward said storage target for reproducing information under the control of the charge pattern on said storage target, and means for maintaining the potential of said second cathode near the potential of the cathode of said scanning beam.

24. In a system for storing information represented by an electrical signal, the combination which comprises means for producing an electron scanning beam including an electron emissive cathode, an accelerating electrode

and focussing means, a storage target comprising a conductive screen and an insulating surface in contact therewith, deflection means for deflecting said scanning beam over said storage target in a two-dimensional repetitive scanning pattern, means for varying the potential of said cathode in the negative direction from a reference potential in accordance with variations in said electrical signal to thereby modulate the velocity of the electrons in said scanning beam, decelerating electrode means positioned near said storage target to decelerate the electrons in said scanning beam below the velocity corresponding to substantially the first cross-over of the secondary-emission characteristic of said insulating surface, whereby a charge pattern may be produced on said storage target corresponding to the information to be stored, the decay time-constant of said storage target being substantially longer than the period of repetition of said two-dimensional scanning pattern, means including a second electron-emissive cathode for producing a second electron beam, said second electron beam being directed toward said storage target for reproducing information under the control of the charge pattern on said storage target, and means for maintaining the potential of said second cathode substantially at said reference potential.

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U. S. DEPARTMENT OF COMMERCE

PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 2,821,653 — January 28, 1958

John N. Dyer

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 2, line 33, after the syllable "ing" and before "of" insert -- up --; line 66, for "furnace" read -- surface --; column 8, line 55, for "conected" read -- connected --; column 9, line 44, for "targe" read -- target --; column 13, line 65, after "CONVERTER" insert -- TUBE --.

Signed and sealed this 1st day of April 1958.

(SEAL)

Attest:

KARL H. AXLINE

Attesting Officer

ROBERT C. WATSON

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