

[54] **DISPLAY APPARATUS HAVING
SEGMENTED INTEGRAL REGULATOR**

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340/343

[51] Int. Cl. **G09f 9/32**

[58] Field of Search 315/168, 169 R, 169 TV,
315/147; 340/336, 324 R, 324 M, 343, 166 EL

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Primary Examiner—Marshall M. Curtis

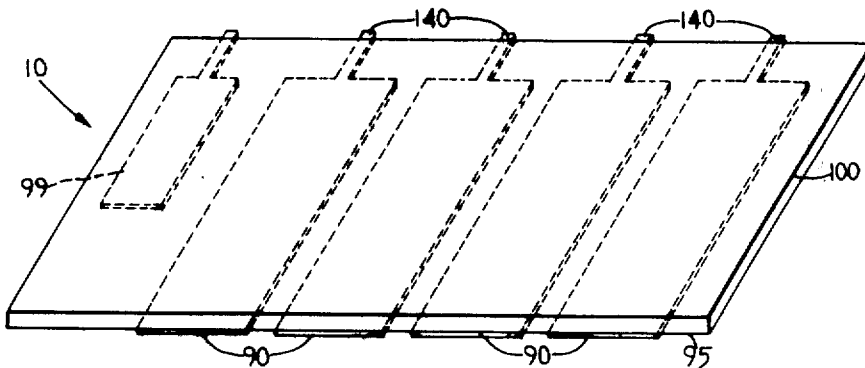
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Penn; Robert B. Green

[57]

ABSTRACT

These segmented-electrode gas panel displays include a plurality of groups of cathode electrodes arranged in a display matrix, each group having an anode electrode operably associated therewith, and an auxiliary voltage reference device formed within the display panel itself. The reference device comprises at least a pair of electrodes that are spaced apart and in contact with the same gas in the panel that is in contact with the display electrodes thereof. The regulator cathode is formed of multiple or segmented cathode elements or comprises several exposed portions of an electrode element that is masked by an apertured insulating layer. The display apparatus further includes circuit means coupled to the integral voltage reference device and to the display electrodes to regulate the bias on one set of them at a level which allows direct operation of the display panel by semiconductor integrated circuits which have limited output voltage signals available for energizing the display electrodes. Current in the regulator segments, if connected in common, will be automatically apportioned among them as a function of their glow-sustaining characteristics which provides improved regulation in the apparatus.

18 Claims, 14 Drawing Figures



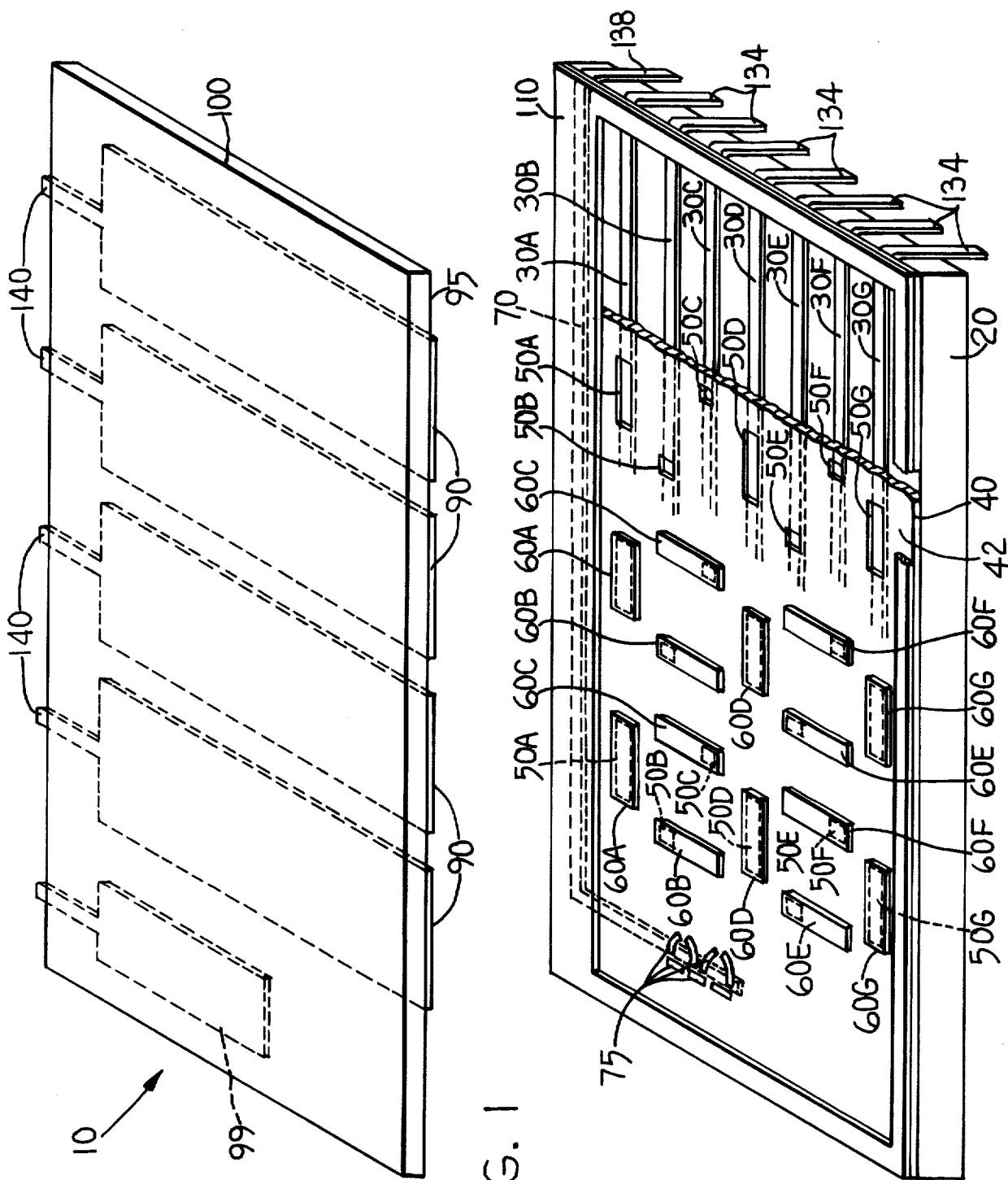
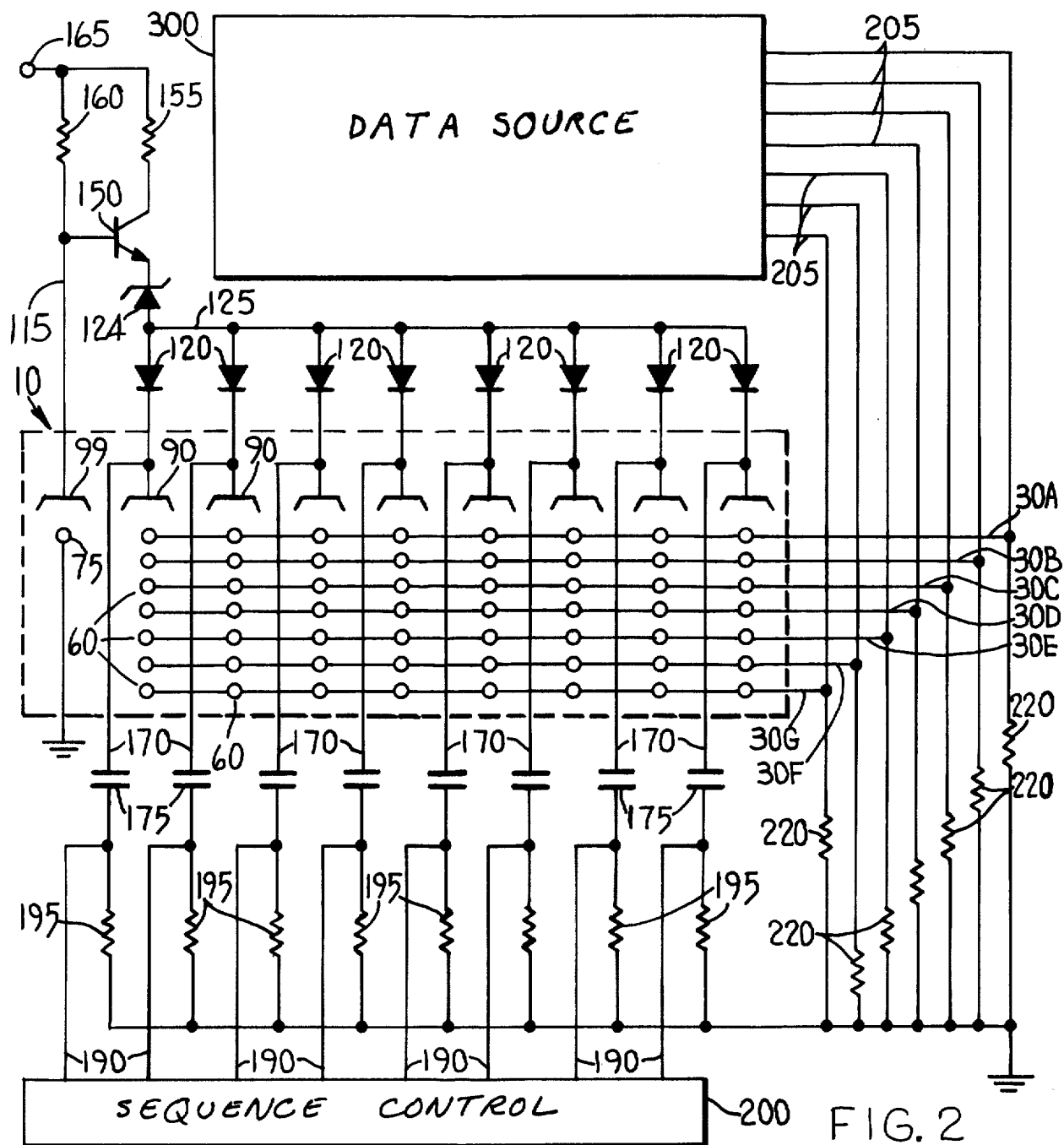
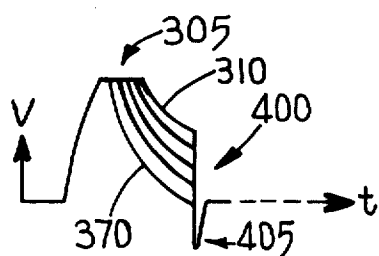
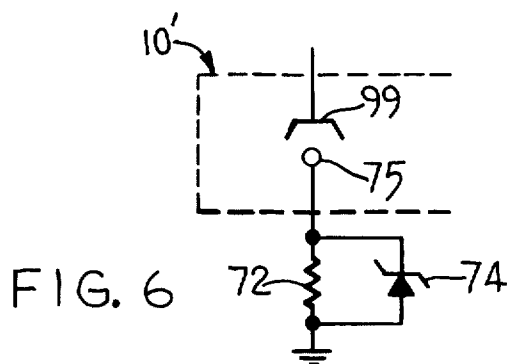
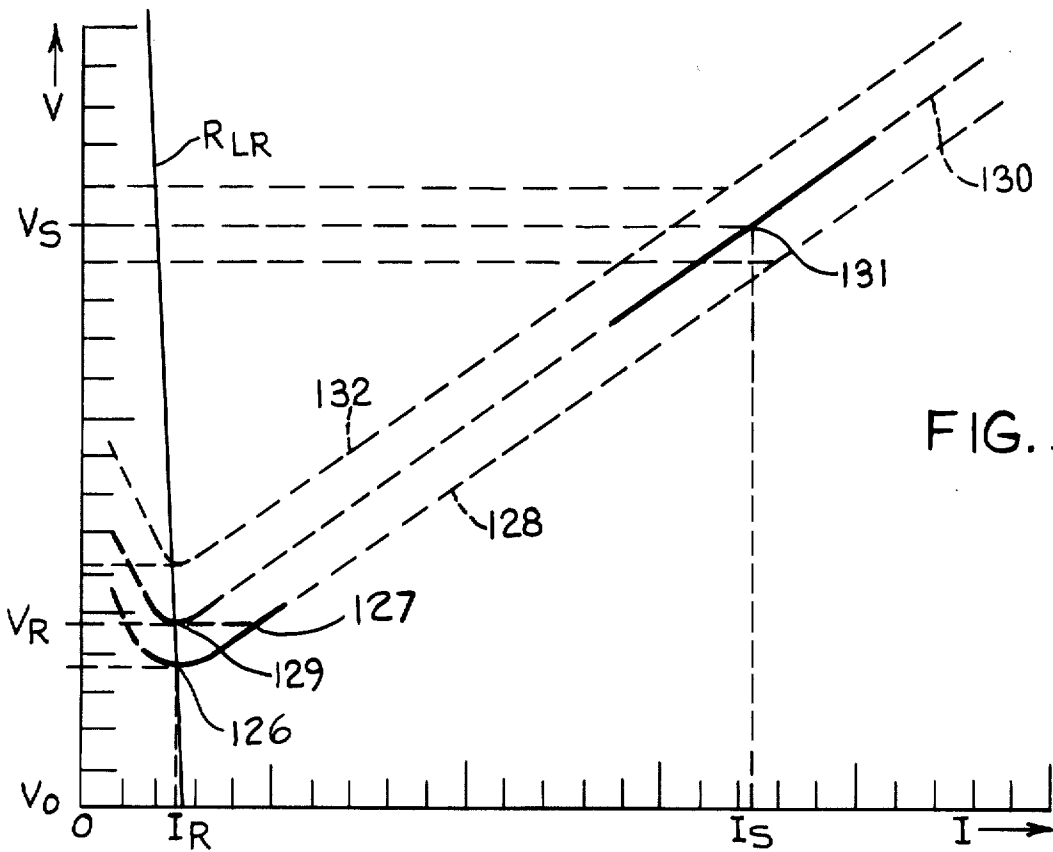
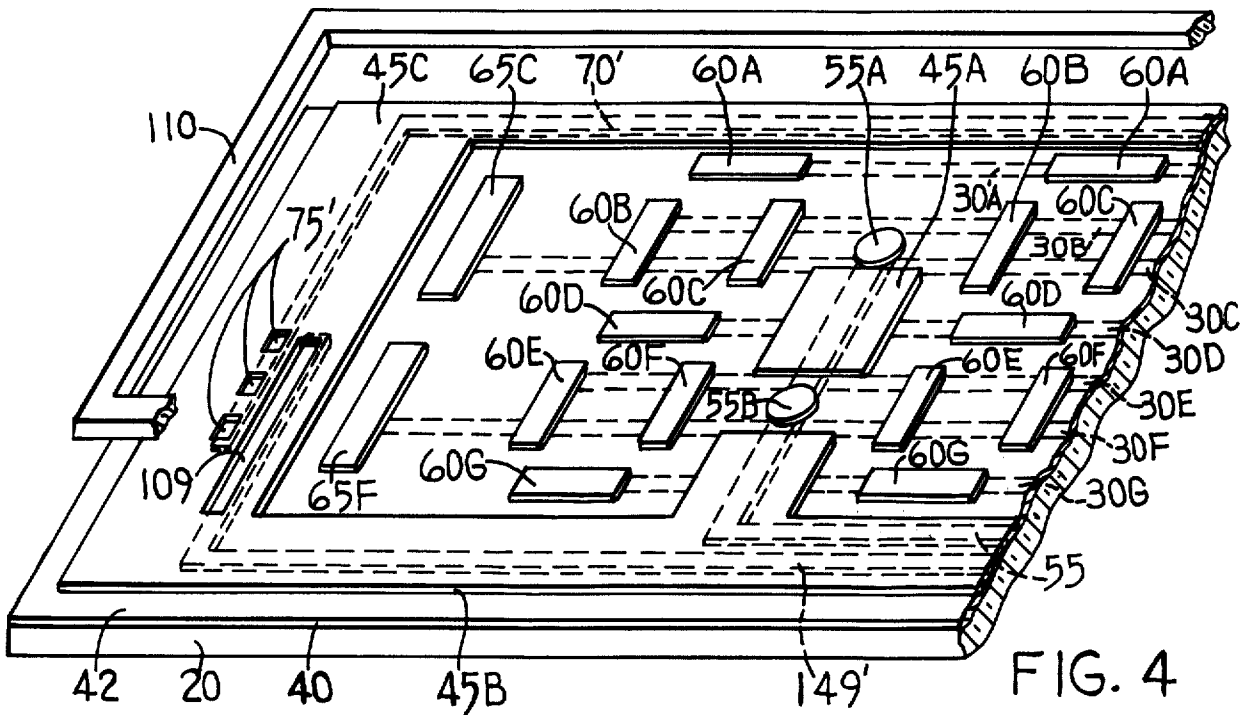


FIG. 1





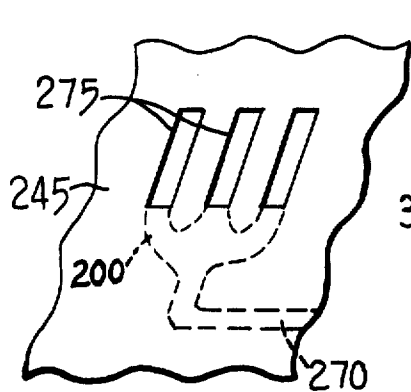


FIG. 7

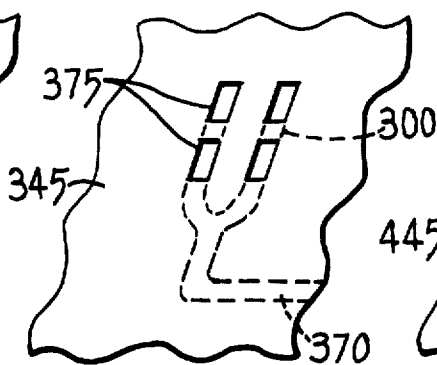


FIG. 8

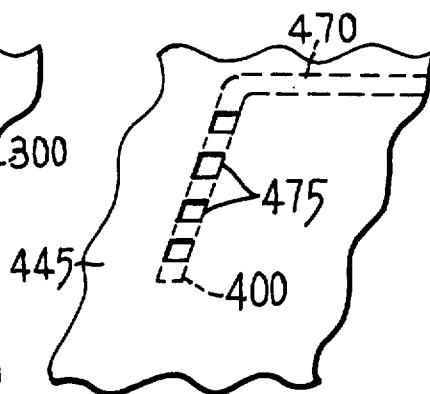


FIG. 9

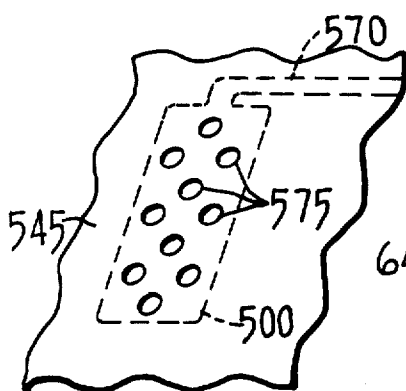


FIG. 10

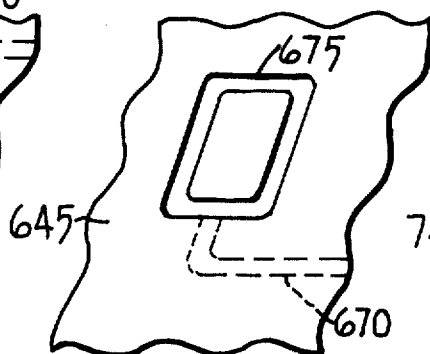


FIG. 11

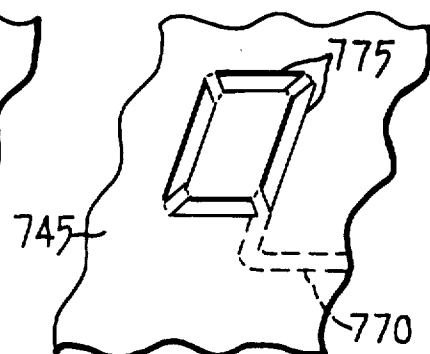


FIG. 12

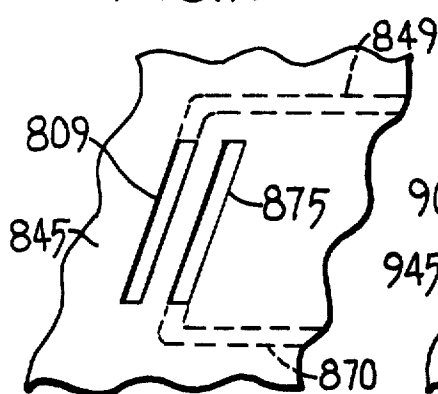


FIG. 13

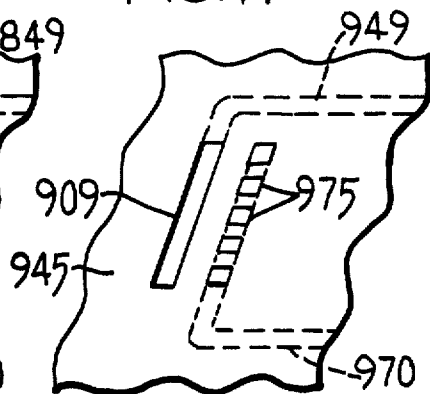


FIG. 14

DISPLAY APPARATUS HAVING SEGMENTED INTEGRAL REGULATOR

This application is related to Ser. No. 481,172 titled "Multi-Position Character Display Panel Having Display Cathodes and Auxiliary Cathodes for Operating" 5 filed June 20, 1974 by James Y. Lee.

BACKGROUND OF THE INVENTION

Various multiple electrode display devices may be adapted to operate according to the subject invention, including segmented-electrode displays such as the PANAPLEX panel display. Such panels include groups of cathode electrodes in the form of segments of characters or symbols to be displayed, and each group has an associated anode electrode. The cathodes of each group are selectively energized together with each of the anodes at different times to display different characters at the various display positions in the device.

Displays of this type are frequently used in digital devices and instruments such as electronic calculators and the like which are presently being widely marketed. In general, each type of calculator requires an associated circuit for driving the display device, which preferably is free of unnecessary complexity and is operable from a poorly regulated power supply. Also, it is usually desirable that it operate such display devices from semiconductor integrated circuits and the like which have limited output signal voltages and yet be tolerant of considerable variations in the ionization potential and the operating potential drop across such devices, for example.

Furthermore, it has previously been found to be necessary to blank or interrupt the signals applied to such devices at the beginning or at the end of each display period to eliminate excited particles in the gas for preventing spurious glow or cross-talk between adjacent display positions.

SUMMARY OF THE INVENTION

An object of this invention is to permit the operation of gas panel displays by a wide variety of low voltage logic circuit modules such as semiconductor integrated circuits.

Another object of the invention is to permit operation of different display panels from unregulated power supplies.

Another object of the invention is to improve the stability of integral voltage regulation in gas panel display systems.

According to a feature of the invention, the glow discharge on a segmented integral reference device can fully cover one or more portions of its cathode at low current and provide a more stable reference voltage than otherwise.

Other advantages and features of the invention are made clear in the following description, with reference to the accompanying drawings, wherein:

FIG. 1 is an enlarged exploded view of a gas panel display with integral voltage reference device,

FIG. 2 is an electrical schematic block diagram of a display apparatus incorporating integral voltage regulation,

FIG. 3 is an illustration of the electrical characteristics of a typical display panel in the invention,

FIG. 4 is a view of a portion of a panel showing a variation of the integral regulator element,

FIG. 5 illustrates an anode waveform,

FIG. 6 shows an alternative connection of the integral reference device, and

FIGS. 7-14 illustrate various improvements in the structure of integral regulator cathodes, FIGS. 13 and 14 also showing associated anode elements.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

A display panel with which the apparatus of the invention is usable is known as the PANAPLEX gas panel display, such as is described and claimed in co-pending application Ser. No. 173,854, filed Aug. 23, 1971. Briefly, the panel includes a base plate 20, on which a plurality of groups of cathode segments 60A-G are formed by a silk screen process, with corresponding cathodes of each group being connected to a conductive run 30A-30G as shown in FIG. 1. The arrangement of the parts is such that the runs and each of the cathodes are suitably insulated from the adjacent runs and their cathodes, as by layer 40 having front surface 42. One of a plurality of anode electrodes 90, . . . is associated with each group of cathodes for selective electrical discharge with the individual cathode segments. Each anode preferably comprises a transparent conductive coating formed on the inner surface 95 of the face plate 100 of the panel. An ionizable gas atmosphere at a pressure suitable for sustained cathode glow discharge is sealed in the panel between the plates.

Generally, in the operation of panel 10 in a calculator, the groups of cathodes are energized in turn to display a numeral at each display position. This is accomplished by applying sets of negative-going information signals which are spaced apart in time to the cathode runs and by applying positive-going signals to each of the anodes in order, and synchronous with, the cathode signals. As this scanning operation is repeated at a suitable repetition rate, a series of apparently stationary characters or symbols can be displayed by the panel.

According to the invention, auxiliary control elements are formed within the display panel as an integral voltage reference device. In FIG. 1, the voltage reference device comprises an anode 99 formed on the inner surface of face plate 100 and a cathode 75 disposed on the base plate within the gas in the panel as the other electrodes. The reference device may be provided in the display envelope adjacent the first group of cathodes 60 that are scanned, as shown, or one may be provided at both ends of the panel, if desired.

This integral reference device provides a reference voltage at a sustaining potential which is used in the circuit of FIG. 2 to regulate the bias voltage that is maintained on the other anodes of the display. The anode 99 and cathode 75 of the integral reference device may be in contact with the same gas that is in contact with display cathodes 60, as shown, to serve as a source of excited particles therein to shorten ionization delay in the panel. If not needed as a source of excited gas particles in the display, however, the anodes and cathodes of the integral reference device may be disposed in an envelope that is isolated from the display envelope. The gas about the reference elements also may be different than the display gas or may include different additives, and the reference elements may be formed of different materials than the display elements and may be processed differently, if desired.

If the auxiliary regulator electrodes are formed of the same materials with the same processing as display

electrodes **60** and **90**, however, they will have electrical characteristics which are similar to those of the display electrodes. Further, if the reference elements are disposed in the same gas as the display electrodes at the same pressure and spacing, they may all have substantially the same electrical characteristics as represented by curve **130** of FIG. **3**. The voltage across the reference elements appears at point **129** on curve **130**, and the operating point of the display elements is at point **131** on the curve. Thus, if the electrical characteristic of the display segments shifts downward or upward toward dashed curves **128** or **132** due to variations in manufacturing or processing, or as a result of operation, the potential across the reference elements will shift likewise. The reference element thereby provides a means of adjusting the potential applied to the display device in accordance with shifts in the electrical characteristics of the display elements thereof. The integral regulator apparatus of the invention thus compensates for variations or shifts in the operating characteristics within a display device or among different display devices.

In the circuit shown in FIG. **2**, which embodies the invention, a display panel **10** is illustrated schematically. The display panel includes a plurality of substantially identical groups of cathode segments of which corresponding elements are electrically interconnected by conductors **30A** - **30G**. A plurality of substantially identical anodes **90** are provided, one for each group of cathode elements. This panel is thus suited for use as a display unit in calculators, instruments or other readouts. Also disposed in the panel is a voltage reference device including an auxiliary cathode **75** and an auxiliary anode **99**. Reference cathode **75** is shown grounded in the figure, but a resistance element may be connected between it and ground for raising its potential when conducting, or it may be connected to a source of negative potential to lower its potential, if desired.

The cathode conductors **30A** - **30G** are each connected to an output conductor **205** of a source of data signals **300** and to a resistor **220**, the other end of which is connected to ground. The cathode segments are thereby held near ground potential normally, and are switched negative by a predetermined voltage via conductors **205** when selected by data source **300** for a display.

The anodes **90**, associated with the groups of cathode elements, are each connected to one plate of a coupling capacitor **175** by a conductor **170**. The other plate of each capacitor **175** is connected to an output conductor **190** of sequencer **200** and to one end of a resistor **195**. The other ends of resistors **195** are connected to ground and hold conductors **190** normally at ground potential. Sequence controller **200** selectively raises the potential on one of conductors **190** toward a positive potential to address an anode **90**. The associated capacitor **175** is pulled positive thereby, and this rise in potential is coupled by the addressed capacitor **175** to the corresponding anode **90** which it energizes to produce a glow discharge at simultaneously energized ones of the cathodes.

The anode electrodes **90** are also each connected to the cathode of a diode **210**, the anode of which is connected to a reverse-biased Zener diode **124** which is connected to the emitter of transistor **150**, by bus **125**. The collector electrode of transistor **150** is connected

to one end of resistor **155**, the other end of which is connected to a positive voltage supply terminal which may vary by ± 35 per cent or more, for example. The base electrode of transistor **150** is connected to the auxiliary reference anode **99** by conductor **115** and is coupled to the positive voltage supply terminal **165** by resistor **160**.

Transistor **150** functions as the pass element of a regulator which biases the display anodes **90** sufficiently positive with respect to the display cathodes so that relatively small signal voltage excursions on the anodes and cathodes will cause a glow discharge in the panel. In operation, a glow discharge between the auxiliary reference cathode **75** and anode **99** is established by the voltage supply potential on terminal **165**, and resistor **160** presents a load represented by the steep R_{LR} load line on FIG. **3**. This establishes a reference potential V_R across the reference device and a current I_R through it, based at the low point **129** in the normal glow region on characteristic curve **130**. As the reference current I_R changes due to a change in the voltage supply potential, the reference voltage V_R changes relatively little at this point on the curve.

This reference voltage V_R appears on anode **99** of the integral reference device and on the base electrode of regulator transistor **150** since the cathode **75** of the reference device is at ground potential. The emitter of transistor **150** follows this voltage and serves as a current source to charge capacitors **175** through diodes **120**, and Zener diode **124** which subtract from the reference voltage. Bus **125** is thereby maintained at several volts below reference voltage V_R and the anodes **90** of the display panel **10'** are biased at less than a volt below the potential on bias bus **125** through diodes **120**. The amount that Zener diode **124** drops the bias voltage on the anode electrodes below reference voltage V_R assures that a signal applied only to one of the anodes or to one or more of the cathodes will not cause a discharge in the panel. This bias voltage that is maintained on anodes **90** by the integral reference device and transistor **150** permits the display to be operated by small voltage signals, and depends on the characteristics of the panel rather than the circuit.

The display electrode segments or elements **60** are customarily operated in the abnormal glow region and the operating point **131** is determined by the magnitude of reference voltage V_R , minus the voltage drop of the Zener diode, and the cathode and anode signal voltages, which are additive. The sum of these voltages is represented by voltage V_S , which is developed across the display elements of the panel and causes current I_S in the display segments and the resultant level of glow discharge that is desired. The difference between the bias on the anodes based on reference voltage V_R and the desired operating voltage V_S , that is maintained by this regulator, allows the signal voltages applied to the display cathodes and to the anodes to be of suitably small amplitude for low voltage semiconductor drivers and the like.

In the regulator circuit, each of the cathode runs **30A-30G** is connected to a separate conductor **205** which is coupled through a resistor **220** to ground and is also connected to a source of information signals **300** which may be embodied within an integrated circuit chip. An anode input terminal **190** is connected to the junction of each capacitor **175** and resistor **195**, and each terminal **190** represents a connection to a control

signal source 200 which also may be portions of an integrated circuit module.

In operation of the circuit of FIG. 2, when the circuit is turned on, the voltage reference element fires, and transistor 150 conducts until capacitors 175 are charged through diodes 120 to the reference voltage V_R on each anode 90, at which time the transistor turns off. This provides a pre-bias voltage on each of the anode electrodes in the panel. With the anodes thus set at a pre-bias level, as signals are applied to the cathodes and to each anode in turn, only a relatively small signal pulse of the order of 15 to 40 volts is required to energize each group of cathode electrodes and each anode electrode, in turn.

The waveform of the signal which appears at each anode is shown in FIG. 5. The waveform includes a rising portion while capacitors 175 are being charged and then a horizontal portion 305 during the delay time before the gas is ionized and firing takes place. The curved falling portions 310-370 represent the conduction time of a group of cathodes, curve 310 representing discharge by one cathode element, curve 370 representing discharge by all segments in a cathode group and the curves for other combinations of cathode segments falling in between those curves. The waveform includes a final vertical portion 400 which extends below the initial level of the anode signal. During this negative-going portion 405 of the anode signal, transistor 150 conducts as a current source to recharge anode input capacitors 175 and to neutralize the remaining charge or plasma at the display position being turned off. By proper choice of the value of capacitors 175, the current at the end of each pulse is considerably less than the initial amount due to the capacitors being discharged as indicated by curves 310-370. The low terminal current and the low signal voltages employed introduce an effective blanking interval between adjacent digits, thus eliminating the need of specifically timed blanking or of extra circuit elements to provide such blanking.

In a modification of the regulator, Zener diode 124 is eliminated from the circuit so that anode bias bus 125 is connected directly to the emitter of transistor 150. The bias on the anode electrodes is then determined by reference voltage V_R minus the base-emitter drop in transistor 150 and the forward voltage drop of diodes 120. If this level of bias voltage allows energized cathodes to discharge with unaddressed ones of the anodes, then cathode 75 of the integral reference device may be connected to a slightly negative potential terminal instead of to ground. Such a connection will lower the bias voltage on anode 99 of the reference device as well as on the other anodes 90 and thereby prevent spurious discharges in the panel to unenergized anode electrodes.

Further, if it is possible to raise the bias on the anodes without causing extraneous or spurious glow in the panel, then the cathode 75 of the voltage reference device may be connected to a slightly positive potential terminal. Alternatively, cathode 75 of the integral reference device may be coupled to ground through a resistor 72 and a reverse-biased Zener diode 74, as shown in FIG. 6. Both of these modifications will raise the reference potential on anode 99 of the integral reference device and on anode bias bus 125, thus allowing the use of yet smaller anode and cathode input signal voltages.

It should be noted that anode 99 of the integral reference device may be connected directly to a reference potential terminal such as terminal 165, with reference cathode 75 coupled to ground through a load, to provide a reference voltage from cathode 75 for biasing display cathodes 60 rather than anodes 90. Reference cathode 75 is then connected to the control electrode of a regulator transistor or other element for charging capacitors connected in series with display cathodes 60 rather than anodes 90 and thereby biasing the display cathodes. The input signals for the cathodes are thus shifted through the coupling capacitors, superposed on the cathode bias, and the application of simultaneous signals on the anodes results in glow discharges in the display.

It is usually desirable to operate the integral voltage reference device at or near the low point 129 in the normal glow region on characteristic curve 130, for example. This may be done simply by connecting it in series with a resistive load such as resistor 160 to a voltage supply terminal 165 as in FIG. 2. That point provides a relatively constant reference voltage V_R since the characteristic is nearly flat at that point for reference current densities near I_R , and it accommodates increases or decreases in the reference current with little change in the reference voltage.

Under some circumstances, however, the characteristic of the integral reference device changes during operation so that the reference voltage provided by it decreases. It appears that this change is especially pronounced in display panels including mercury as an anti-sputtering agent. It is believed that reference cathode 75 operates at a lower temperature than the display cathodes 60 and that mercury vapor or other substances condense or accumulate upon the reference cathode. This is caused by the integral reference device being operated in the normal glow region at low current density I_R and the display cathodes 60 being operated in the abnormal glow region at the much higher current density I_S .

Some of the mercury that condenses onto cathode 75 of the integral reference device is believed to amalgamate with it and in some cases form a binary alloy and thereby lower the work function of its surface. The cathode fall of the reference cathode is thereby decreased and the reference voltage available for biasing the display electrodes, consequently, also decreases. The accumulation of free mercury or other material on the surface of reference cathode 75 also may lower the work function of the surface of the reference cathode.

It appears, however, that the material of low work function on the surface of the reference cathode 75 is thermally unstable or evaporates if operated at a sufficiently elevated temperature. Various solutions to this problem are illustrated in the drawing. It has been discovered that a glow discharge at a sufficiently high current density can be sustained on one or more of a plurality of discrete areas 75, 75', 275, . . . 975 of a segmented or suitably masked reference cathode as those illustrated in FIGS. 1, 4 and FIGS. 7-14. These discrete areas or segments 75, 275, . . . 975 may be exposed portions of a common area of cathode material or may be individual elements which are electrically connected together in common. It appears that total area of the discrete cathode areas 75, 275, . . . 975 should ideally approximate that of a display cathode segment 60. The area of the reference cathode may, however, be some-

what less than that of a segment of a display cathode, or it may be considerably larger, if desired, since only a few of the discrete areas or portions of the reference cathode usually glow at a given time.

Specific embodiments of a segmented or discontinuous integral reference device are illustrated in the drawing. In FIG. 1, a segmented reference cathode 75 is shown as a block letter B comprising several interconnected discrete areas, and in FIG. 4, the integral reference cathode is shown as exposed areas 75' adjacent an exposed anode area 109 situated on insulating surface 42 and masked by insulating layer 45C. In FIGS. 5-8, the reference cathode of the integral reference device comprises areas 275-575 exposed through apertures in insulating layers 245-575, interconnected by conductive portions 200-500 and connected to conductors 270-570, respectively.

In FIG. 9, the integral reference cathode is a closed circuitous region 675 and, in FIG. 10, it comprises discontinuous portions 775 exposed beneath apertures in insulating layers 645 and 745 and being connected to conductors 670 and 770, respectively. In FIG. 11, the cathode 875 of the integral reference device is exposed and situated adjacent and parallel to associated anode 809, with corresponding connectors 870 and 849, beneath insulating layer 845. In FIG. 12, the integral reference cathode comprises exposed discrete areas or segments 975 adjacent an associated anode 909, and having corresponding connectors 970 and 949, situated beneath insulating layer 945 which masks them.

This glow discharge at increased current density on cathodes 75, 275, . . . 975 of a segmented integral reference device seems to drive off or prevent the accumulation of excess mercury or other material on it. The reference voltage established by the integral reference device thereby tends to stabilize at some level rather than continuing to decrease further with time, as before. A representation of the process involving the segmented reference device is illustrated in FIG. 3. One or a few of the reference cathode segments 75, 275, . . . 975 begins to discharge after a suitable potential is applied to terminal 165 in FIG. 2, for example. It then begins to accumulate mercury on its surface and the voltage across it decreases from V_R at point 129 on characteristic curve 130 to point 126 on characteristic curve 128 and then toward point 127 at voltage V_R on curve 128.

The voltage across the segmented integral reference device then tends to remain near V_R and the corresponding increased current through the reference device appears to drive off or prevent further coating or contamination of the reference cathode. The cathode fall of the segments or discrete areas 75, 275, . . . 975 of the integral reference cathode is thus prevented from decreasing any further. Also, if any non-glowing segment 75, 275, . . . 975 experiences a decrease in its work function below that of the segment(s) that are actively glowing, then some of the reference current transfers to the lower work function segment and it will begin to glow instead of the reference segment of higher work function. This occurs principally when the coating, contamination, or amalgam on the surface of a reference cathode segment glowing in the abnormal glow region becomes "cleaned-up" or dissipated during operation and the work function of its surface increases toward that of its principal material. The potential across the integral reference device thus hovers

around or between points 129 and 126 on characteristic curves 130 and 128, respectively, the stability of the reference voltage developed across the integral reference device is thereby improved considerably.

Also, it should be understood that it is not necessary that the integral voltage reference device assume an electrical characteristic which is below that of the display electrodes of the device, such as curve 128. With a segmented cathode 75, 275, . . . 975 of sufficient area, an integral voltage reference device may exhibit a characteristic which is above that of the display electrodes, such as curve 132. The voltage which appears across the integral reference device then will approach the low point on curve 132 and will reach a point on a characteristic curve near curve 130, or between them, during operation. The voltage across the integral reference device then will tend to stabilize at that level, as previously described, which is suitable for biasing the display electrodes of the device. Also, means such as Zener diode 124 in FIG. 2 may be employed for dropping the potential that is used for biasing the display electrodes below the reference voltage by a suitable amount, if desired.

Although the preferred embodiments of the invention have been described in detail, it should be understood that this disclosure has been by way of example only. Many modifications and variations of the invention are possible in light of the above teachings. It is, therefore, to be understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically disclosed.

That which is claimed is:

1. A display device comprising

a gas-filled envelope having a viewing window and an insulating base plate,

a plurality of groups of cathodes shaped in the form of segments of different characters to be displayed and disposed along the front surface of the base plate and having terminals extending out of the envelope,

an anode electrode associated with each group of cathodes for selective discharge therewith and having terminals extending out of the envelope,

an integral voltage reference device comprising at least a plurality of interconnected discrete cathode elements and an anode electrode associated with the elements within the envelope, and

means connected to the electrodes of the reference device for receiving a current sufficient to sustain a discharge between one or several of the reference cathode elements and the associated anode electrode to maintain thereby a stable reference voltage across the reference device.

2. The display device of claim 1 wherein the discrete cathode elements of the integral voltage reference device comprise individual portions of a conductive layer exposed by apertures in an insulating masking layer adjacent the conductive layer.

3. The display device of claim 1 wherein the discrete cathode elements of the integral voltage reference device comprise conductive elements which are smaller in area than the display cathode elements of the display device for conducting at higher current density than occurs in the display cathode elements themselves.

4. The display device of claim 1 wherein the discrete cathode elements of the integral voltage reference de-

vice and the display cathode elements of the display device are formed of common materials.

5. The display device of claim 1 wherein the discrete cathode elements of the integral reference device are situated in substantially the same gas atmosphere at substantially the same distance from the anode of the reference device as are the display cathode elements of the display device from the associated electrodes.

6. The display device of claim 1 wherein the discrete cathode elements of the integral voltage reference device are substantially equal in area and are situated substantially equidistant from the associated anode electrode within the envelope of the display device.

7. Display apparatus comprising

a display device including a plurality of groups of cathode elements shaped in the form of segments of different characters to be displayed and situated in a gas-filled envelope having a viewing window and electrode terminals outside the envelope, an anode electrode associated with each group of cathode elements for selective discharge therewith, an integral voltage reference device comprising at least an anode electrode and a plurality of interconnected but separate portions of a cathode electrode associated therewith, and means for conducting a current through said integral reference device comprising resistance means connected in series with it between a pair of voltage supply terminals,

the current established in the integral voltage reference device being sufficient to cause a glow discharge on one or more of the discrete portions of the reference cathode for maintaining a voltage across the reference device near the low voltage point in the normal glow discharge region thereof.

8. The display of claim 7 wherein the cathode electrode of the integral voltage reference device comprises a conductive layer having separate portions which are exposed by apertures in an insulating masking layer adjacent the conductive layer.

9. The display apparatus of claim 7 wherein the separate but interconnected portions of the cathode electrode of the integral voltage reference device are smaller in area than the display cathode elements of the display device for conducting a higher current density than occurs in the display cathode elements themselves.

10. The display apparatus of claim 7 wherein the interconnected but separate portions of the cathode electrode of the integral voltage reference device and the display cathode elements of the display device are formed of common material.

11. The display apparatus of claim 7 wherein the separate portions of the cathode electrode of the integral reference device are situated in substantially the same gas atmosphere at substantially the same distance from the anode of the reference as are the display cathode elements of the display device from the associated anode electrodes.

12. The display apparatus of claim 7 wherein the interconnected portions of the cathode electrode of the integral voltage reference device are substantially equidistant from the associated anode electrode within the envelope of the display device.

13. A display device comprising

a gas-filled envelope having a viewing window and an insulating base plate,

a plurality of groups of cathode elements shaped in the form of segments of different characters to be displayed and disposed along the front surface of the base plate, with terminals extending out of the envelope,

an anode electrode associated with each group of cathode elements for selective discharge therewith and having terminals extending out of the envelope,

an integral voltage reference device comprising at least an anode electrode and a cathode electrode associated with each other within a portion of the envelope, and

a pair of terminals for the integral reference device separate from the other electrodes for receiving a current sufficient to develop a sustained discharge in the reference device for maintaining a reference voltage across it independent of the state of the other electrodes.

14. Display apparatus comprising

a display device including a plurality of groups of cathode elements shaped in the form of segments of different characters to be displayed and situated in a gas-filled envelope having a viewing window and electrode terminals outside the envelope,

an anode electrode associated with each group of cathode elements for selective discharge therewith, an integral voltage reference device comprising at least an anode electrode and an associated cathode electrode situated within a portion of said envelope and each having terminals extending out of the envelope, and

voltage regulating means coupled between an electrode of the integral reference device and one set of the display electrodes to bias them at a voltage related to the potential across said reference device,

the other set of display electrodes and the other electrode of the integral reference device each being electrically connected to a second voltage supply terminal.

15. Display apparatus comprising

a display device including a plurality of groups of cathode elements shaped in the form of segments of different characters to be displayed and situated in a gas-filled envelope having a viewing window and electrode terminals outside the envelope,

an anode electrode associated with each group of cathode elements for selective discharge therewith, means for driving the display device having first and second sets of terminals for providing data and digit address signals, respectively,

means for interconnecting corresponding ones of the cathode elements and for electrically connecting them to the respective data signal terminals,

capacitive means for electrically coupling each of the anode electrodes to a different one of the digit address signal terminals, and

means for biasing the cathodes and anodes of the display device toward the operating potential thereof.

16. The display apparatus of claim 15 wherein the display means for the cathodes and anodes of the display device comprise voltage regulating means coupled to the anode electrodes and a voltage reference device and resistance means coupled between a voltage supply terminal and the cathode elements of the display device.

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17. The display apparatus of claim 16 wherein the reference device for the voltage regulating means is integral with the display device within the common gas atmosphere in which the display cathode elements are situated in the envelope of the device.

18. The display apparatus of claim 16 wherein the

electrodes of the reference device for the voltage regulating means are formed within the envelope of the display device in substantially the same gas atmosphere at substantially the same pressure in which the display cathode elements of the device are situated.

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