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

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Related U.S. Application Data

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[52] **U.S. Cl.** **313/109.5,** 315/169, 313/108

[51] **Int. Cl.**.....**H01j 61/66**

[58] **Field of Search** .....313/108, 108 A, 108 B, 313/109.5; 315/169

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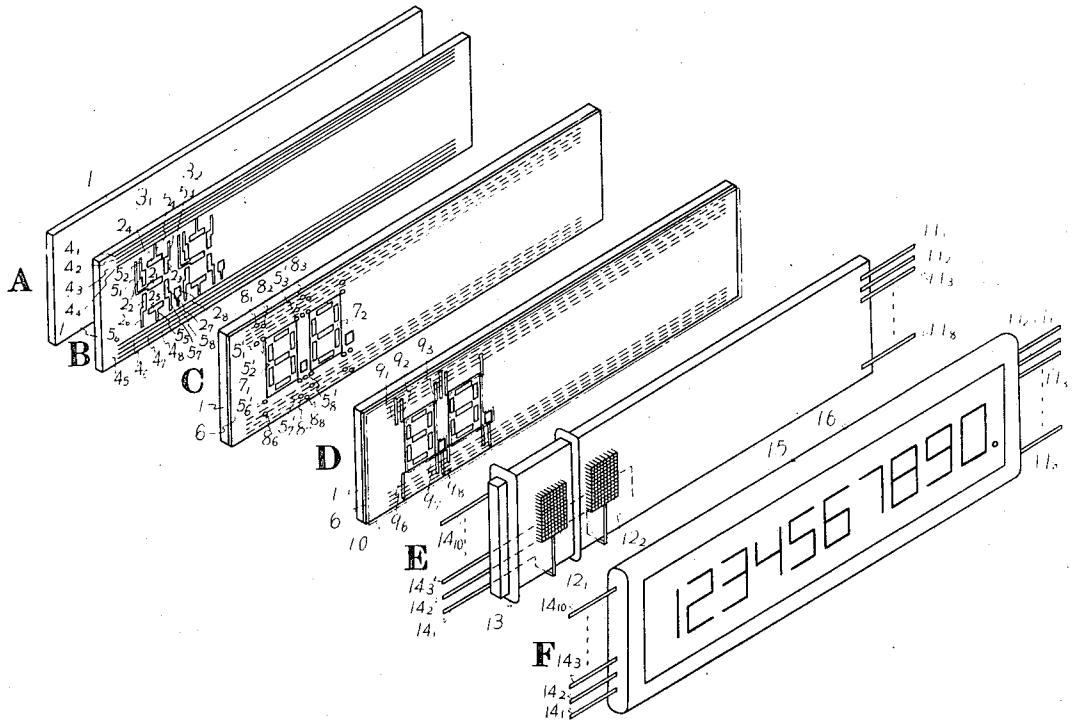
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[57] **ABSTRACT**

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.

9 Claims, 3 Drawing Figures



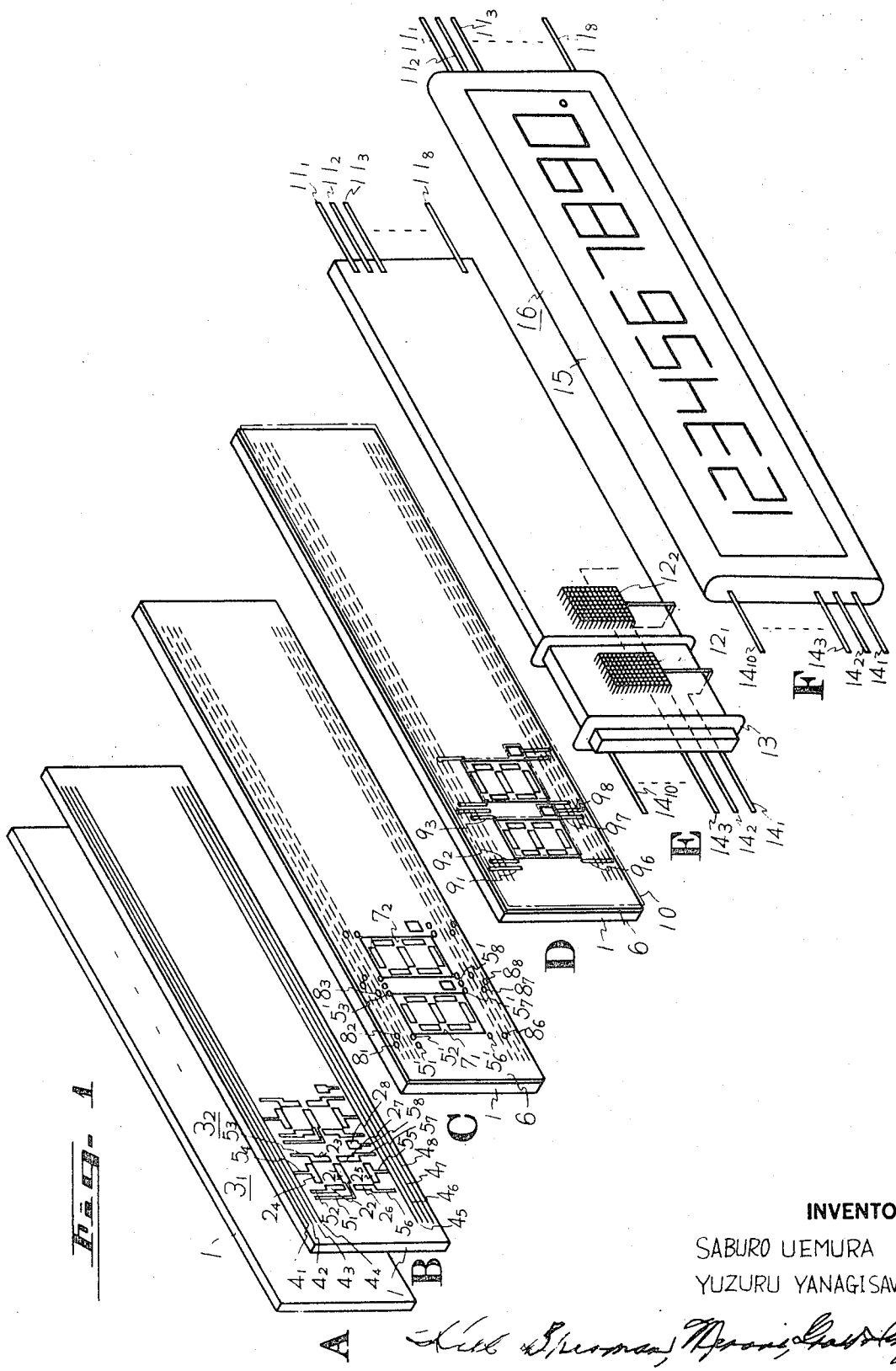


Fig. 1

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Fig. 2

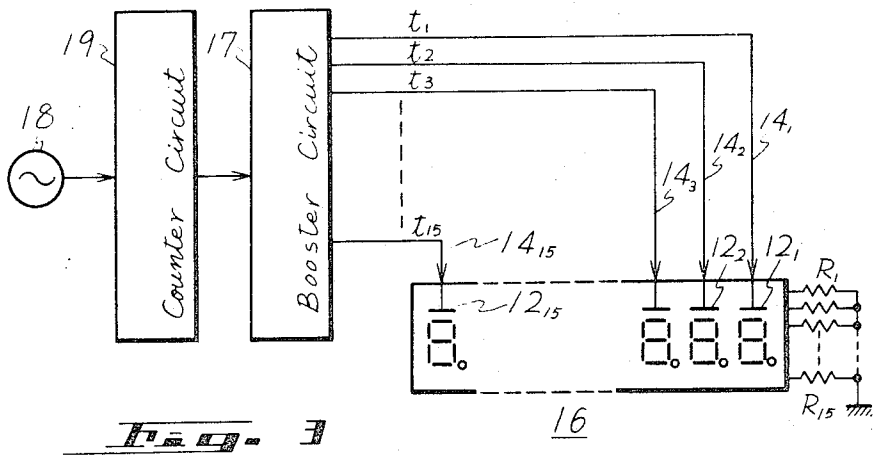
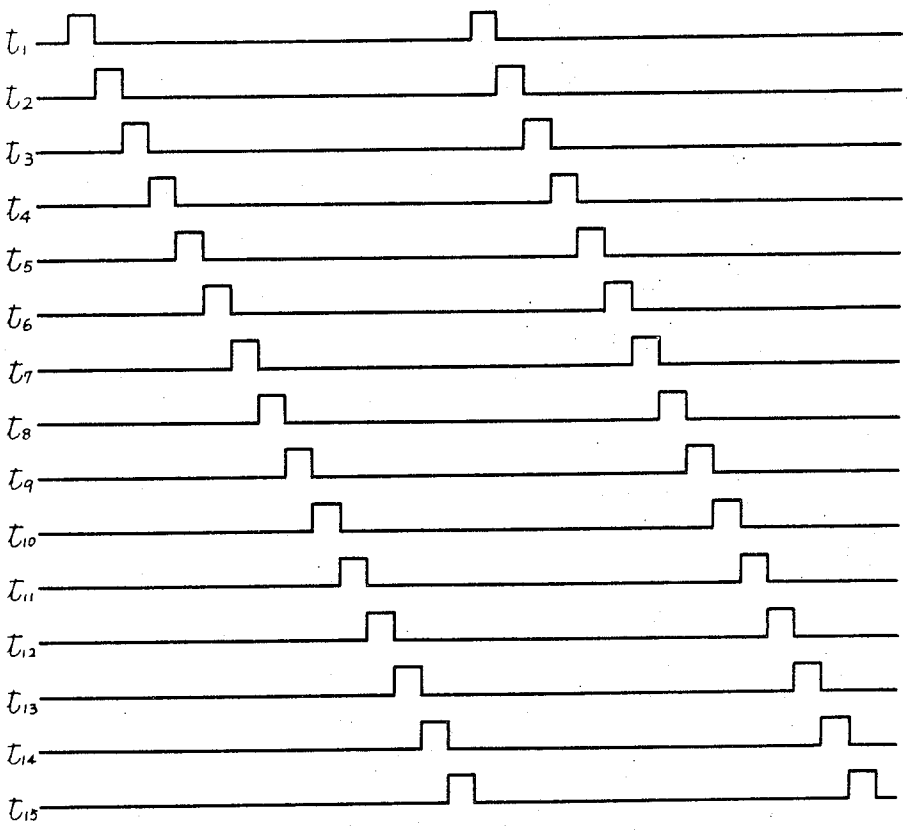


Fig. 3



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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. This application is also related to our pending application, filed Mar. 19, 1971, Ser. No. 128,888 which is a division of Ser. No. 741,668.

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

FIG. 1 (A through F) illustrate the method of fabricating 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 3_1 through 3_{10} 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 2_1, at the center of the plate 1, 2_4 above segment 2_1 and 2_5 below the segment 2_1. On the left edge of these segments relative to FIG. 1B are formed the vertical segments 2_2 and 2_6. On the right edge of the horizontal segments are formed the vertical segments 2_3 and 2_7. A period or decimal segment 2_8 is formed adjacent the electrode 2_7. Conductive segments 5_1 through 5_8 are connected to each of

the indicator electrode segments 2_1 through 2_8. Along the upper edge of the plate **1** are formed four energizing conductors 4_1 through 4_4 and along the lower edge are formed four more energizing electrodes 4_5 through 4_8. The strip 5_4 is connected to the conductor 4_4 and the strip 5_5 is connected to the conductor 4_5. After the conductors 4_1 through 4_8 and the electrodes and connector strips 2_1 through 2_8 and 5_1 through 5_8 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 2_1 through 2_8 and openings 7_1 through 7_{10} are left for each of the indicator units 3_1 through 3_{10}. In addition, small windows 8_1 to 8_3 and 8_6 to 8_8 are left. Also, small apertures $5_1'$ to $5_3'$ and $5_6'$ to $5_8'$ are formed at the free ends of the strip conductors **5**. The apertures 8_1 to 8_3 and 8_6 to 8_8 and apertures $5_1'$ to $5_3'$ and $5_6'$ to $5_8'$ allow the electrode segments to be connected to the leads 4_1 through 4_3 and 4_6 through 4_8, 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 9_1 to 9_3 and 9_6 to 9_8 are then formed over the insulating layer **6** between the small apertures $5_1'$ and 8_1, between $5_2'$ and 8_2, between $5_3'$ and 8_3, between $5_6'$ and 8_6, between $5_7'$ and 8_7, and between $5_8'$ and 8_8, 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° 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 7_1 to 7_{10} 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° to 120° C in the air for 10 to 15 minutes before 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 furnace at about 850° C for 10 minutes to bake the insulating layer **10**. The electrode segments 2_1 through 2_8 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 11_1 to 11_8 are connected to the segment selecting leads 4_1 to 4_8. The leads 11_1 to 11_8 are welded into one end of the base plate **1** at the positions corresponding to the ends of leads 4_1 to 4_8 so that they make electrical contact therewith.

Mesh screen anode electrodes 12_1 to 12_{10} are attached to the base plate **1** over each of the individual display units 3_1 through 3_{10} and are connected to external leads 14_1 to 14_{10} 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 14_1 to 14_{10} of an anode electrode and to different external leads 11_1 to 11_8 which supply electrical potential to the segments 2_1 through 2_8, various segments may be caused to glow.

To assure that the indicator electrodes 2_1 through 2_8 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 R_1 through R_{15} with the other side of each resistor connected to ground. The anode electrodes 12_1 to 12_{15} 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 14_1 through 14_{15} to respectively energize the anode screens 12_1 through 12_{15}. The counter circuit **19** distributes the output pulses of the oscillator **18** to the leads 14_1 to 14_{15} 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 14_1 to energize the anode electrode 12_1, and wave-shape t_2 which is slightly delayed from the wave-shape t_1 is supplied to the lead 14_2, etc. The pulses in FIG. **3** might, for example, be 100 microseconds in width and 1.5 milliseconds apart.

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, an 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° 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 9_1 to 9_3 and 9_6 to 9_8 were formed after the insulating layer 6, it is to be realized that the selecting leads 4_1 to 4_8 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° 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.

What we claim is:

1. A gaseous glow indicator tube comprising:
a planar layer of insulating material;
a plurality of indicating units having a plurality of segmented electrodes formed on said insulating layer and arranged in line in a longitudinal direction thereof;
a plurality of selecting leads corresponding to the number of segments in each indicating units formed on said insulating layer and said plurality of selecting leads extending longitudinally of said insulating layer adjacent said indicating units;
a plurality of interconnecting leads corresponding to the number of segments in all indicating units connecting the corresponding segments of said indicating units to respective ones of said selecting leads;
a transparent cover sealed to form an envelope enclosing at least said plurality of indicating units; and
an ionizing gas in said sealed envelope.

2. A gaseous glow indicator tube according to claim 1 wherein said plurality of selecting leads are divided into two portions with said indicating units therebetween.

3. A gaseous glow indicator tube according to claim 2 wherein certain of said interconnecting leads insulatingly pass over certain of said selecting leads.

4. A gaseous glow indicator tube comprising:
a planar layer of insulating material;
a plurality of indicating units having a plurality of segmented electrode patterns formed on said insulating layer and said indicating units arranged in line in a first direction;
a plurality of selecting leads corresponding to the number segments in each of said indicating units formed on said planar layer and extending in said first direction;
a plurality of interconnecting leads corresponding to the number of segments and connecting corresponding segments of said indicating units together and to respective ones of said selecting leads;
a transparent cover attached to said planar layer to form a sealed envelope enclosing said indicating units; and
an ionizing gas in said sealed envelope.

5. A gaseous glow indicator tube according to claim 4 wherein said plurality of selecting leads are divided into two portions with said indicating units therebetween.

6. A gaseous glow indicator tube according to claim 5 wherein certain of said interconnecting leads insulatingly cross over certain of said selecting leads.

7. A gaseous glow indicator tube comprising:
a planar layer of insulating material;
a plurality of indicating units having a plurality of segmented cathode electrode patterns provided on said insulating layer and said indicating units arranged in line in a first direction;
a plurality of cathode selecting leads corresponding to the number of segments and connecting corresponding segments of said indicating units together and to respective ones of said cathode selecting leads;
a plurality of mesh anode electrodes corresponding to the number of indicating units and spacing away from the corresponding cathode electrodes;

a transparent cover attached to said planar layer to form a sealed envelope enclosing said indicating units; and

an ionizing gas in said sealed envelope.

8. A gaseous glow indicator tube according to claim 7 wherein said plurality of cathode selecting leads are divided into two portions with said indicating units therebetween.

9. A gaseous glow indicator tube according to claim 8 wherein said interconnecting leads insulatingly pass over certain of said cathode selecting leads.

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