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Johanns et al.

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[54] **PICTURE DISPLAY DEVICE COMPRISING A PLURALITY OF LIGHT PRODUCING ELEMENTS**

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Related U.S. Application Data

[63] Continuation of Ser. No. 173,482, Aug. 20, 1971, abandoned.

[52] **U.S. Cl.** **313/484,** 313/185, 313/220, 313/225

[51] **Int. Cl.** **H01j 61/42**

[58] **Field of Search** ..... 313/108 R, 108 A, 108 B, 313/185, 188, 196, 220, 225; 315/169 TV

[56] **References Cited**

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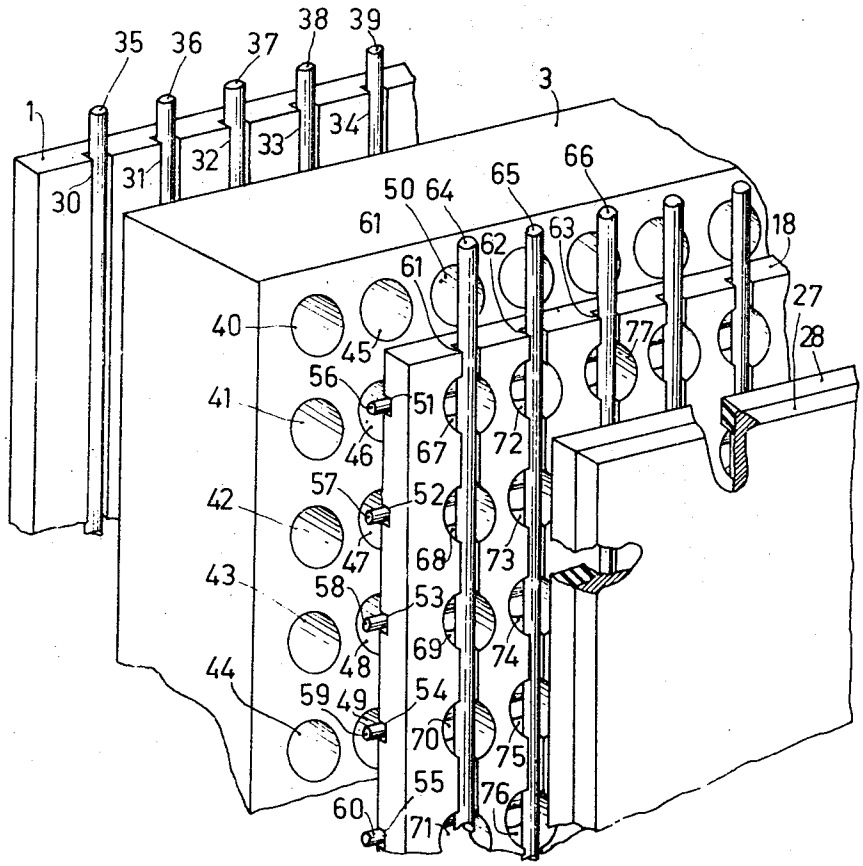
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[57] **ABSTRACT**

A gas-discharge picture-display panel comprising a plurality of gas-discharge tubes. The gas-discharge tubes are closed on one side by a window. An electrode is arranged at each end of each gas-discharge tube. The length of the gas-discharge tubes is at least twice the dimension normal to the directions of length and the wall of the tube is coated with a phosphor material. A positive column is formed in the gas-discharge tubes and the ultra-violet radiation produced thereby causes the phosphor to luminesce. A device which reduces the ignition voltage of the positive column is connected in series with the gas-discharge tubes. The device produces either a glow discharge or a plasma to reduce the ignition voltage.

4 Claims, 5 Drawing Figures



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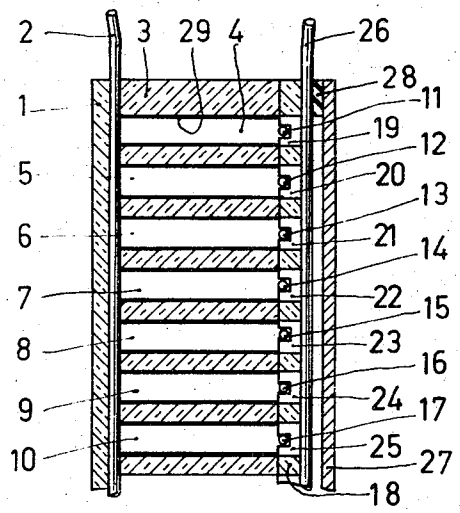


Fig.1

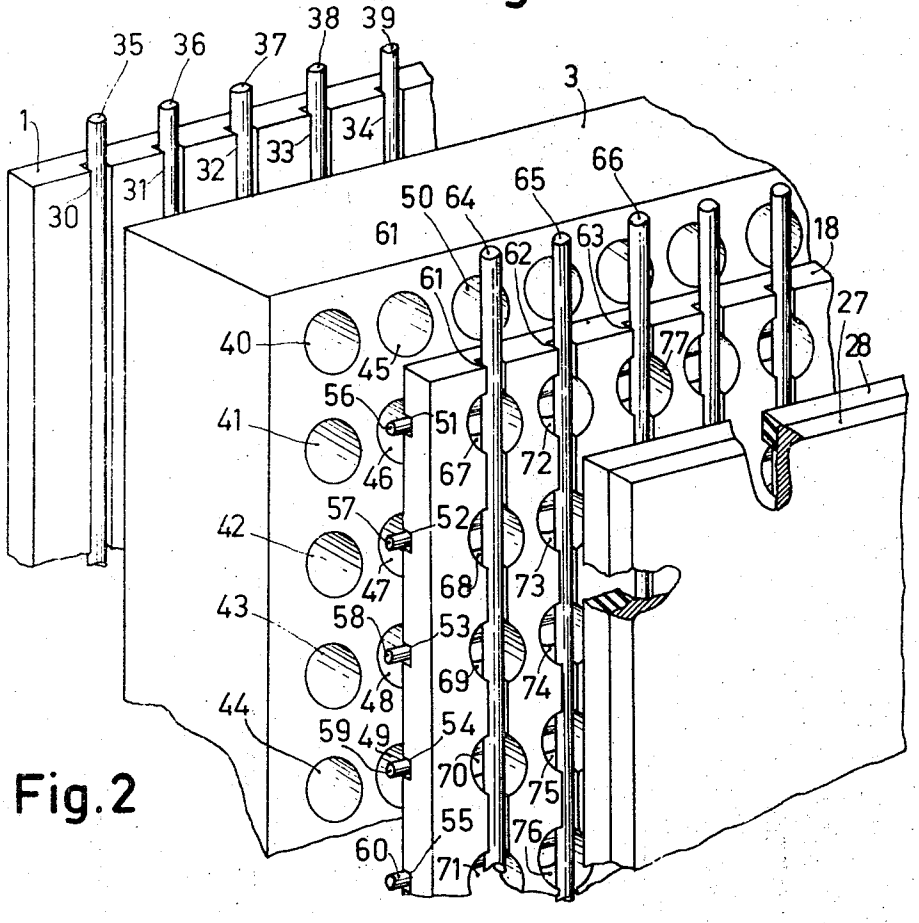


Fig.2

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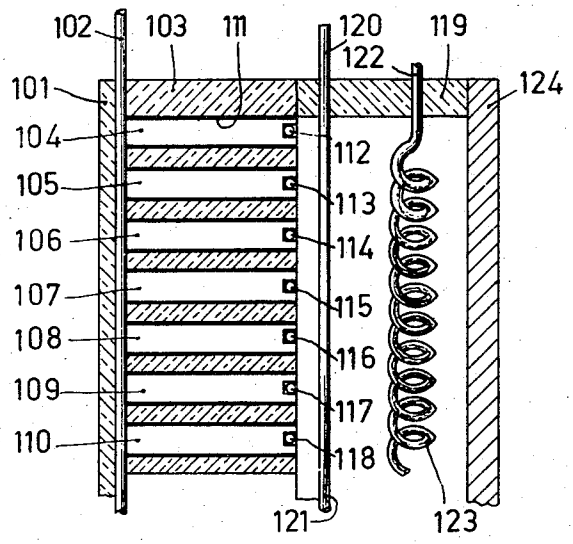


Fig.3

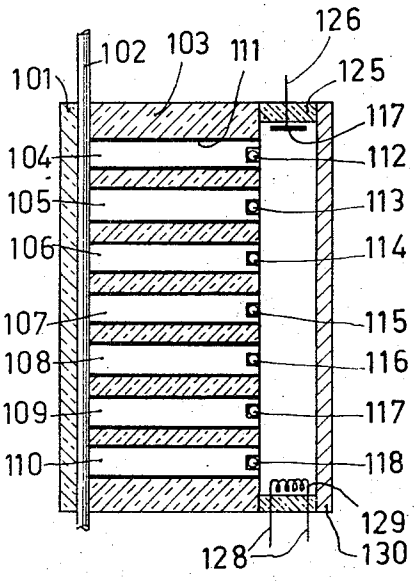


Fig.4

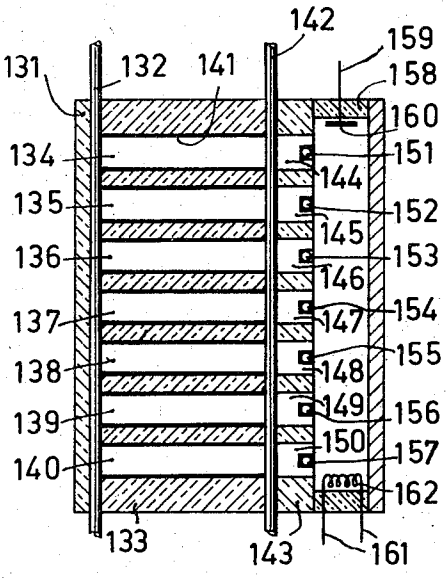


Fig.5

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PICTURE DISPLAY DEVICE COMPRISING A PLURALITY OF LIGHT PRODUCING ELEMENTS

This is a continuation, application Ser. No. 173,482, filed Aug. 20, 1971, and now abandoned.

The invention relates to a picture display device comprising a plurality of gas-discharge tubes, each of which is closed at one end by a window and is filled with a mixture of mercury and at least one rare gas, the walls being coated with a luminescent material, the length of each gas-discharge tube being at least twice the dimension normal thereto, an electrode being provided on either side of each gas-discharge tube. Such a picture display device may be used for television and for the display of symbols, for example, figures, letters, characters of electrical magnitudes and the like. For this purpose the luminescent material of given gas-discharge tubes of the device is caused to luminesce by applying a voltage to said tubes. The device may be constructed so that all electrodes located on one side of the discharge tubes are separately taken to the outside so that the required voltage can be applied separately to each discharge tube. In an alternative construction the electrodes located on one side of the discharge tubes are interconnected in a particular manner, which simplifies the construction in the case of a large number of discharge tubes. The electrodes located on either side of the discharge tubes may then form separate grids of electrodes not intersecting each other, while each electrode of one grid crosses all electrodes of the other grid. In particular the electrodes of one grid cross those of the other grid at right angles.

From U.S. Pat. No. 3,334,269 such a device is known, in which the luminescent material on the wall of a discharge tube is caused to luminesce by ultraviolet radiation, which is produced by a discharge in a mixture of mercury and argon in the discharge tube at the application of a voltage difference between the electrodes of the discharge tube. From the description of said Patent Specification it may be understood that the ultraviolet radiation is produced by a glow discharge, since if in the device described therein positive columns were produced, the latter could be controlled at normal working temperature only with great difficulty due to the high ignition voltage. At a higher temperature switching would be facilitated, but the Patent Specification does not refer anywhere to a high temperature during operation. Moreover in column **4** lines **45** to **49** only state as an advantage of the presence of the luminescent material on the walls of the discharge tube that the light produced is perceived without being reduced during its passage through the phosphor layer, which does occur when the phosphor is applied to the windows. This statement is not indicative of the presence of a positive column. The Patent Specification refers to the presence of a phosphor layer on the window and to the presence of a phosphor layer on the tube wall as being substantially equivalent alternatives. If the phosphor layer is located on the window and if the ultraviolet radiation should emanate from a positive column, only a very small portion of the ultraviolet radiation would attain the phosphor layer on the window due to the self-absorption of the ultraviolet radiation in the positive column; this also is indicative of the absence of a positive column. Since in a glow discharge a comparatively slight ultraviolet radiation is produced, a small part of the energy supplied is converted into visible light so that the efficiency of the device is low, as shown by the low brightness.

The invention recognizer that an appreciably larger portion of the energy supplied is converted into visible light, when a higher amount of ultraviolet radiation is produced. This is achieved in the case of a positive column of a suitable chosen gas discharge i.e., of a mixture of mercury and at least one rare gas, the length of the discharge tube being at least twice the dimension normal thereto and the gas pressure being adapted to the diameter of the discharge tubes in order to obtain a positive column. A difficulty in obtaining a positive column resides in the comparatively high ignition voltage required at normal working temperature. According to the invention a positive column is formed in the gas discharge tubes, while a device reducing the ignition voltage is connected in series with the gas-discharge tubes. Said device comprises a gas-discharge space freely communicating with the gas-discharge tubes so that charge carriers can diffuse from said device to the gas-discharge tubes. The phosphor material is applied to the walls of the gas-discharge tubes. It is thus ensured that the self-absorption of the ultraviolet radiation in the positive column only has a minimum effect on the quantity of visible light obtained. By means of the device reducing the ignition voltage of the positive column in the gas-discharge tubes the picture display device provides a high brightness, while its elements can be separately switched on without the need for high voltages. For each gas-discharge tube a separate device reducing the ignition voltage may be provided, but as an alternative one ignition-voltage-reducing device may be provided in common for a plurality or all of the gas-discharge tubes.

In the case of a separate device reducing the ignition voltage of the positive column for each gas-discharge tube a second gas-discharge tube may be provided in series with each of said gas-discharge tubes. The length of each of the second gas-discharge tubes is at the most equal to the dimension normal thereto. On either side of the second gas-discharge tube an electrode is provided, while the first gas-discharge tube and the associated second gas-discharge tube may have in common the intermediate electrode. If the gas-discharge is ignited in the second gas-discharge tube, which occurs at a comparatively low voltage difference in view of the dimensions, a glow discharge is produced owing to the dimensions. The presence of this glow discharge leads to the production of a positive column in the associated first gas-discharge tube at a comparatively low potential difference. The operation may be as follows: the potential difference across a given first gas-discharge tube is lower than the ignition voltage required, if no further precautions were taken, but it is higher than the ignition voltage required in the presence of a device reducing the ignition voltage. When a glow discharge is produced in the associated second gas-discharge tube, charge carriers therefrom diffuse towards the first gas-discharge tube so that at this potential difference a gas discharge is produced in the first gas-discharge tube, which is a positive column owing to the dimensions of the tube and to the gas pressure employed. The switching operation is thus performed across the second gas-discharge tube. A further mode of operation consists in that the potential difference across a given first gas-discharge tube is lower than the ignition voltage required in the presence of a device reducing the ignition

voltage. When a glow discharge is produced in the associated second gas-discharge tube, charge carriers diffuse towards the first gas-discharge tube. However, the potential difference across the first gas-discharge tube is too low for producing a discharge. When the potential difference across this first gas-discharge tube is raised above the required ignition voltage a gas discharge is ignited which is a positive column owing to the tube dimensions and the prevailing gas pressure. The switching operation then occurs via the first gas-discharge tube. On the side remote from the window a second gas-discharge tube is connected in series with each first gas-discharge tube, the length of said second tube being at the most equal to the dimension normal thereto, while on either side of each second-discharge tube an electrode is provided. The first gas-discharge tube and the second gas-discharge tube have, in particular, between them a common electrode.

In further embodiment in which for each gas-discharge tube a separate device is provided for reducing the ignition voltage of the positive column said device may be arranged inside the gas-discharge tube. For this purpose an additional electrode is provided inside the gas-discharge tube at a short distance from the electrode not located on the side of the window. The device reducing the ignition voltage is then formed by the electrode not located on the side of the window, the additional electrode and the portion of the gas-discharge tube located between said two electrodes. The distance between these two electrodes is at the most equal to the dimension of the gas-discharge tube normal thereto. If a gas-discharge is produced in said portion of the gas-discharge tube, which occurs at a comparatively low potential difference in view of the dimensions, a glow discharge is produced in said portion of the gas-discharge tube owing to the dimensions. The operation is similar to that described in the preceding paragraph. In this case each gas-discharge tube comprises an additional electrode located at a distance from the electrode not located on the side of the window which is at the most equal to the dimension of the gas-discharge tube at right angles to said electrode.

In the two cases described the electrodes located on one side of the second gas-discharge tubes or the additional electrodes may be connected in a given manner so that, for example, they form a grid of electrodes not intersecting each other. Various constructions are possible, also in dependence upon the mode of switching. If a second gas-discharge tube is provided and the first and the second gas-discharge tubes a common electrode, the grids located on either side of the second discharge tubes are formed each by electrodes not intersecting each other, when switching is performed across the second gas-discharge tubes, each electrode of one grid-crossing all electrodes of the other grid, particularly, at right angles. The grid located on the other side of the first gas-discharge tube is formed by electrodes not intersecting each other. These electrodes may be parallel to those of one of the grids located on either side of the second gas-discharge tubes and are then normal to those of the other one of said grids. This means that the first gas-discharge tubes are located between two grids, the electrodes of one grid crossing those of the other grid at right angles or the electrodes of one grid being parallel to those of the other grid. If a second gas-discharge tube is provided and a first and a second gas-discharge tube have a common electrode, the grids located on either side of the first gas-discharge tubes are formed by electrodes not intersecting each other, when the switching operation is performed across the first gas-discharge tubes, each electrode of one grid crossing all electrodes of the other grid, particularly, at right angles. The grid located on the other side of the second gas-discharge tube is formed by electrodes not intersecting each other and extending, for example, parallel to those of one of the grids located on either side of the first gas-discharge tubes. The same applies to the cases in which the discharge tube in which a positive column is formed comprises an additional electrode. In order to produce a gas-discharge consecutively in two gas-discharge tubes, one of the electrodes of which is associated with the same grid wire, each of the parallel current paths required a separate resistance because owing to the voltage drop across an active gas discharge it would not be possible to ignite the second gas-discharge. This is usually achieved by providing all electrodes of one grid with a resistor outside the panel proper. A resistance may be provided in the panel itself by providing all electrodes of one grid with a layer of high-resistive material.

An embodiment in which a device reducing the ignition voltage is common to a number or all of the gas-discharge tubes by providing at least during a given period of the operation of the display device a plasma for these gas-discharge tubes. The term "plasma" is to denote a mixture of charged gas particles, which in total is electrically about neutral. This plasma, common to the gas-discharge tubes, is produced between a cathode and an auxiliary anode. Various geometrical dispositions are possible, the cathode and the auxiliary anode may be arranged so that the line of connection between the cathode and the auxiliary anode is approximately at right angles to the direction of the gas-discharge tubes. In another geometrical arrangement the auxiliary anode is located between the cathode and the gas-discharge tubes. In this case the auxiliary anode need not be common to all those gas-discharge tubes, to which the cathode is common. The phosphor of a given gas-discharge tube is excited when the potential difference across said gas-discharge tube exceeds the burning voltage, whereas it is nevertheless lower than the ignition voltage which would be required if no further precautions were taken. Since charge carriers diffuse from the plasma into the gas-discharge tube, sufficient pre-ionisation is obtained in the gas-discharge tube for starting the discharge. The gas-discharge tubes whose phosphors should not be excited have a potential difference which is lower than the burning voltage. In this case the switching-on operation is performed by controlling the potential difference across the gas-discharge tube. The device reducing the ignition voltage is thus formed by a cathode and an auxiliary anode, between which a plasma common to at least a number of the gas-discharge tubes is produced. In dependence upon the voltage applied the positive column is formed between the electrodes on either side of the gas-discharge tube or between the cathode of the plasma and the electrode located on the other side of the gas-discharge tube. If the electrodes on either side of the gas-discharge tubes are interconnected and thus form grids of electrodes not intersecting each other, each electrode of one grid crosses all electrodes of the other grid, particularly, at right angles. It is furthermore possible to arrange in line with each first gas-discharge

tube a second gas-discharge tube between the former and the plasma, an electrode being provided on either side of said second tube, the intermediate electrode being common to the first and the associated second gas-discharge tubes. The overall potential difference across the first and the associated second gas-discharge tubes is then always higher than the burning voltage. The switching operation is not performed by varying this overall potential difference, but it results from a variation of the voltage at the intermediate electrode, that is to say, a variation of that portion of the potential difference which occurs across the second gas-discharge tube. This second gas-discharge tube then operates like a valve. The plasma is capable of reducing the ignition voltage for those first gas-discharge tubes for which the potential difference across the associated second gas-discharge tubes is so high that charge carriers can penetrate into the first discharge tubes. This has the advantage that the main current need not be switched. Between the gas-discharge tubes and the device reducing the ignition voltage it is preferred in this case to connect a second gas-discharge tube in series with every first gas-discharge tube, an electrode being provided on either side of each second gas-discharge tube.

It should be noted that U.S. Patent No. 2,595,617 discloses a picture display device comprising a plurality of gas-discharge tubes whose windows are coated with a phosphor, there being provided a common compartment in which a spare quantity of ionized gas or vapour is produced, which constitutes a kind of plasma. Though in this Patent Specification the terms "column" and "positive column" are used, it is obvious from many paragraphs of the specification that the phosphor material is caused to luminesce by electron excitation. It is stated, for example, in column 12, lines 70 to 72, that electric charges in each cell locally act upon the fluorecent layer. Moreover, a modulation of the resultant brightness by the control of the anode voltage as stated in column 4, lines 39 to 41, is only possible in the case of electron excitation. In addition, at the low pressure referred to the gases (mercury vapour, hydrogen and helium) mentioned in column 3, lines 67 to 68 provide only a very slight ultraviolet radiation. The phosphor material is applied to the window; if ultraviolet radiation were produced, only a very small portion of the ultraviolet radiation would attain the phosphor material on the window due to the self-absorption of the ultraviolet radiation in the positive column.

In the device embodying the invention the phosphor material arranged on the walls of the gas-discharge tubes determines the colour of the emitted light. By using materials luminescing in different colours a device is obtained for displaying colour pictures.

The brightness obtained is further increased by providing light-reflecting properties for the wall of the gas-discharge tube coated with the phosphor material.

The invention will be described by way of example with reference to a drawing which shows

in FIG. 1 a cross sectional view of part of a display panel,

in FIG. 2 part of a developed view of the diaplay panel of FIG. 1,

in FIG. 3 a sectional view of a different construction of the display panel,

in FIG. 4 a sectional view of a further structure of a display panel and

in FIG. 5 also a sectional view of a further structure of a display panel.

FIG. 1 is a cross sectional view of part of a display panel embodying the invention. It comprises a glass plate **1**, a first grid of parallel wires, a wire **2** being shown in the Figures, a glass plate **3** having apertures **4, 5, 6, 7, 8, 9** and **10**, a second grating of parallel wires **11, 12, 13, 14, 15, 16, 17**, a glass plate **18** having apertures **19, 20, 21, 22, 23, 24**, and **25** registering with the apertures in the plate **3**, a third grating of parallel wires, a wire **26** being shown in the Figures, and a metal cover **27**, which is connected by an insulating intermediate piece **28** with the plate **18**. The wires of the first grating are sunk in grooves in the plate **1** and the wires of the second grating and those of the third grating are sunk in grooves of the plate **18**. The walls of the aperture of the plate **3** are coated with a layer **29** of a phosphor. The apertures in the plates **3** and **18** are filled with a mixture of mercury and at least one rare gas. The sealed exhaust and filling opening is not shown in the Figure.

FIG. **2** is part of a developed view of the display panel of FIG. **1**. The glass plate **1** has vertical grooves **30, 31, 32, 33** and **34**, accommodating wires **35, 36, 37, 38** and **39** of the first grating. One of these wires corresponds with the wire **2** of FIG. **1**. The glass plate **3** has apertures in an array of vertical columns and horizontal rows, a number of which is shown, i.e., **40, 41, 42, 43, 44, 45, 46, 47, 48, 49** and **50**. The apertures of one of the columns correspond with the apertures **4, 5, 6, 7, 8, 9** and **10** of FIG. **1**. The glass plate **18** is provided on one side with horizontal grooves **51, 52, 53, 54** and **55**, accommodating wires **56, 57, 58, 59** and **60** of the second grating. These grooves correspond with a number of grooves of FIG. **1**, which also applies to said wires and a number of the wires **11, 12, 12, 13, 14, 15, 16** and **17** of FIG. **1**. On the other side the glass plate **18** has vertical grooves **61, 62, 63** holding wires **64, 65** and **66** of the third grating one of these wires corresponds with the wire **26** of FIG. **1**. At the crossings of the grooves **51, 52, 53, 54** and **55** with the grooves **61, 62, 63** the plate **18** has apertures **67, 68, 69, 70, 71, 72, 73, 74, 75, 76** and **77**. The apertures in one of the columns correspond with a number of the apertures **19, 20, 21, 22, 23, 24** and **25** of FIG. **1**. FIG. **2** furthermore shows the metal cover **27** and the insulating intermediate piece **28**.

In a practical embodiment the apertures in the plates **3** and **18** have a diameter of **1** mm. The length of the apertures in the plate **3** is **5** mms and that of the apertures of the plate **18** is 0.5 mm. The apertures are filled with a mixture of saturated mercury vapour and argon at a pressure of 7 cms Hg. The wires of the first, second and third gratings have a thickness of 0.1 mm and are held in grooves of a depth of 0.1 mm and a width of **0.1** mm. The apertures in the plate **3** are coated with a reflective layer of titanium oxide, on which a phosphor layer of calcium halophosphate is provided. This material produces white light. In the operation of this display panel the wires of the first grating and the wires of the second grating have a potential difference of 350 V. This potential difference is not sufficient to ignite a positive column in the apertures of the plate **3**. If a potential difference of 300 V prevails between a given wire of the second grating and a given wire of the third

grating a glow discharge is produced in the aperture concerned in the plate **18** owing to the geometry of the aperture therein. Charge carriers then diffuse towards the corresponding aperture in the plate **3** and provide a reduction of the ignition voltage so that at said potential difference of 350 V a positive column is ignited in the aperture concerned of the plate **3.** The ultraviolet radiation produced therein causes the phosphor in said aperture to luminesce. The switching operation is performed in this case by controlling the potential difference between the wire of the second grating and those of the third grating.

FIG. **3** is a sectional view of another construction of the display panel. It comprises a glass plate **101,** a first grating of vertical wires, a wire **102** being shown in the Figure, a glass plate **103** having apertures **104, 105, 106, 107, 108, 109** and **110,** the walls of which are coated with a layer **111** of a phosphor, a second grating of horizontal wires **112, 113, 114, 115, 116, 117,** and **118,** a glass ring **119,** through which a supply wire **120** for an auxiliary anode **121** and a supply wire **122** for an auxiliary cathode **123** are taken, and furthermore a metal cover **124.** The wires of the first and second gratings are held in grooves in the plate **103.** The panel is filled up with a mixture of mercury and at least one rare gas. The ignition voltage of the positive column to be produced in one or more of the apertures in the plate **103** is reduced in this case by the plasma formed at a given potential difference between the auxiliary cathode **123** and the auxiliary anode **121.** The switching operation is performed by varying the potential difference between the wires of the first grating and those of the second grating.

FIG. **4** is a sectional view of a further structure. Apart from the device reducing the ignition voltage the parts are identical to those of FIG. **3** and designated by the same reference numerals. The panel comprises a glass ring **125,** through which a supply wire **126** for an auxiliary anode **127** and supply wires **128** for an auxiliary cathode **129** are passed and furthermore a metal cover **130.** The ignition voltage of the positive column to be produced in one or more of the apertures of the plate **103** is reduced by the plasma formed at a given potential difference between the auxiliary cathode **129** and the auxiliary anode **127.**

FIG. **5** is a sectional view of a further variant of the structure of a display panel. It comprises a glass plate **131,** a first grating of vertical wires, the wire **132** being shown in the Figure, a glass plate **133** having apertures **134, 135, 136, 137, 138, 139** and **140,** the walls of which are coated with a layer **141** of a phosphor, a second grating of vertical wires, the wire **142** being shown in the Figure, a glass plate **143** having apertures **144, 145, 146, 147, 148, 149** and **150,** registering with the apertures of the plate **133,** a third grating of horizontal wires **151, 152, 153, 154, 155, 156, 157** a glass ring **158,** through which a supply wire **159** for an auxiliary anode **160** and supply wires **161** for an auxiliary cathode **162** are taken, and furthermore a metal cover **163.** The wires of the first grating are held in grooves of the plate **133** and the wires of the second and third gratings are held in grooves of the plate **143.** The panel is filled up with a mixture of mercury and at least one rare gas. The ignition voltage of the positive column to be produced in one or more of the apertures in the plate **133** is reduced in this case by the plasma produced at a given potential difference between the auxiliary cathode **162** and the auxiliary anode **160.** The ignition voltage of the positive column is only reduced at those apertures in the plate **133** at which the potential difference from the associated apertures in the plate **143** is so high that charge carriers of the plasma can diffuse through the aperture in the plate **143** into the aperture of the plate **133.** The switching operation is performed in this case by varying the potential difference between the wires of the second grating and those of the third grating. The gas-discharge tubes in the plate **133** operates as a kind of valve.

What is claimed is:

1. A picture display device comprising a first transparent, insulating plate member having a first electrode system comprising a plurality of elongated electrodes embedded in one surface thereof, a second insulating plate member having a plurality of longitudinal apertures orthogonal to its end surfaces and arranged in rows and columns, one surface of said second member confronting the surface of said first member having said electrodes embedded therein, said longitudinal apertures corresponding with said electrodes and having their walls coated with a phosphor material capable of converting ultraviolet radiation into visible light, a third insulating plate member having a plurality of additional apertures communicating with said longitudinal apertures, a second electrode system comprising a plurality of elongated electrodes arranged between said second and third plate members and corresponding with said apertures, and a third electrode system arranged confronting the other surface of said third member, means for sealing said first, second and third members to form a sealed envelope, a mixture of mercury vapor and at least one rare gas for filling said apertures at such a pressure as to form within said sealed envelope a plurality of positive column discharges between said first and second electrodes systems when ignited, the length of said elongated apertures being at least twice the normal dimension thereof, whereby an ionization voltage applied between said second and third electrode systems reduces the ignition voltage required for said positive column discharges.

2. A picture display device comprising a first transparent, insulating plate member having a first electrode system comprising a plurality of elongated electrodes embedded in one surface thereof, a second insulating plate member having a plurality of longitudinal apertures orthogonal to its end surfaces and arranged in rows and columns, one surface of said second member confronting the surface of said first member having said electrodes embedded therein, said longitudinal apertures corresponding with said electrodes and having their walls coated with a phosphor material capable of converting ultraviolet radiation into visible light, a second electrode system comprising a plurality of elongated electrodes embedded in the other surface of said second member and corresponding with said apertures, and a third electrode system spaced apart from said second system, a sealing envelope enclosing said electrode systems, a gas mixture filling said envelope at such a pressure as to form positive column discharges within said apertures when ignited whereby an ionization voltage applied between said second and third electrode systems reduces the ignition voltage required for said positive column discharges.

3. A device as claimed in claim **2,** further comprising an additional electrode means located in the space between the envelope and said second electrode system.

4. A device as claimed in claim **3,** wherein said additional electrode means comprises a cathode and an auxiliary anode for producing a plasma therebetween.

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