

Aug. 1, 1944.

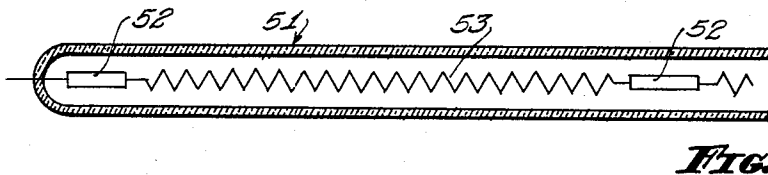
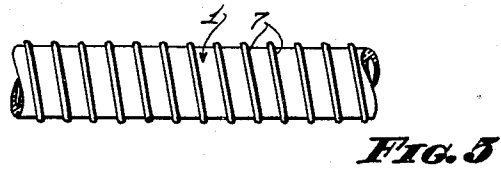
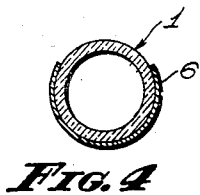
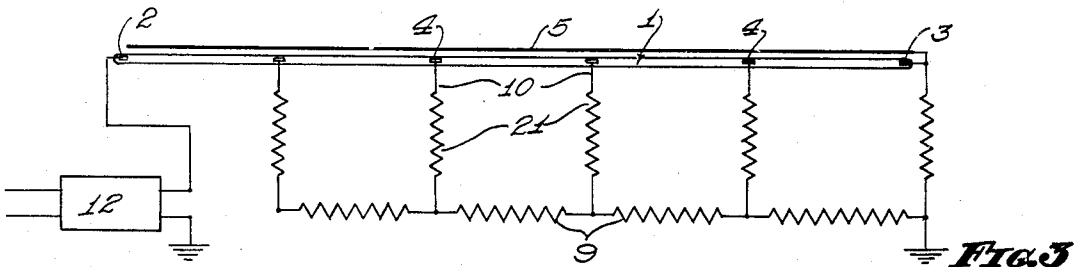
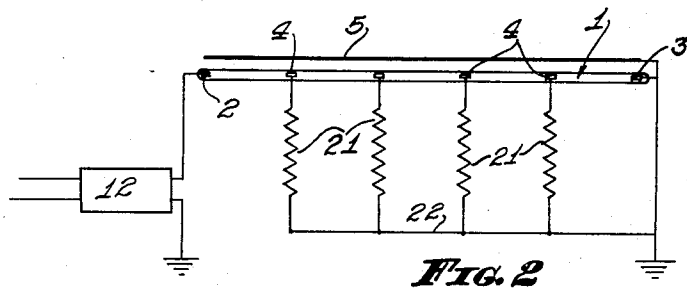
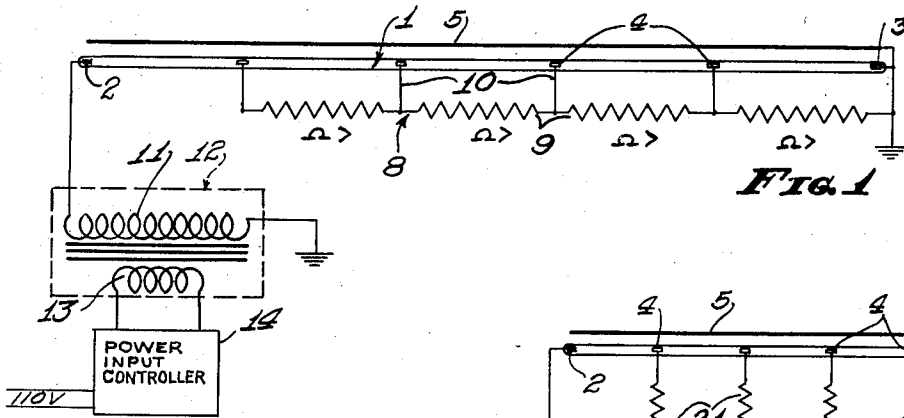
H. C. METTLER

2,354,696

LOW FREQUENCY MOBILE GLOW DISCHARGE SYSTEM

Filed Nov. 12, 1940

2 Sheets-Sheet 1



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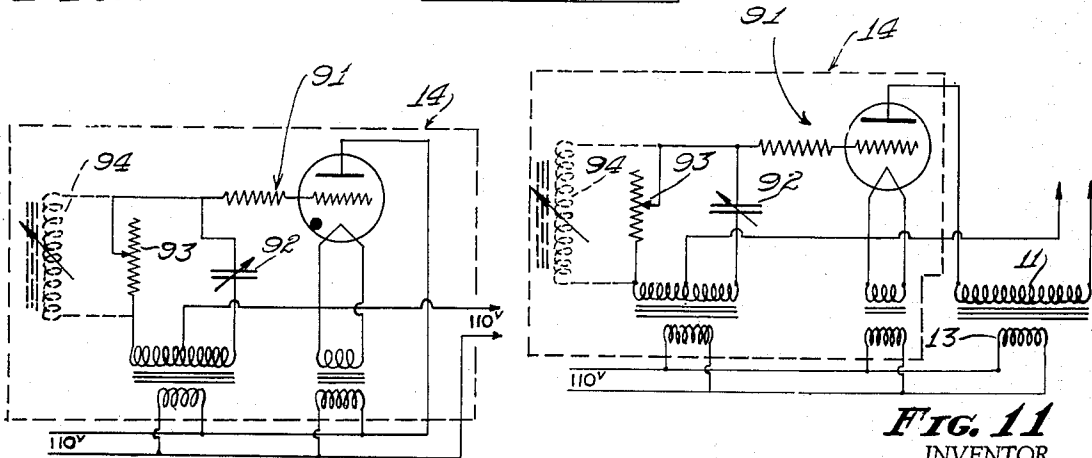
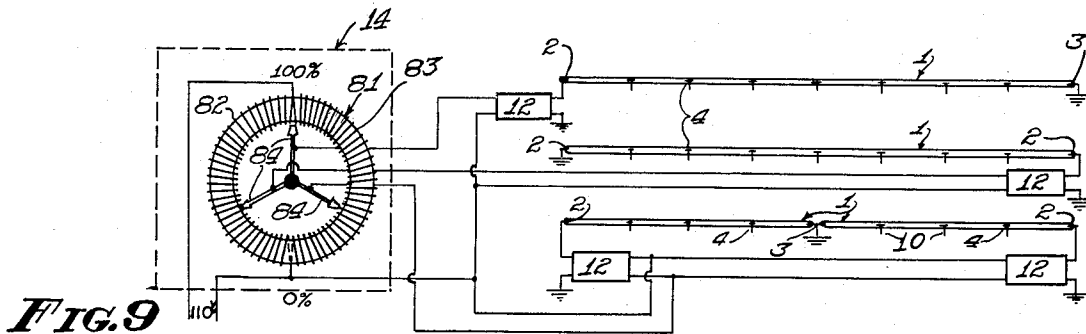
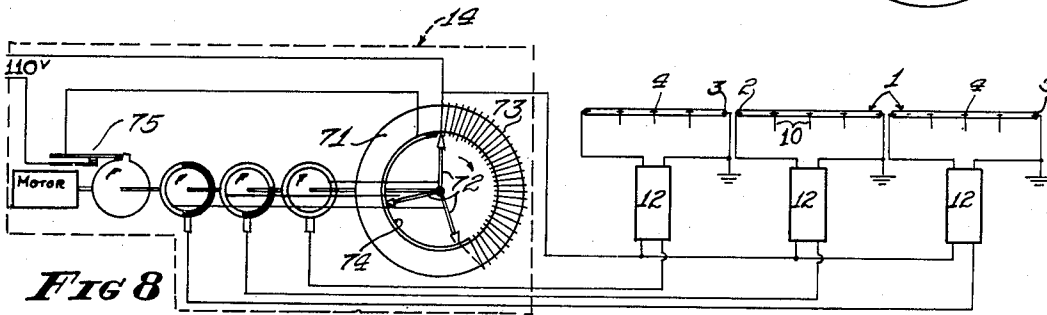
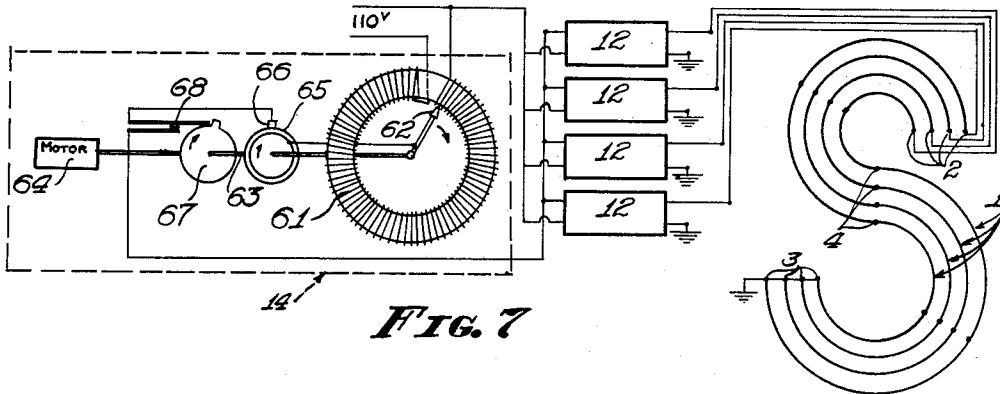
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LOW FREQUENCY MOBILE GLOW DISCHARGE SYSTEM

Filed Nov. 12, 1940

2 Sheets-Sheet 2



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2,354,696

LOW FREQUENCY MOBILE GLOW
DISCHARGE SYSTEMHal C. Mettler, Los Angeles, Calif., assignor of
one-half to Lloyd Spencer, Los Angeles, Calif.

Application November 12, 1940, Serial No. 365,206

20. Claims. (Cl. 315—187)

My invention relates to low frequency mobile glow discharge systems; that is, to glow discharge systems incorporating so-called "neon" tubing for the purpose of producing a progressive movement of light through a sign or display so as to give the effect of writing.

Among the objects of my invention are:

First, to provide a mobile glow discharge system which produces in a length of glow discharge or "neon" tubing, when operated by commercial alternating current, such as sixty cycle current, a progressive illumination or writing effect, similar to that accomplished by the use of audio or radio frequency current, such as disclosed in the Kayser Patent No. 1,939,903;

Second, to provide a mobile glow discharge system which may be operated through a conventional "neon" transformer, controlling or varying the voltage output from such transformer to effect a progressive movement of light through the "neon" or glow discharge tubing;

Third, to provide a mobile glow discharge system which incorporates substantially conventional glow discharge tubing whether containing "neon" or other gases, or mercury, and whether plain or coated with fluorescent material;

Fourth, to provide a mobile glow discharge system employing a series of relatively short glow discharge tubes, or longer tubes having intermediate electrodes, the sections being caused to glow in sequence without commutating or otherwise making and breaking high voltage connections between the tubing sections and the high voltage side of the transformer which supplies power to the tubing, the progressive or mobile control of illumination in the tubing sections being entirely controlled in the primary of the transformer or other low voltage circuit.

Fifth, to provide a mobile glow discharge system which is particularly easy to install and service, and which is inherently designed to operate without attention for long periods of time under adverse conditions.

Sixth, to provide a mobile glow discharge system wherein a single glow discharge control unit is inherently capable of controlling a materially greater footage of tubing than has heretofore been possible with high frequency mobile glow discharge controllers;

Seventh, to provide a mobile glow discharge system which does not in any manner increase bombardment of or current load on the electrodes of the glow discharge tubing beyond that imposed by a conventional "neon" transformer; furthermore the excessive current load inherent in high frequency mobile glow discharge systems, particularly on the input electrode at which the progressive animation starts, is entirely eliminated; and,

Eighth, to provide a mobile glow discharge sys-

tem whereby not only a writing or progressive illumination effect may be obtained, but all manner of mobile effects may be obtained, all without necessitating change in the transformer or its voltage control means, thus providing a mobile glow discharge system which is particularly flexible.

With the above and other objects in view as may appear hereinafter, reference is directed to the accompanying drawings in which:

Figure 1 is a wiring diagram illustrating one form of my low frequency mobile glow discharge system;

Figure 2 is a wiring diagram illustrating another form thereof;

Figure 3 is another wiring diagram illustrating a combination of the circuits shown in Figures 1 and 2;

Figure 4 is a typical cross-sectional view of a "neon" tubing having a metallic coating thereon as employed in the exercise of my invention to produce a capacity effect;

Figure 5 illustrates a fragmentary length of "neon" tubing having a wrapping of wire thereabout for purposes similar to Figure 6; and

Figure 6 is a fragmentary sectional view of a "neon" tube illustrating a further modified construction wherein the resistance network is disposed within the "neon" tube.

Figure 7 is a wiring diagram of an arrangement of my invention wherein a moving brush transformer controls a plurality of tubing sections simultaneously;

Figure 8 is a wiring diagram of a modified form of moving brush transformer which controls a plurality of tubing sections in sequence;

Figure 9 is a wiring diagram of another modified form of moving brush transformer in which the illumination in a plurality of tubing sections is caused to progress and recede in time displaced relation;

Figure 10 is a wiring diagram of a "Thyratron" control circuit controlling the primary side of a neon tubing transformer; and,

Figure 11 is a wiring diagram similar to Fig. 10 in which the "Thyratron" control is located in the secondary circuit of the neon tubing transformer.

Glow discharge tubing embraces what is popularly termed "neon" tubing such as used in signs or displays. Actually such tubing may contain any one of several of the rare gases, mercury vapor or mixtures, and may be internally coated with fluorescent material. Glow discharge tubing is caused to ionize by application of high voltage and, under normal conditions, breaks down or ionizes instantly throughout its length without hint of progressive illumination.

When radio frequency is applied to such tubing, the glow discharge will not necessarily extend

from end to end, but may ionize at only one end of the tubing. The extent of ionization will depend upon the amount of power applied; thus, as disclosed in the above mentioned Kayser patent, a writing effect may be obtained by applying radio frequency current and varying the power. This phenomenon is not peculiar to radio frequency, but may be produced with audio frequency. The controlling factor is the amount of distributed capacity along the tubing. That is, at radio frequency, there is sufficient capacity between the glow discharge column and the surrounding air to cause sufficient leakage or radiation to ground or the return side of the circuit to produce the desired writing effect. As the frequency is lowered, the distributed capacity must be increased in order to produce a similar effect. This is accomplished by bringing the tubing into close proximity to a metal backing, by wrapping with wire, or by partially coating with metal the tubing itself.

In any event, the leakage along the tubing to the return side of the circuit causes a gradation in brilliancy of illumination from the input electrode to the end of the ionized column. If the frequency-capacity relationship is proper the noticeable attenuation is quite short so that there is a definite demarcation between the ionized and un-ionized parts of the tube.

However, if the frequency is too low for a given distributed capacity, the attenuation becomes so great that the writing or progressive effect becomes inconspicuous and the desired effect is lost. Of the means for increasing distributed capacity, coating of the tubing is the greatest; however, a satisfactory frequency metal coated tubing is still materially higher than commercial alternating current frequency, in other words, several hundred cycles as distinguished from fifty or sixty cycles.

Applicant has found however, that by providing a resistance network paralleling the glow discharge column, the network being electrically connected at spaced points therewith, and in addition to the capacity relation between the glow discharge column and the return side of the circuit, a very satisfactory progressive or mobile illumination may be effected, at commercial frequencies.

More specifically, reference is directed to Figure 1. A length of neon tubing 1 is provided with input and ground electrodes 2 and 3, respectively, and intermediate electrodes 4. Or, these electrodes may be termed an anode 2, main cathode 3, and auxiliary cathodes 4. All are preferably the "cold" type used in standard "neon" tubing. The tubing may be a single piece or divided into independent tubing sections connected in series, in the latter case several or all of the intermediate electrodes may be the series connected, end electrodes of the different tubing sections.

The neon tubing 1 is provided throughout its length with a grounded distributed capacitance or external cathode 5, which may constitute a metallic coating 6 as shown in Fig. 4 or a wire wrapping 7 as shown in Fig. 5, or other suitable means to provide a high capacity between the glow discharge column within the tubing and the return side of the circuit. If several tubing sections are used, the coating for each section is grounded without contact with the terminals of the tubing section. The end or ground electrode 3, however, being grounded may be connected with the capacitance 5.

An electrical path 8 parallel to the glow dis-

charge column within the neon tubing is provided between the first intermediate electrode 4 and the ground electrode 3. Interposed therein and in series with each other are a plurality of resistors 9. Leads 10 from the several intermediate electrodes 4 are connected to the path 8 between the resistors.

The input electrode 2 is connected to the high voltage end of a secondary coil 11 of a neon transformer 12, the other end thereof being grounded. The primary 13 of said neon transformer is connected with a source of power through a suitable power controller 14.

A conventional neon transformer is so constructed that it passes only a predetermined current when the secondary is shorted. The open circuit potential between the ends of the secondary of a neon transformer ranges from 4,000 to 15,000 volts depending upon the length of tubing it is intended to handle. The short-circuit current is limited, and ranges from 12 to 120 milliamperes depending upon the intensity desired in the neon tubing. Current limitation is accomplished in the standard type of neon transformer by a magnetic shunt in the iron core. It is essential that the current be limited as the neon tube has a comparatively low resistance when ionized and, unless the current is limited the electrodes will burn up. Thus, essentially, a neon transformer is a high potential, limited current transformer.

The character or manner of progressive or mobile illumination in the neon tubing 1 is dependent on the values selected for the different resistors. To produce a substantially uniform progression of illumination from the input electrode 2 to the ground electrode 3 of the neon tubing, the resistors decrease in resistance from said input electrode to the ground electrode. For example, a unit comprising ten neon tube sections operated very satisfactory on a 7,000 volt neon transformer when the resistors had the following values: 5, 1.5, 1, .6, .4, .3, .25, .2, .15 megohm and the distance between electrodes was approximately three feet but may be more. While, except for the first resistor or two, the values decline roughly at the rate of two-thirds the preceding resistor, a rather wide latitude is permissible. The tubing lengths and therefore the electrode spacing is of course, a factor determining the relative values of the resistors.

Before the glow discharge column ionizes, its resistance is high, consequently the current flows principally through the resistors; but when the column once ionizes, its resistance materially drops and the resistors carry only a nominal current. In effect, the resistors form a distributed resistance network which sufficiently supplements the distributed capacitance whereby the attenuated region embraces only one or two sections so that from an ordinary viewing distance there is a definite line of demarcation between the illuminated and un-illuminated portions of the tubing. The distributed capacity provided by the extended external electrodes 5, although of itself incapable of causing an appreciable mobile or progressive glow discharge at commercial frequencies, has the effect of stabilizing the action of the resistors. That is, without the capacitive electrode, the glow in each section is likely to fail to ionize at the proper time, but jump or flash on after the potential has raised substantially above threshold value, the tubing section may glow for a half cycle then fail to ionize for several cycles. This materially disturbs the desired even progress in illumination. The capacitive coupling

afforded by the external electrode 5 not only causes the glow to be sustained, once the tubing section ionizes, but also, apparently, facilitates ionization at a point which the glow is barely discernible. The effect is that of a uniform progression of light giving no hint that the resistors divide the tubing into sections, and the appearance closely approximates the writing or progressive effect heretofore produced only by means of high frequency current.

Unlike a high frequency control system, the brilliancy of the tubing, except for its comparatively short attenuated leading zone, is almost uniform; whereas in a high frequency control system there is a definite gradation in brilliancy from one end to the other, even when the tubing becomes completely illuminated. This distinction is important, for it has been found necessary to limit high frequency controlled units to approximately fifteen feet to avoid undue difference in brilliancy between the beginning of one unit and the end of a preceding unit. With my system herein disclosed, thirty, forty or even more feet may be incorporated in a single unit.

By rearrangement of the resistor values from the graduated range suggested hereinbefore a wide variety of mobile effects may be obtained, for example, wherever higher resistors are placed, the corresponding sections will illuminate first, while those controlled by lower resistors will follow in sequence. Thus, illumination may appear from both ends, from several points throughout the length of the tubing and progress in two directions or in one direction until completely illuminated. In all cases the distributed capacity has a stabilizing effect eliminating erratic or jerky sequencing.

With the arrangement shown in Figure 1, each resistor need only stand its proportionate share of the total voltage between the extremities of the neon tubing 1. Thus, if a ten section tubing is subjected to 10,000 volts each resistor need withstand only 1000 volts.

It is not mandatory that the resistors be connected in series with each other, but comparable operation may be obtained with the arrangement shown in Fig. 2. Here, the resistors 21 are connected in parallel with each other, each joining a common lead 22 which may be grounded and connected to the respective leads 10 of the intermediate electrodes 4. If a high capacity network such as the coating shown in Fig. 4 is provided, the resistors 21 may be equal in value. Resistors of one megohm value have proven satisfactory, but the resistor value is not critical and may vary materially, particularly if various mobile effects are desired.

Still further, it is possible to combine the circuits as shown in Fig. 3. In so doing it is not necessary that each intermediate electrode be connected. The variations indicated, all serve to increase the combinations whereby a wide selection of mobile effects may be readily obtained.

By proper selection of the rate at which the power input changes, a wide range of illumination effects or progression rates may be had without altering the resistor combination; furthermore, operation of the controller may be so regulated that the difference in resistor values between sections may be materially less than the values hereinbefore given.

With reference to Fig. 7, a carbon brush transformer 61 is shown. This type of transformer is essentially an auto-transformer in which the core is ring-shaped with a torus winding connected at

its ends to a source of low frequency current and a contact or brush 62. A brush 62 is mounted on a shaft 63 driven by a motor 64 and engages the winding. The shaft may carry a slip ring 65 connected with the brush and upon which rides a contact 66. In addition a cam 67 may be mounted on the shaft to control a switch 68 in series with the brush 62 so as to permit travel of the brush between the ends of the winding. Leads from the switch and the supply to the transformer 61 connect to the transformer 12.

Not only one but several transformers may be connected so that several tubing units may be operated simultaneously. By proper arrangement of electrodes and choice of resistor values the relative progression of the tubes connected with the several transformers 12 may be controlled. This is desirable, for example, in "writing" the letter "S," the illumination may be caused to progress faster in the outer or longer tube than in the inner or shorter tube so that the light front is maintained roughly coincident with radius lines drawn through the tubes. This desirable result is easily obtained with the resistor circuit shown in Fig. 2 for the reason that the electrodes may be moved closer or spread out a substantial amount without appreciable change in the time required for the light to progress. Thus, assuming a given rate of power increase, increased spacing causes the light to progress faster, while decreased spacing caused the light to progress slower. With the arrangement shown in Figs. 1 and 3 the resistor values are the principal controlling factor.

Heretofore, because of the difficulty in controlling the relative progression of illumination in a plurality of tubes, it has not been practical to cause "writing" of a letter or character with more than one tube unit. This definitely limited the writing or progressive effect to smaller signs. Whereas, with my arrangements, the large signs in which more than one tube is required to delineate the letters or characters may now be progressively animated.

Reference is now directed to Fig. 8. The carbon brush transformer 71 here shown is provided with several brushes 72. These progress in sequence over the winding 73 of the transformer which occupies only a part of the circumference, an extended 100% contact strip 74 completing the circle. As in Fig. 7 suitable slip rings are provided to connect the brushes 72 with corresponding transformers 12; also, as in Fig. 7 a main switch 75 is in series with the transformer circuit to open it when the cycle of operation is completed. With this arrangement, several tubing sections each from twenty to fifty feet in length may be "written" in sequence. By adjustment of the relative positions of the several brushes 72, all indication of a break or pause between the tubing sections may be eliminated. Furthermore, as in Fig. 7, not only one but several sections may be written simultaneously.

Reference is directed to Fig. 9. Again, a carbon brush transformer 81 is illustrated. Two windings 82 and 83 are provided each occupying one half the circle and each would reverse to the other so that the output is graduated from zero to one-hundred percent and back to zero. One or several brushes 84 may ride on the windings and be suitably connected through slip rings to corresponding neon transformers and their tubing sections. With, for example, three brushes 84, a very novel and striking effect is obtained; particularly if the tubing sections differ in color.

Light progresses in the different tubing sections in out-of-phase relationship so that one color blends with the others and the blending of color progresses from one end to the other of the tubing sections.

Reference is now directed to Fig. 10 in which a Thyatron control circuit 9 is shown in the primary circuit of the neon transformer 12; and attention is also directed to Fig. 11 in which the control circuit 9 is shown in the secondary circuit of the transformer. Operation in either location is similar, but advantage is gained by location in the secondary circuit for the reason that the power which a Thyatron of a given rating may handle increases with increased voltage.

Control may be effected by several conventional manners such as a variable condenser 92, variable resistor 93, or variable reactance 94.

A Thyatron is essentially a current control means. That is, the voltage remains constant while the average current output is varied, preferably from approximately zero to one hundred percent. The neon tubing has a predetermined critical breakdown voltage, and the voltage input from the Thyatron control is maintained above this point. However, because of the limitation in current, the leakage to ground through the resistors tend to lower the voltage in the remainder of the neon tube below this critical voltage, and consequently as the average current supply is increased the critical voltage is reached in the several units of the tubing in sequence, depending upon the arrangement of the resistors, and the illumination is caused to progress.

Because of the fact that with the Thyatron control the potential is maintained and current only is regulated, there is less tendency for the tubing sections to flash or flicker as ionization is initiated than is the case where the voltage input is varied. Therefore, current or Thyatron control and the capacitive coupling afforded by the electrode 5 both contribute to minimize or eliminate the objectional flash or flicker.

While a carbon brush transformer control and a Thyatron control have been illustrated and these controls have successfully controlled the writing effect in the neon tubing, other controls which gradually increase the voltage or current input or power input the neon tubing may be employed.

In advertising art to which the present invention is directed, novelty in appearance is of primary importance. Due to the almost infinite selection of resistor combinations, and wide range of controller rates both uniform and variable, the number of progressive or mobile effects obtainable is practically unlimited, thus insuring the requisite novelty.

Reference is directed to Figure 6 in which is illustrated a modified form of my invention. In the arrangement here shown, the neon tubing 51 is provided with a series of electrodes 52 therein connected by resistors 53, all within the tubing. Such resistors may be continuous from electrode to electrode or be relatively short and the remaining distance occupied by a conductor; however such conductor should be insulated from the gaseous column within the tubing. Resistor values are comparable to those used with the arrangements shown in Figs. 1, 2, and 3.

Although I have shown and described a particular embodiment of my invention, I do not wish to be limited thereto but desire to include in the scope of my invention the constructions, 75

combinations and arrangements substantially as set forth in the appended claims.

I claim:

1. In a mobile glow discharge system: glow discharge tubing having a distributed capacity therealong; a plurality of electrodes arranged along said tubing; a resistance network connecting said electrodes; a source of low frequency alternating current connected to the extreme electrodes of said tubing and means for varying the power of said source as applied to said electrodes.

2. In a mobile glow discharge system: glow discharge tubing, adapted when energized to support a glow discharge column therein; a resistance network communicating at intervals with said glow discharge column; a distributed capacitance along said tubing; a source of alternating current connected with said tubing and means for varying the power of said source as applied to said electrodes.

3. In a mobile glow discharge system: glow discharge tubing; a source of alternating current connected to the extremities of said tubing to effect an ionized glow discharge therein; a controller interposed between said extremities of said tubing and said power source for gradually and uniformly changing the power input thereto; parallel capacity and resistance circuits so distributed along said tubing to effect a progression of a luminous ionized discharge in said tubing as the power input from said source of alternating current is increased.

4. An animated electric sign adapted to operate on a source of low frequency current such as commercial sixty cycle current, comprising: glow discharge tubing having end electrodes and intermediate electrodes; a transformer having a primary coil connected with said source of low frequency current and a high potential limited current secondary coil connected to the end electrodes of said tubing; means for progressively varying the effective power output from said transformer to said tubing; a plurality of resistors connected to said intermediate electrodes and forming a resistance network by-passing the electrical path through said tubing between said end electrodes; and a metal coating partially covering said tubing and forming therewith an external distributed cathode capacitively coupled with the gas column within the tubing.

5. An animated electric sign adapted to operate on a source of low frequency current such as commercial sixty cycle current, comprising: glow discharge tubing having end electrodes and intermediate electrodes; a current limiting means interposed between said source of low frequency current and the end electrodes of said tubing; means for progressively varying the effective power output from said current limiting means to said tubing; a plurality of resistors connected to said intermediate electrodes and forming a resistance network by-passing the electrical path through said tubing between said end electrodes; and a metal coating partially covering said tubing and forming therewith an external distributed cathode capacitively coupled with the gas column within the tubing.

6. An animated electric sign adapted to operate on a source of low frequency current such as commercial sixty cycle current, comprising: glow discharge tubing including end electrodes and intermediate electrodes, all of the cold cathode type, one end electrode being grounded; resistors connected to the intermediate electrodes and

forming a resistance network to ground; means having a high potential, limited current output interposed between said source of low frequency current and connected directly with said end electrodes and indirectly with said intermediate electrodes through said resistance network; a controller for progressively varying the effective power output from said means whereby, by reason of said resistance network, ionization progresses correspondingly in the sections of tubing between said electrodes; and a metal coating partially covering said tubing and forming therewith an external distributed cathode capacitively coupled with the gas column, said coating being grounded to said grounded electrode.

7. An animated electric sign adapted to operate on a source of low frequency current, comprising: glow discharge tubing having end electrodes and intermediate electrodes; a resistance network connected to said intermediate electrodes; a high potential source of low frequency current connected with said end electrodes and with said intermediate electrodes through said resistance network; a controller progressively changing the effective power output from said source to said tubing and said resistance network adapted to cause the sections of tubing between said electrodes to ionize in corresponding progression; and means for stabilizing the ionization in each section as the threshold ionization potential is exceeded.

8. An animated sign as specified in claim 7 wherein said stabilizing means is incorporated in said controller and includes a device for maintaining a high potential across said tubing while the current applied to said tubing is varied.

9. An animated sign as specified in claim 7, wherein said stabilizing means comprise a capacitance distributed along said tubing.

10. In a mobile glow discharge system; glow discharge tubing; a resistance network connected at spaced points to said glow discharge tubing; a source of high potential alternating current connected to the extremities of said tubing and to said resistance network whereby, upon progressive change in the effective power output from said source to said tubing, the sections of said tubing between said points ionize in corresponding progression; and means for stabilizing and sustaining ionization in each section as the threshold ionization potential occurs therein.

11. A mobile glow discharge system as set forth in claim 10 wherein said stabilizing means includes a controller for progressively varying the current output from said source while maintaining a substantially high potential across the extremities of said tubing.

12. A mobile glow discharge system as set forth in claim 10 wherein said stabilizing means includes a controller for progressively varying the current output from said source while maintaining a substantially high potential across the extremities of said tubing, and a distributed capacitance along said tubing.

13. A mobile glow discharge system as set forth in claim 10 wherein said stabilizing means includes an external metal coating distributed along said tubing capacitively coupled with the gas column within said tubing.

14. A gaseous glow discharge tube of extended length having: an external cathode extending lengthwise thereof; an anode within one end of said tube exposed to the gas column therein; a series of internal cathodes positioned within said tube at spaced points and likewise exposed to the

gas column therein; and an external resistance network connecting said internal cathodes with said external cathode.

15. In a mobile glow discharge system: glow discharge tubing; an anode within one end of said tubing; a cathode within the other end of said tubing; a series of intermediate cathodes within said tubing; an external resistance network connecting said intermediate cathodes with said end cathodes; and an external cathode extending along said tubing, said external cathode conductively connected with said end cathode and capacitively associated with the interior of said tubing.

16. A glow discharge means adapted for mobile glow discharge effects comprising: tubing containing a gas adapted, when ionized, to support a glow discharge; end electrodes and spaced intermediate electrodes within said tubing in electrical contact with said gas; an external electrode in electrical contact with one of said electrodes and capacitively coupled with the gas within said tubing.

17. In a mobile glow discharge system: a series of glow discharge tubes forming separate envelopes, each including electrodes at least in the extremities thereof having external connecting means adapted to connect said tubes in electrical series; and external resistors joined to said connecting means and forming a resistance network to ground, one extreme electrode of said series of glow discharge tubes likewise being grounded.

18. In a mobile glow discharge system: a series of glow discharge tubes forming separate envelopes, each including electrodes at least in the extremities thereof having external connecting means adapted to connect said tubes in electrical series; external resistors joined to said connecting means and forming a resistance network to ground, one extreme electrode of said series of glow discharge tubes likewise being grounded; a limited current high potential source connected to the extreme electrodes of said series of glow discharge tubes; and means for progressively changing the effective power output from said source to said tubes.

19. In a mobile glow discharge system: a series of glow discharge tubes forming separate envelopes, each including electrodes at least in the extremities thereof having external connecting means adapted to connect said tubes in electrical series; and external resistors joined to said connecting means and forming a resistance network to ground, one extreme electrode of said series of glow discharge tubes likewise being grounded; an external grounded cathode distributed along said tubes and capacitively coupled with the gas columns therein.

20. In a mobile glow discharge system: a series of glow discharge tubes forming separate envelopes, each including electrodes at least in the extremities thereof having external connecting means adapted to connect said tubes in electrical series; and external resistors joined to said connecting means and forming a resistance network to ground, one extreme electrode of said series of glow discharge tubes likewise being grounded; an external grounded cathode distributed along said tubes and capacitively coupled with the gas columns therein; a limited current high potential source connected to the extreme electrodes of said series of glow discharge tubes; and means for progressively changing the effective power output from said source to said tubes.

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