

[54] **GASEOUS GLOW INDICATOR TUBE
FORMED ON A SUBSTRATE WITH A
PLURALITY OF INSULATING LAYERS**

[75] Inventors: Saburo Uemura, Yokohama;
Yuzuru Yanagisawa, Fujisawa,
both of Japan

[73] Assignee: Sony Corporation, Tokyo, Japan

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29/25.17, 25.18, 25.1, 25.13; 316/11, 12

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Primary Examiner—Charles W. Lanham

Assistant Examiner—J. W. Davie

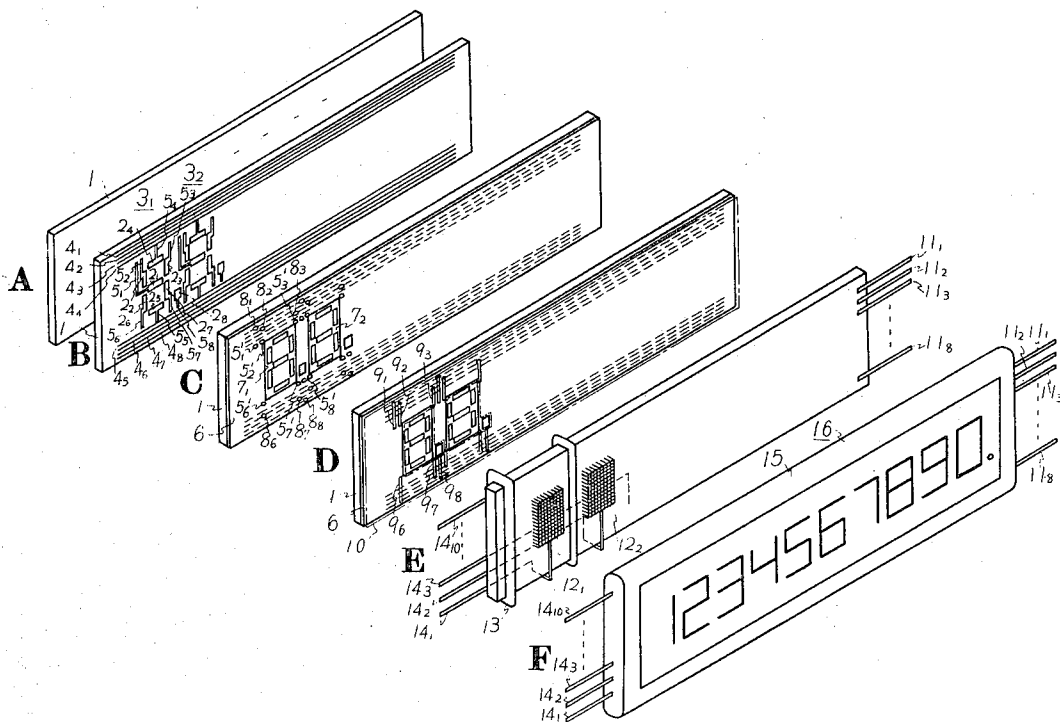
Attorney—Hill, Sherman, Meroni, Gross & Simpson

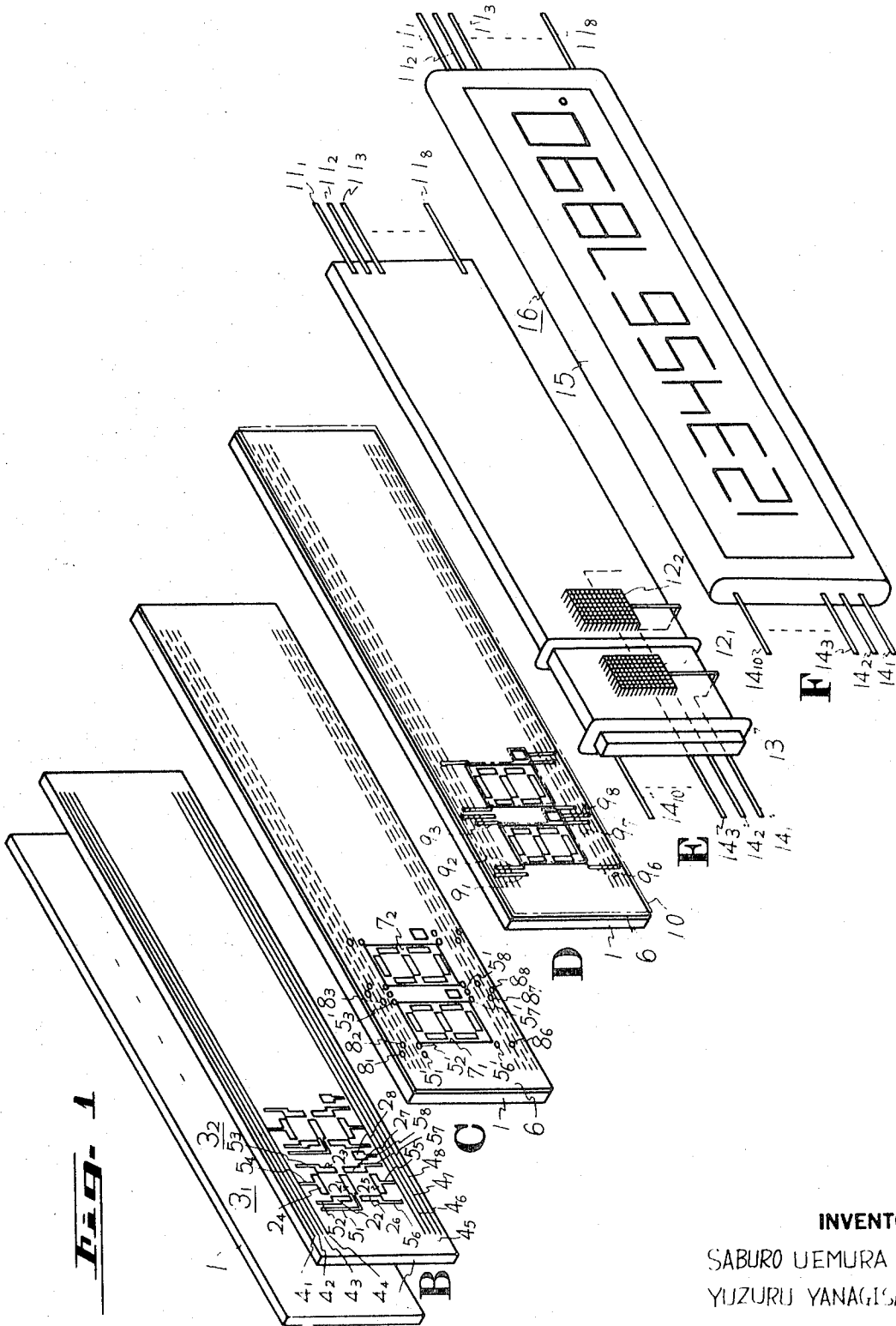
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ABSTRACT

A gaseous glow indicator tube including a method of manufacturing and aging in which the elements of the indicator electrodes are arranged in a single plane by plating conducting segments on a base insulating plate which also carries a plurality of element energizing electrodes. The various elements of the indicator elements are individually connected to the energizing electrodes. Anode electrodes are mounted adjacent the indicator electrodes and are connected to anode energizing leads so as to selectively energize various indications. A method for aging the gaseous glow indicator is also disclosed.

12 Claims, 3 Drawing Figures





INVENTORS

SABURO UEMURA

YUZURU YANAGISAWA

Hill, Sherman, Merone, Gross & Kimpson

ATTORNEY

Fig. 2

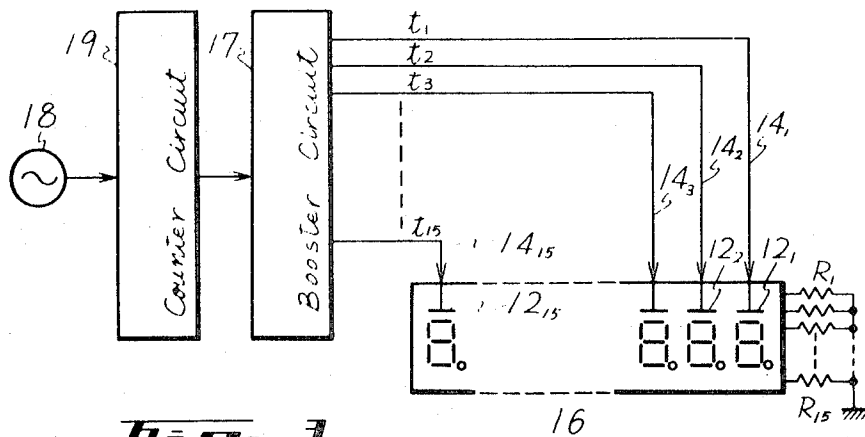
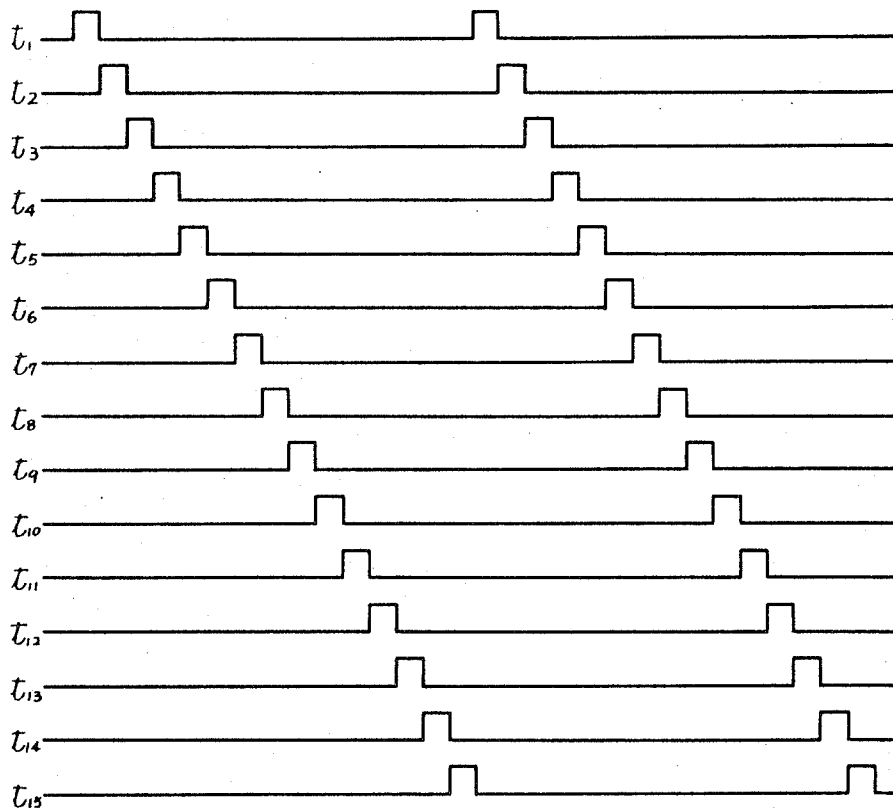


Fig. 3



INVENTORS

SABURO UEMURA

YUZURU YANAGISAWA

Hill, Sherman, Neroni, Gross & Simpson

ATTORNEY

GASEOUS GLOW INDICATOR TUBE FORMED ON A SUBSTRATE WITH A PLURALITY OF INSULATING LAYERS

CROSS-REFERENCE TO RELATED APPLICATIONS

This present application is a division of our pending application, Ser. No. 741,668, filed July 1, 1968 now U.S. Pat. No. 3,588,571.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates in general to gaseous glow indicator tubes and in particular to a novel gaseous glow indicator tube and method of manufacturing and aging such tube.

2. Description of the Prior Art

Gaseous glow indicator tubes which include a plurality of indicator cathode units mounted inside of a transparent envelope for providing displays of numerals, symbols, letters or the like, have been commercially available. For example, the so-called "Nixie Tube" is a tube which utilizes a transparent envelope that contains an anode electrode and a plurality of cathode glow indicator electrodes aligned in a stack one above the other. Such tubes require substantial thickness because the electrode indicator units are placed one above the other and a number of electrodes are used and are relatively expensive to manufacture. Such tubes are difficult to manufacture and are illegible unless the observer is directly in front of the indicator tube. This is because the gaseous glow indicator electrodes are numerous and are mounted in different planes.

SUMMARY OF THE INVENTION

The present invention relates to a gaseous glow indicator tube which has a plurality of indicator cathode units mounted inside of a transparent envelope with the indicator electrode units mounted in substantially the same plane. The indicator electrode units may be formed with thin film techniques and each electrode is connected to energizing leads by printed circuit or thin film conductors to obtain an efficient, inexpensive and compact unit. Mesh screen anode electrodes are attached over the indicator electrode units and are connected to energizing electrodes by thin film or printed circuit techniques.

The printed circuit indicator assembly is placed into a transparent envelope and sealed with a suitable ionizable gas such as neon with a small amount of mercury so as to cause the cathodes to glow upon the suitable energization of a cathode electrode and an anode electrode.

An aging apparatus and method is provided for rapidly aging a number of cathode elements by applying energizing signals on a time sequence basis which provides a higher than normal operating potential so as to rapidly age the indicators.

Other objects, features and advantages of the present invention will be readily apparent from the following detailed description of certain preferred embodiments thereof taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1A through 1F illustrate the method of fabri-

cating a glow indicator tube in accordance with this invention;

FIG. 2 illustrates a testing apparatus and method for testing a glow indicator tube according to this invention; and

FIG. 3 illustrates wave forms t_1 through t_{15} which are used in the apparatus of FIG. 2 to test a gaseous glow indicator tube according to this invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The invention relates to a glow indicator apparatus made with printed circuit techniques and results in a very thin unit. The number of weld and solder junctions are substantially reduced in the present structure and the symbols, letters or numerals appear very clear because the electrode segments which are caused to glow when energized are mounted in the same plane.

FIG. 1 illustrates a planar board 1 of insulating material upon which the individual indicator electrode units are to be attached by plating processes with suitable energizing leads. The particular unit being illustrated in FIGS. 1 comprises a 10-element indicator as illustrated in FIG. 1F. It is to be realized, of course, that any number of elements may be placed in the indicator device and they need not be placed in a horizontal line but may be mounted at any position as, for example, vertically or in a matrix.

Each of the numerals 1 through 0 illustrated in FIG. 1F may be constructed by using seven indicator elements with three of the indicator elements mounted horizontally and symmetrically on the indicator and with four of the indicator electrode elements mounted vertically on two opposite sides of the three elements.

By selectively energizing various of the indicator electrode elements, all of the numerals 1 through 0 may be produced. An additional period or decimal element is also mounted to each of the numeral electrode element groups to provide a period or decimal where desired. FIG. 1A illustrates a rectangular insulating base plate 1 which might be formed of aluminum oxide, for example, of a purity exceeding 92 percent. A plurality of indicator units 3₁ through 3₁₀ are formed on the base plate 1 by suitable thin film techniques, as for example, printing and baking. For example, molybdenum-manganese may be sintered in a hydrogen or ammonium gas atmosphere at about 1,000°C to produce a metalized plating. The sintered materials are then plated with nickel and subjected to diffusion of hydrogen gas at about 780°C. The nickel plating prevents oxidation of molybdenum-manganese by the hydrogen gas diffusion and eliminates the necessity of treatment in a non-oxidizing atmosphere in later manufacturing processes.

Each of the indicator units 3 comprises three horizontal electrode segments 2₁, at the center of the plate 1, 2₄ above segment 2₁ and 2₅ below the segment 2₁. On the left edge of these segments relative to FIG. 1B are formed the vertical segments 2₂ and 2₆. On the right edge of the horizontal segments are formed the vertical segments 2₃ and 2₇. A period or decimal segment 2₈ is formed adjacent the electrode 2₇. Conductive segments 5₁ through 5₈ are connected to each of the indicator electrode segments 2₁ through 2₈. Along the upper edge of the plate 1 are formed four energizing conductors 4₁ through 4₄ and along the lower edge are formed four more energizing electrodes 4₅ through 4₈. The strip 5₄

is connected to the conductor 4₄ and the strip 5₅ is connected to the conductor 4₅. After the conductors 4₁ through 4₈ and the electrodes and connector strips 2₁ through 2₈ and 5₁ through 5₈ are formed on the board, an insulating layer 6 is formed over the entire surface of the base plate 1 except on the indicator electrode segments 2₁ through 2₈ and openings 7₁ through 7₁₀ are left for each of the indicator units 3₁ through 3₁₀. In addition, small windows 8₁ to 8₃ and 8₆ to 8₈ are left. Also, small apertures 5₁' to 5₃' and 5₆' to 5₈' are formed at the free ends of the strip conductors 5. The apertures 8₁ to 8₃ and 8₆ to 8₈ and apertures 5₁' to 5₃' and 5₆' to 5₈' allow the electrode segments to be connected to the leads 4₁ through 4₃ and 4₆ through 4₈, respectively. The insulating layer 6 may be formed by the silk-screen process in the same manner as the electrode segments 2 and the leads 4 and strips 5 are formed. The insulating layer 6 may be formed, for example, of "glass frit No. 8190" manufactured by the Du Pont Corporation. The insulating layer 6 may be formed by coating the glass frit on the base plate 1 two or three times and then drying it in the air at 100°C for 10 to 15 minutes. The insulating layer is further heated in an oxidizing atmosphere of approximately 300°C for about 15 minutes to disperse a binder contained in the glass frit and thereafter is exposed to nitrogen gas at about 850°C for about 10 minutes in a quartz glass furnace to bake the glass frit.

The connecting leads 9₁ to 9₃ and 9₆ to 9₈ are then formed over the insulating layer 6 between the small apertures 5₁' and 8₁, between 5₂' and 8₂, between 5₃' and 8₃, between 5₆' and 8₆, between 5₇' and 8₇, and between 5₈' and 8₈, as shown in FIG. 1D. These connecting leads may be formed by silk-screen printing techniques as, for example, by using a mixture of silver and palladium powder with glass frit. After the printing of the leads 9, the printed mixture is dried in the air at 100°C to 225°C for approximately 10 to 15 minutes and is then heated in an oxidizing atmosphere of 300°C or so for about 15 minutes to disperse a binder in the mixture. It is then exposed to nitrogen gas for about 10 minutes in a quartz glass furnace maintained at 760° to effect baking of the printed mixture.

The second insulating layer 10 is formed over the insulating layer 6 to cover the connecting leads 9, but the windows 7₁ to 7₁₀ are again left open. The insulating layer 10 is formed in the same manner as the layer 6 by fusing the glass frit over the layer 6, after which the unit is held at 100°C to 120°C in the air for 10 to 15 minutes before placing it in an oxidizing atmosphere at about 360°C for about 15 minutes to disperse the binder in the glass frit. Nitrogen gas is then passed over the unit in a quartz glass furnace at about 850°C for 10 minutes to bake the insulating layer 10. The electrode segments 2₁ through 2₈ may be plated with nickel before the formation of the insulating layer 10 or they may be coated with a nickel layer after the formation of the insulating layer 10. The nickel layer may be formed by electrolytic or non-electrolytic plating, and it is desirable that the electrode segments 2 be covered with a nickel layer thick enough to act as cathodes and that the nickel be of a purity in excess of 99.9 percent.

After the formation of the insulating layer 10, external leads 11₁ to 11₈ are connected to the segment selecting leads 4₁ to 4₈. The leads 11₁ to 11₈ are welded into one end of the base plate 1 at the positions corresponding to the ends of leads 4₁ to 4₈ so that they make electrical contact therewith.

Mesh screen anode electrodes 12₁ to 12₁₀ are attached to the base plate 1 over each of the individual display units 3₁ through 3₁₀ and are connected to external leads 14₁ to 14₁₀ which extend through the base plate 1. Insulating partition walls or supports 13 are spaced on either side of each of the indicator units 3 and may be constructed, for example, of mica or other similar insulating material. An insulating layer of glass frit or other similar material may be formed on the back of the base plate 1 in the manner as previously described.

The completed electrode assembly is placed into a transparent envelope, for example, a glass tube 15, as shown in FIG. 1F. The envelope 15 is filled with an ionizable gas such as neon and a small quantity of mercury and sealed. By applying a voltage potential to a particular external lead 14₁ to 14₁₀ of an anode electrode and to different external leads 11₁ to 11₈ which supply electrical potential to the segments 2₁ through 2₈, various segments may be caused to glow.

To assure that the indicator electrodes 2₁ through 2₈ produce uniform glow over their entire length, it is desirable to age or activate the electrodes.

FIG. 2 illustrates apparatus to accomplish this. The device illustrated allows current to be sequentially applied between anode electrodes and each of the indicator electrodes of each display unit to repeat the discharge of current between them on a time-divisional basis.

In the case of a gaseous glow indicator tube 16, which has, for example, 15 display units, the electrode segment selecting leads are connected together through resistors R₁ through R₁₅ with the other side of each resistor connected to ground. The anode electrodes 12₁ to 12₁₅ are connected to a booster circuit 17 which receives an input from an oscillator 18. A counter circuit 19 is connected between the oscillator 18 and the booster circuit 17 to distribute the output of the oscillator to the various leads 14₁ through 14₁₅ to respectively energize the anode screens 12₁ through 12₁₅. The counter circuit 19 distributes the output pulses of the oscillator 18 to the leads 14₁ to 14₁₅ so that each of the indicator units are sequentially turned on. For example, a wave-shape t_1 , illustrated in FIG. 3, is supplied to lead 14₁ to energize the anode electrode 12₁, and wave-shape t_2 which is slightly delayed from the wave-shape t_1 is supplied to the lead 14₂, etc. The pulses in FIG. 3 might, for example, be 100 microseconds in width and 1.5 milliseconds apart. Thus, it is seen that the drive is on a time divisional basis.

It is seen that this invention employs printing circuit techniques for the manufacture of display discharge indicators and substantially reduces the amount of welding required. For example, in the conventional Nixie Tube, 516 welding points are required for connecting the electrodes of the indicator. In the present invention, as indicator tube produced according to this invention requires only 30 points of welding or substantially less than 10 percent as many as required in the Nixie Tube. The insulating layers 6 and 10 are formed by heating the base plate 1 coated with the glass frit at 300°C in an oxidizing atmosphere to disperse the binder contained in the glass frit and by heating the base plate 1 at a temperature from 700°C to 800°C in an inert gas atmosphere to fuse the glass. This enables formation of the glass layers which form the insulating

layers without oxidizing the metal of the electrodes or leads.

The base plate coated with glass frit may also be heated in a forming gas atmosphere to reduce lead contained in the glass to provide black insulating layers which enhances the contrast in color between the discharge glow of the electrodes and the insulating layers and allows easier interpretation of a number or symbol being displayed.

The aging apparatus illustrated in FIG. 2 allows units having 15 display units to be properly aged in about 15 minutes. Where each individual display unit is aged in a sequential fashion, a minimum time of about 5 minutes for each unit is required or a total of 75 minutes for 15 units. The unit of FIG. 2 allows 15 units to be aged in about 15 minutes for a saving of 60 minutes.

Although in the process described above, the connecting leads 9₁ to 9₃ and 9₆ to 9₈ were formed after the insulating layer 6, it is to be realized that the selecting leads 4₁ to 4₈ and the various strip conductors may be formed in various sequences to obtain the same result.

The insulating base plate 1 may be formed of glass, steatite or the like, if desired, rather than aluminum. When the base plate 1 is formed of ceramic, it is possible that the base plate may be blackened by mixing an oxide with the ceramic in the ratio of about 10 percent relative to the ceramic to provide an indicator tube of good contrast. It is also to be realized that the electrodes may be formed on convex or concave portions of the base plate which are aligned with the indicator units. This increases the distance between adjacent electrode segments and avoids undesirable discharge between adjacent electrode segments. This also reduces the possibility of short circuits between the electrodes due to sputtering caused by discharge and thus lengthens the life of the indicator tube.

The electrode segments may be formed of usual conductive materials other than molybdenum-manganese. For example, silver-palladium film, palladium film or gold-platinum film may be used. A silver-palladium film results in very stable connections.

When using silver-palladium film, it is coated on the base plate by printing techniques, dried in the air at a temperature of 100°C to 120°C for 10 to 15 minutes and is then heated in an electric furnace at about 750°C for 45 minutes or so, thus hardening the film to provide the electrode segments.

Although the present invention has been described in connection with an indicator with individual units mounted in a row, it is to be realized that other arrangements of the indicator units may be made, such as in columns or in a matrix. Also, it is to be realized that a plurality of indicator units may be mounted in a single envelope.

Although minor modifications might be suggested by those versed in the art, it should be understood that we wish to embody within the scope of the patent warranted hereon all such modifications as reasonably and properly come within the scope of our contribution to the art.

We claim as our invention:

1. The method of making a gaseous glow indicator tube comprising the steps of:
forming a plurality of indicator electrode units each having a plurality of segments with strip conductors on a planar surface of an insulating base plate,

forming indicator electrode selecting leads on the base plate;

depositing an insulating layer on the insulating base plate except over the indicator electrode segments and the areas where the indicator electrode selecting leads and the strip conductors are to be connected together, forming leads on the insulating layer to connect the indicator electrode selecting leads with the strip conductors such that the associated segments of each indicator unit are connected to the same indicator electrode selecting lead; and depositing a second insulating layer on the base plate which leaves the indicator electrode segments uncoated.

2. A method of making a plurality of indicator units for a gaseous glow indicator tube comprising the steps of:

forming a plurality of indicator electrode units each having a plurality of segments formed in the same pattern, on a planar surface of an insulating plate; forming a first indicator electrode selecting lead on said insulating plate on said planar surface along one longitudinal edge and which is connected to similar first segments of each of said plurality of indicator units;

forming a second indicator electrode selecting lead on said insulating plate on said planar surface along the other longitudinal edge and which is connected to certain other similar second segments of each of said plurality of indicator units;

depositing an insulating layer by silkscreen process on said insulating plate so as to cover said first and second indicator electrode selecting leads, but not covering said segments; and

forming external leads on said insulating plate which are connected to said first and second indicator electrode selecting leads.

3. The method of claim 2 comprising forming a first plurality of indicator electrode selecting leads along said one longitudinal edge of said plurality of indicator electrode units and thereafter, through and over said insulating layer, means connecting said first plurality of indicator electrode selecting leads to other associated similar ones of segments of the predetermined pattern of said plurality of indicator units.

4. The method of claim 3 comprising mounting a plurality of anode electrodes adjacent each of said plurality of indicator units, and connecting external anode leads to said anode electrodes.

5. The method of claim 4 comprising aging said plurality of indicator electrode units by repeatedly applying an energizing voltage between said anode electrodes and said segments of said plurality of indicator units.

6. The method of claim 5 wherein said first and second indicator electrode selecting leads and said first and second plurality of indicator electrode selecting leads are connected together through a plurality of impedances which have a common ground and said energizing voltage has one side grounded.

7. The method of claim 5 wherein said energizing voltage is sequentially applied to said anode electrodes of said plurality of indicator units.

8. The method of claim 7 wherein said energizing voltage is applied to each of said plurality of indicator units in pulses between 50 and 200 microseconds in width.

9. The method of claim 8 wherein said pulses are spaced between 1 and 2 milliseconds apart.

10. The method of claim 3 comprising forming a second plurality of indicator electrode selecting leads along said other longitudinal edge of said plurality of said indicator units and thereafter, through and over said insulating layer, means connecting said second plurality of indicator electrode selecting leads to other associated similar ones of segments of the predetermined pattern of said plurality of indicator units.

11. The method of claim 10 comprising forming a second insulating layer on said insulating plate so as to cover said first and second plurality of indicator electrode selecting leads.

12. A method of making a plurality of indicator units for a gaseous glow indicator tube comprising the steps of:

forming a plurality of indicator electrode units having

a plurality of segments arranged in the same pattern on a planar surface of an insulating plate;

forming a first indicator electrode selecting lead on said insulating plate on said planar surface along one longitudinal edge and which is connected to similar first segments of each of said plurality of indicator units;

forming a second indicator electrode selecting lead on said insulating plate on said planar surface along the other longitudinal edge and which is connected to certain other similar second segments of each of said plurality of indicator units; and

aging said plurality of indicator electrode units by repeatedly applying voltage to them through said first and second indicator selecting leads in a time-divisional manner.

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