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SYSTEM FOR PRODUCING ILLUMINATION OF PROGRESSIVE PORTIONS OF A GAS-FILLED LUMINESCENT TUBE

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ABSTRACT OF THE DISCLOSURE

This invention relates to a system for illuminating a portion of the length of a luminescent tube and for varying the illuminated portion of the length of the luminescent tube on a progressive basis. The tube has a gas at a reduced pressure relative to the pressure required to produce arcing of the gas in the tube so that ionization of the gas in the tube occurs. The system varies the excitation voltage applied to the tube, the current through the tube and the frequency of such voltage and current in a particular manner to provide a luminescence of progressive portions of the length of the tube.

This invention relates to an electronic circuitry for supplying input excitation signals to gas-filled luminescent tubes and more particularly to new and inventive input excitation signal circuitry capable of causing illumination in selectable portions of the luminescent tube less than the full length thereof.

Prior to the discovery of the principles of the present invention, it has been difficult to design "writing signs" in which illumination could be made to occur in a closely controlled, small or large portion of the whole lighting tube and could be made to progress along the tube at any desired rate. With incandescent bulbs, of course, the effect of the writing sign can be approximated by progressively switching illumination current to the bulbs along the writing line. Somewhat similarly, a length of neon tube can be made to "write" by constructing a long series of electrodes at 2 or 3 intervals along the tube and then progressively switching these electrodes into the lighting circuit to cause the illuminated portion of the tube to extend or retract. These multi-electrode neon writing tubes offer only a marginally satisfactory solution to the writing sign problem, for the necessity of penetrating the tube with an electrode every 2 or 3 inches makes manufacturing a very costly process. Moreover, such multi-electrode tubes have very short operating lives because of the uneven temperature gradients and varying stresses produced by the complicated and shifting electrode energization arrangement. Therefore, the general object of the present invention is to provide a gas tube writing sign in which illumination can be made to progress and regress across portions of the length of the tube merely by varying the characteristics of the input signal being applied to the usual end electrodes found in any gas tube.

In the pursuit of the above general object, this invention includes several new principles which in various combinations will achieve the writing effect. First and most important, illumination can be made to progress slowly along the length of a tube if the input excitation signal has its voltage amplitude, current amplitude and/or frequency increased, the rate of increase governing the rate of "writing." At the same time, the waveform of each cycle of the input excitation signal should be of such shape that numerous harmonics of the fundamental frequency are applied across the electrode or electrodes of the gas tube and that the potential of the valence elec-

trons of the gas molecules is lowered as much as possible during the negative swing of each cycle. Thus, illumination can be accomplished by gas ionization, rather than the usual arcing technique which cannot occur without causing complete illumination of the tube between the electrodes excited. Once illumination by ionization is used in place of arcing, the writing effect can be achieved by polarizing the tube electrodes, as the above-described waveform will necessarily do, and then varying input excitation signal current level, voltage, or frequency, or various combinations of these three, to cause the critical ionization level for illumination to be reached at limited lengths from whichever one of the electrodes is in effect the anode of the tube.

As another feature of applicant's invention, the lowering of gas pressure in lighting tubes used for writing below the pressure normally used is found to facilitate achievement of the writing effect; for arcing is thereby retarded, while ionization is made easier, both due to the thinning out of electron density. For example, in a 10 mm. diameter tube normally using 13–15 mm. of mercury gas pressure, 10 mm. of mercury would be used in writing sign applications. The result of this thinning of the luminescent gas is that the individual electrons of the gas molecules have greater freedom of movement and require less energy to ionize or take complete leave of the atomic structure and, accordingly, the power level of the input excitation signal can be lowered.

Since too high an excitation voltage will cause arcing and since increased excitation frequency agitates the electrons more to give the equivalent of higher pressure, the principles of the invention include the lowering of excitation voltage while raising current amplitude (to increase lighting level) and frequency. This combination gives the ionization and non-arcing type illumination necessary when writing is to be done, yet at an acceptable level of brilliance. Brilliance can then be increased even more by the provision of metallic particles in the tube glass or vacuum-deposited thereon or by the positioning of a metallic strip along the glass so that the metallic material emits secondary electrons under the influence of the free electrons excited from the luminescent gas. Metallic tube glass, coating, or backing also aids in controlling the length of tube illuminated and to provide a sharper delineation or boundary between illuminated and dark portions by providing improved conductance between the light-dark boundary to the electrode at the dark end. Without this improved conductance, the capacitance between the light-dark boundary (i.e., the end of the ionized portion) and the dark end electrode would be a strong factor in the equation of tube reactance to input power, requiring greater voltage which would increase the arcing danger.

Additional inventive features appear in the embodiment of the above-mentioned principles in circuitry for producing a writing sign input excitation signal from a standard power supply. Experience has shown that most tubes perform poorly at excitation frequencies below 800 c.p.s. and will ionize too fast and grow inefficient at frequencies above 23 kilocycles, the latter because electron movement has become too erratic and wide.

The circuitry for supplying the input excitation signals, therefore, provides first means for converting a power supply signal into a polarized waveform rich in harmonics of the fundamental and having a deep negative excursion at one point in each cycle, said first means tending to increase the frequency of the waveform as input power is increased, and second means for varying the power applied to the first means, preferably automatically over a timing cycle.

A typical circuit meeting these requirements has an AC

power supply with first and second terminals and a diode-bridge rectifier having first and second input terminals and first and second output terminals, the first AC power supply terminal being coupled to the first input terminal of the diode-bridge rectifier. The typical circuit also has, for power-metering, a first silicon-control rectifier (SCR) having input, output and control electrodes. The input and output electrodes of the first silicon-control rectifier are coupled between the second terminal of the AC power supply and the second control terminal of the diode-bridge rectifier. A time-constant circuit including the series combination of a photocell, a first resistor and a first capacitor is coupled between the input and output electrodes of the first silicon-control rectifier, and triggering means are coupled from a point between the first resistor and the first capacitor to the control electrode of the first silicon-control rectifier.

A light source is operatively associated with the photocell such that variations in the intensity of light received from the light source by the photocell vary the electrical resistance of the photocell, and means including a resistance-capacitance timing circuit electrically connected between the AC power supply and the light source cause the intensity of the output of the light source to vary cyclically with time.

A second capacitor appears across the output terminals of the diode-bridge rectifier both to smooth rectified current and switch off the first SCR after a short charging period. The lighting tube is supplied through a transformer having a primary winding with first and second terminals, the first terminal being connected to the first output terminal of the diode-bridge rectifier.

A third capacitor is connected between the first and second terminals of the primary of the transformer to form a resonant tank circuit, the resonance frequency of which varies to accommodate changing conditions in the tube. A second silicon-control rectifier is connected between the second output terminal of the diode-bridge rectifier and the second terminal of the primary of the transformer and its timing circuit is made up of the series combination of a second resistor and a fourth capacitor connected between the second output terminal of the diode-bridge rectifier and the second terminal of the transformer and a second trigger device connected from a point between the second resistor and the fourth capacitor and the control electrode of the second silicon-control rectifier.

Other objects and features of applicant's invention and a fuller understanding thereof may be had by referring to the following description and claims taken in conjunction with the accompanying drawings, in which:

FIGURE 1 is a schematic diagram of a first writing sign electrical system embodying the principles of applicant's invention;

FIGURE 2 is a schematic diagram of a portion of a second writing sign electrical system embodying the principles of applicant's invention;

FIGURE 3 is a schematic diagram of a portion of a third writing sign electrical system embodying the principles of applicant's invention;

FIGURE 4(a) is a graph of the input and output voltages of the diode-bridge rectifiers used in the circuits of FIGURES 1 and 2;

FIGURE 4(b) is a graph of the waveform produced by the circuits of FIGURES 1, 2 and 3; and

FIGURE 5 is a schematic diagram of a modified form of fluorescent tube which may be included in this invention.

Referring to FIGURE 1, the first circuit which is the preferred embodiment of applicant's invention has for its purpose the application of input excitation signals to the electrodes of a gas tube 10 in such manner that the writing effect can be achieved. The gas tube 10 is shown symbolically in the figure; in practice, it would be of 10 or so millimeters in diameter and several feet in length.

As a feature of the invention, the pressure of the luminescent gas in the tube is made lower than usual to aid in the writing process. For example, the pressure of the gas in the tube may be 10 mm. of mercury. A transformer 12 having primary 14 and secondary 16 has the ends of its secondary 16 connected across the electrodes of the tube 10. Alternative arrangements of this hookup would be to have one end of the tube 10 grounded and one end of the secondary 16 grounded or to ground one or both and leave the other "free-floating." The effects of applicant's invention can be achieved with any of these arrangements, and in many situations, the "free-floating" connection is preferable.

The primary 14 of the transformer 12 has a first end 18 and a second end 19 between which a capacitor 20 is coupled. The capacitor 20 cooperates with the primary 14 of the transformer 12 to form a resonant tank circuit which, among other things, serves to insulate the circuitry coming before from the tube 10 so that even the wider variations of load imposed by the tube 10 do not affect the performance of the circuitry.

The purpose of the circuitry of FIGURE 1 is to meter power and to supply it in the form shown in FIGURE 4(b) to the primary 14 of the transformer 12. The metering function is performed by the network centered about a first silicon-control rectifier (SCR) 26 having input electrode 28, output electrode 30 and control electrode 32. The input electrode 28 of the first SCR 26 is coupled through a current limiting choke 34 and a limiting resistor 36 to the terminal 22 of the power supply. The output electrode 30 of the first SCR 26 is coupled through a resistor 38 to a diode-bridge rectifier 40 having input terminals 42 and 44 and output terminals 46 and 48. The terminal 24 of the power supply is directly connected to the output terminal 44, while the silicon-control rectifier 26 intervenes between the terminal 22 of the power supply and the other input terminal 42 of the diode-bridge rectifier 40. Thus, the amount of power supplied to the output terminals 46 and 48 depends on the "on" time of the first SCR 26.

The "on" and "off" states of the first SCR 26 are governed by a timing circuit composed of the series combination of a resistor 50, a photocell 52 and a time-constant capacitor 54. A trigger 56 is coupled from a point 57 between the capacitor 54 and the resistive elements 50 and 52 to the control electrode 32 of the first SCR 26. The trigger 56 in its "off" state presents a very high impedance to signals at the point 57; but, when the voltage at the point 57 has risen due to charge accumulation in the capacitor 54 to a certain breakdown point or "firing" level of the trigger 56, the trigger fires or switches to a very low impedance state so that a positive signal is applied to the control electrode 32. This positive signal causes the first SCR 26 to fire, so that power is applied across the terminals 42 and 44 of the diode-bridge rectifier 40. A diode 58 is coupled essentially between the output electrode 30 of the first SCR 26 and the point 57 to clamp the voltage at the output electrode 30 to a relatively stable point and thus prevent damaging current swings at the instant of turn-on of the SCR 26.

In the operation of the network centered about the first SCR 26, the power waveform appearing on the input electrode 28 is practically pure A.C., since the resistor 36 and choke 34 serve only to cut down extreme surges and spikes that might otherwise damage the SCR 26. Referring to FIGURE 4(b), a graph of time versus voltage at the input electrode 28 and the output electrode 38 of the SCR 26, the line 60 represents the input voltage. By the very nature of the SCR, of course, any such negative-going voltage serves to back bias and turn-off the SCR 26, regardless of the signal on the control electrode 32; turn-off effect is aided by the reverse current caused by the inductor 34 as the portion 64 reaches its end and the A.C. waveform 60 approaches a zero crossing before swinging negative (FIGURE 4(a), 62). Because

of those turn-off effects just before the beginning of the negative-going portion 62, the SCR does not remain on at the end of the positive-going portion 64, but rather is left off until given another turn-on signal at its control electrode 30 due to charging of the capacitor 54 beyond the breakdown point of the trigger 56.

At the beginning of each positive-going portion 64 of the A.C. input waveform 60, the capacitor 54 begins to charge positively through the resistor 50 and the photocell 52 at a speed variable as the resistance of the photocell 52 varies. Variation of charging speed of the capacitor 54 varies the amount of time after the beginning of the positive-going portion 64 before the trigger 56 fires to turn-on the SCR 26. Once the SCR 26 is turned on, it remains on until the negative-going portion 62 begins so that variation of a time delay of charging of the capacitor 54, in effect, varies the amount of the positive-going portion 64 that the SCR 26 passes on to the diode-bridge rectifier 40. When the photocell 52 is receiving a minimum amount of light and, therefore, has maximum resistance, the SCR 26 does not turn-on at all and no power appears at the diode-bridge rectifier 40. As more light is received by the photocell 52, its resistance declines to the point where the capacitor 54 charges above the breakdown point of the trigger 56 before the end of the positive-going portion 64 of the A.C. input waveform, resulting in the passage of a small signal 66 to the diode-bridge rectifier 40. As the amount of light to the photocell 52 is increased and its resistance is decreased, the charging current of the capacitor 54 is increased, resulting in the passing of increased portions of the positive-going portion 64 to the diode-bridge rectifier 40. For example, at a progressive time after the passage of the small signal 66 to the rectifier 40, a signal 66' of increased amplitude and power is passed to the rectifier 40 because of a decrease in the resistance provided by the photocell 52 and an increase in the flow of current through the capacitance 54.

When, as is usually the case in writing sign applications, it is desired to cause the tube 10 to light according to a repeated automatic program, a light source 70 associated with the photocell 52 may have power metered to it from the power supply terminals 22 and 24 by a timing circuit of the sort now to be described. A diode-bridge rectifier having input terminals 76 and 78 and output terminals 80 and 82 has its input terminal 76 coupled through a resistor 84 to the power supply terminal 22. The input terminal 78 of the diode-bridge rectifier 74 is coupled to a point between two voltage division resistors 86 and 88 connected between the power supply terminal 24 and a power supply terminal 22. The output terminal 80 of the diode-bridge rectifier 74 is coupled to the collector of a transistor 90 having its emitter 92 connected to one side of the bulb 70. The other side of the bulb 70 is coupled through a protective resistor 98 to the output terminal 82 of the diode-bridge rectifier 74. The conduction of the transistor 90 is regulated by a network centered about a timing capacitor 100 having one plate directly connected to the output terminal 82. The other plate of the timing capacitor 100 is coupled through a variable resistor or potentiometer 102 to the output terminal 80 of the diode-bridge rectifier 74. This charge of the capacitor 100 is accomplished by a trigger 104 (such as a Shockley 4-layer transistor) coupled across its ends. A small surge protection resistor 106 is coupled directly in series with the capacitor 100. The instantaneous charge on the capacitor 100 is coupled through a resistor 108 to the control electrode or base 94 of the transistor 90.

In the operation of the circuitry associated with the bulb 70, the transistor 90 remains in its non-conductive or off state until the capacitor 100 has begun to acquire charge. Since the capacitor 100 has a charging path running from the output terminal 80 of the diode-bridge rectifier 74 through the variable potentiometer 102 and also, to a small degree, by leakage currents between the

collector 96 and base 94, the setting of the potentiometer 102 will determine the speed at which the capacitor 100 charges. As the capacitor 100 charges and leakage current from the collector-base diode of the transistor 90 passes through the resistor 108, a voltage drop is induced upon the base 94 to cause the transistor 90 to become more conductive. This increased conduction, of course, results in increased current through and increased light output from the bulb 70. As the transistor 90 becomes more and more conductive, the bulb 70 lights up accordingly, causing the resistance of the photocell 52 to decrease and thus the size of the metered power wave 66 to increase. The setting of the potentiometer 102 controls the rate at which the transistor 90 becomes progressively conductive so as to correspondingly control the rate at which the bulb 70 becomes illuminated.

When the capacitor 100 has accumulated enough charge to reach the breakdown voltage of the trigger 104, this latter element fires and the capacitor 100 then discharges through the trigger 104, turning-off the transistor 90. Once the capacitor discharge current ends, the trigger 104 switches off again. The off time of the bulb 70 (and thus of the writing sign tube 10) is governed by the time it takes the capacitor 100 to build up sufficient charge to pull the voltage on the base 94 of the transistor 90 sufficiently far below the voltage on the emitter 92 for conduction to begin again. This is controlled in part by the value of the resistor 108 since this resistor controls the potential applied from the capacitor 100 to the base of the transistor 90 to make the transistor conductive.

Due to the full wave rectification capabilities of the diode-bridge rectifier 40, the waveforms 66, 66', etc. of FIGURE 4(a) appear on the output terminals 46 and 48 as positive-going pulses. Thereafter, they are smoothed to some extent by the combined cooperation of a capacitor 110 connected across the output terminals 46, 48 and an inductor 112. The output terminal 46 of the diode-bridge rectifier 40 is directly connected to the terminal 19 of the primary 14 of the transformer 12.

A second silicon-control rectifier 120 has an input electrode 122, an output electrode 124 and a control electrode 126. The input electrode 122 is directly connected to the inductor 112 and the output electrode 124 is directly connected to the terminal 18 of the primary 14 of the transformer 12. Thus, when the second silicon-control rectifier 120 is in its conductive state, the primary 14 is in effect switched into electrical connection with the filtering elements 110 and 112 to derive power from the output terminals 46 and 48. Turn-on signals for the silicon-control rectifier 120 are coupled to the control electrode 126 through a diode 128. These turn-on signals could be generated by a time-constant circuit similar to that described in connection with the silicon-control rectifier 26—featuring a capacitor 54 and a trigger 56. Another similar circuit, however, is constructed about a capacitor 130 and a unijunction transistor 132 having an emitter 134 and two bases 136 and 138. A large step-down resistor 140 couples the unijunction circuit to the output terminal 48 to insure that the unijunction circuit receives only a small proportion of the power coming out of the diode-bridge rectifier 40. A first voltage division resistor 142 is coupled between the base 136 and the step-down resistor 140. A second voltage division resistor 144 is coupled between the base 138 and the output electrode of the SCR 120. A resistor 146 between the step-down resistor 140 and the emitter 134 cooperates with the capacitor 130 to form the time-constant circuit for the unijunction 132. The circuit described in this paragraph corresponds somewhat to the circuit included in copending application Ser. No. 437,127 filed Mar. 4, 1965 as a continuation-in-part of application Ser. No. 198,325 now abandoned, filed in the names of Jerome Zonis, John Ketola and me on May 28, 1962 and assigned of record to the assignee of record of this application.

The response of the above-described second SCR 120 and its associated circuitry to the variable DC signals from the diode-bridge rectifier 40 and filters 110 and 112 begins with the charging of the capacitor 130 through the resistors 140 and 146, the capacitor 130 and the parallel combination of the capacitor 20 and the primary 14 so that a division of voltage occurs between the base 136 and the base 138 of the unijunction 132. When the capacitor 130 has charged to such a level that the voltage on the emitter 134 of the unijunction 132 exceeds a certain fixed proportion of the voltage drop across the bases 136 and 138, the unijunction transistor 132 fires and causes a positive-going signal to be passed through the diode 128 to the control electrode 126, turning the SCR 120 on. This turn-on of the SCR is facilitated by the positive charges produced in the capacitors 130 and 20 before the triggering of the unijunction 132. The turn-on of the SCR 120 creates a closed circuit between the output terminal 48 of the diode-bridge rectifier 40 and the terminal 18 of the transformer primary 14 so that a large back E.M.F. appears in the primary 14 and current rushes in to begin charging the capacitor 20. This rush of current is facilitated by the discharge of the capacitor 130 through the unijunction 132 and the SCR 120. The rush of current following the turn-on of the SCR 120 and the charge of the capacitor 20 also produces a back E.M.F. in the inductor 112. This back E.M.F. plus the increasing charge on the capacitor 20 soon initiate a reverse current flow which shuts off the SCR 120 until such time as it receives another positive signal on its control electrode 126, leaving the primary 14-capacitor 20 tank to resonate under the influence of the energy supplied to it. This resonance, of course, is inductively coupled to the secondary 16 of the transformer 12 and thus supplies lighting power for use by the tube 10.

Referring to FIGURE 4(b), the result of each cycle of operation of the SCR 120 is the appearance of the waveform shown therein across the electrodes of the tube 10. The waveform of FIGURE 4(b) begins with a high initial level 150 powered by a decay portion 152 of variable length l and variable angle of slope α . At the end of the decay is a deep negative excursion 154, from which the voltage later rises to form the leading edge of the next individual wave. The purpose of the applied waveform of FIGURE 4(b) is to supply energy to the luminescent gas in the tube 10 whereby valence electrons of the individual atoms of the gas are excited out of their normal orbits into some excited orbit. When each electron later returns to its normal orbit, its excess energy is emitted as a quantum of radiation, thus producing illumination by ionization rather than by arcing.

The SCR 120 and associated components produce the waveform of FIGURE 4(b) from the variable DC drawn from the rectifier output terminals 46 and 48 in the following manner: After the capacitor 130 has charged sufficiently to fire the SCR 120 as described above, the terminal 18 of the primary 14 is allowed to draw current from the output terminal 48. At the instant of SCR turn-on, this results in the deep negative-going excursion 154 of the waveform of FIGURE 4(b), the back E.M.F. of the inductance 112 in response to change in voltage thereacross. At the bottom of the excursion 154, the inductances 14 and 112 have charged sufficiently to block further current flow; so that the SCR 120 turns off. After turn-off of the SCR 120, the leading edge 150 of the waveform of FIGURE 4(b) is produced by the E.M.F. associated with the decay in current through the windings of the primary 14. The declining portion of the curve 152 is the result of discharge of the capacitor 20. It should be noted that the higher the level of power being supplied through the diode-bridge rectifier 40, the quicker the inductances 14 and 112 and the capacitor 20 will switch off the SCR 120, resulting in a short l or decay portion 152 of the waveform of FIGURE 4(b). If l is shortened, of course, the amount of power delivered will

be increased due to shortening of the low-voltage time of the waveform (i.e.—the portion 152) and the frequency of the waveform of FIGURE 4(b) will be increased. The overall result is that as the light output of the bulb 70 causes the resistance of the photocell 52 to decline so that increased power is applied to the diode-bridge rectifier 40, the signal across the tube 10 will increase both in power and frequency—exactly the conditions required in order to achieve the writing effect.

Of great help in the construction of the transformer 12 is the use of a coil material which at the lower frequencies is inefficient but increases in efficiency as the frequency of signal therethrough increases. This increased efficiency means that at higher frequencies the reverse current flow due to back E.M.F. in the primary 14 will snap the silicon-control rectifier 120 off much more quickly. Thus, the SCR and its timing circuit are sooner ready to begin another cycle. The high loss of the transformer core at low frequencies means that the SCR can continue working at no-load, low frequency conditions wherein many circuits would tend to decommutate or burn up because of short circuiting. By providing the transformer 12 with a variable impedance at the different frequencies, the impedance of the SCR 120 at the different frequencies. This impedance match prevents the SCR from continuing to conduct through successive cycles of alternating current without any interruption in the current conduction. If the SCR continued to conduct continuously through such successive cycles, it might tend to overheat and become destroyed.

The selection of the value of the tank capacitor 20 is also important to the functioning of the output transformer 12. If the capacitor 20 is too small, it will not be able to deliver sufficient power; on the other hand, if it is too large, it will not discharge completely and deliver all the power that it has stored. Properly selected, however, it is capable of a unity power factor.

It will be seen from the previous discussion that the values of the resistors 140 and 146 and the capacitors 130 and 20 primarily control the frequency of the repetitive cycles since they control the time at which the unijunction 132 becomes conductive, assuming that a constant voltage is produced across the capacitor 110. Of course, since the voltage across the capacitor 110 is being constantly varied as described above, the frequency of the signals produced in the SCR correspondingly varies. The time for initiating each new cycle is controlled by the transformer 12 as described above since the counter E.M.F. produced in the transformer causes a voltage to be introduced through the capacitor 130 to make the unijunction 132 nonconductive.

It will be seen that the voltage at the SCR 120 and accordingly across the transformer 12 varies in accordance with the variations in the voltage across the capacitor 110. For example, the potential across the primary of the transformer 12 may vary up to 400 volts because of the resonant characteristics of the transformer and the capacitor 20 even though the potential across the capacitor 110 may be considerably less than 4,400 volts. Although there is a 19:1 ratio between the turns in the primary and secondary of the transformer 12, the voltage on the secondary tends to approach only approximately 700 volts since the tube 10 provides a load on the secondary.

As will be seen from the previous discussion, the voltage applied to the tube 10 increases as the frequency of the signals applied to the tube 10 increases. This increase in voltage and frequency causes the illuminated length of the tube to increase, as will be described in detail subsequently. The increase in voltage with increase in frequency is facilitated by the increase in the efficiency of the transformer 12 with increase in frequency. This increase in voltage with increase in frequency is desirable to maintain the lighting in the tube 10 at a particular

level as the illuminated length of the tube 10 increases. The portion 152 of the signal in FIGURE 4(b) also tends to decrease in slope and approach a horizontal level as the frequency of the signal increases so as to increase the power factor of the signal and the level of the energy applied to the tube as the illuminated length of the tube increases.

Referring to FIGURE 2, the circuit shown therein performs according to principles similar to the circuit of FIGURE 1 in creating the writing effect in the gas tube 10. Accordingly, the transformer 12 is again used and the ends of its secondary 16 are coupled across the ends of the tube 10. The primary 14 has the capacitor 20 coupled across its ends 18 and 19 as described before and the SCR 120 with its output electrode connected to the terminal 18 of the primary 14 is used to switch the power on and off. For illustrative purposes, the timing circuit of the SCR 120 uses a trigger 151 rather than the unijunction 132 coupled between the time-constant capacitor 130 and a resistor 153. Coupled between the input electrode 122 of the SCR 120 and the terminal 19 of the primary 14 is a T-filter comprising two inductors 155 and 156 and a capacitor 158. If the capacitor 158 is made extremely large, its storage of spikes and surges in the input supply current to the SCR 120 has a great smoothing effect on signals arriving at the input electrode 122. The result is that a much smaller and less expensive silicon-control rectifier can be used in the position 120, due to the reduced danger of heating or breakdown that current surges and spikes would otherwise produce. Moreover, R.F.I. noise in the circuit is also eliminated, so that radios and the like in the areas are not affected when the lighting circuit is in operation. Extra current limiting may be provided by additional elements 160, 162 and even a diode 164 in case the input current is not strictly DC.

Power is delivered to the above circuitry from the AC input terminals 22 and 24 through a diode-bridge rectifier 170 having an input terminal 172, an output terminal 174 and control terminals 176 and 178. The AC input terminal 22 is connected to the input terminal 172 while the other AC input terminal 24 has essentially a direct connection to the terminal 19 of the primary 14. The output terminal 174 of the diode-bridge rectifier 170 is coupled to deliver power to the input electrode 122 of the SCR 120.

An SCR 180 having input electrode 182, output electrode 184 and control electrode 186 has its input and output electrodes 182, 184 coupled across the control electrodes 176, 178 of the diode-bridge 170, with an inductor 188 intervening between the input electrode 182 and the control electrode 178. The purpose of the inductor 188 is similar to that of the inductor 34 discussed in connection with the silicon-control rectifier 26 or that of the inductor 112 discussed in connection with the SCR 120, that is to say: to deliver a back E.M.F. when the SCR is turned on and, therefore, to turn it off when the current through it has declined sufficiently due to decline in the AC input signal. The timing circuit for the SCR 180 comprises a capacitor 190, a fixed resistor 192 and a photocell variable resistance 194 in parallel with the fixed resistance 192. Thus, under the influence of changing light signals from the light source 70, the change of the resistance of the photocell 194 from infinitely high (no light) to very low results in increased speed of charging of the time-constant capacitor 190. To avoid a shunting effect when the photocell 194 is at a very low resistance, a resistor 196 is placed in series therewith, and a capacitor 198 coupled essentially in series with the resistor 196 between the control electrodes 176, 178 serves to smooth out any large surges of current appearing across the timing circuit. A trigger 200 coupled between the capacitor 190 and the control electrode 186 of the SCR 180 passes turn-on signals to the SCR when the capacitor 190 has charged above the firing point of the trigger 200.

The operation of the above-described power metering

network is slightly different than that of the power metering network of FIGURE 1; for in the present case, the diode-bridge rectifier 170 is not connected across the terminals 22 and 24, but rather, is connected in series with one of the terminals 22 while the terminal 24 is connected directly to the output transformer 12. Thus, power metering becomes a function of how much of the signal appearing on the input terminal 172 is allowed to get through to the output terminal 174. It will be seen that positive-going signals upon the input terminal 172 would be conducted by a diode 202, but blocked by a diode 204 while, conversely, negative-going signals on the input terminal 172 would be blocked by the diode 202, but conducted by the diode 204. Once these positive-and-negative-going signals reach the control terminals 178, 176, respectively, however, they are blocked by diodes 206 and 208, respectively. In order to reach the output terminal 174, therefore, it is necessary for them to pass through the SCR 180 to the opposite control terminal from where they originally were in order to pass through a diode which is conductive in the proper direction to reach the output terminal 174. For example, referring again to FIGURE 4(a), the positive-going portion 64 of the AC input signal 60 would be conducted by the diode 202 to the control terminal 178. With such a positive-going voltage on the control terminal 178, the capacitor 190 begins to charge through the resistor 192 and shunting photocell 194, finally reaching the firing point of the trigger 200. When the trigger 200 fires and applies a positive-going pulse on the control electrode 186 of the SCR 180, the SCR begins to conduct and allows the positive-going signal on the control terminal 178 to pass through to the control terminal 176. At the control terminal 176, the positive-going signal can pass through the diode 208 to the output terminal 174 since the SCR 180 will conduct as long as there is current passing through it in the proper direction. As the waveform 60 reaches the zero crossing of the end portion 64, current through the SCR 180 diminishes and then is reversed by the effect of the inductor 188, causing the SCR 180 to switch off. During the time that the SCR 180 is conducting, it provides a load between the terminals 178 and 176, thereby causing a corresponding voltage to appear between the terminals 172 and 174. This voltage is subsequently applied to the transformer 12 in the manner described in detail in FIGURE 1.

The result of the above cycle appearing at the output terminal 174 is the same pulse train 66, 66' (all rectified to be positive-going) discussed in connection with FIGURE 1. These pulses are smoothed by the elements 155, 156, 158 and 160 to supply a smooth input signal for the SCR 120 and timing circuit associated therewith. The resulting output waveform across the terminals of the transformer 12 is similar to that shown in FIGURE 4(b) and similarly increases in power and frequency as the amount of power metered through to the output terminal 174 is increased.

Referring to FIGURE 3, another way of constructing a power supply according to the principles of the instant invention for achieving a writing sign effect uses a magnetic amplifier 300 having an input winding 302, an output winding 304 and a control winding 306, each of these windings 302, 304 and 306 having first and second ends. The input winding 302 has its first and second ends coupled across the AC input power supply terminals 22 and 24 while the output winding 304 is coupled to an oscillator-transformer circuit of the sort discussed in FIGURE 2. The effect of the control winding 306 on the magnetic amplifier 300 is that, as more current passes through the control winding 306, an amplifier core 308 of suitable material rises closer to saturation, so that signals across the terminals 22, 24 are not as completely inductively coupled to the secondary winding 304 as would be the case if the control winding 306 were not present. The greater the current through the control winding 306, the less the

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power inductively coupled from the winding 302 to the winding 304.

The current through the winding 306 is varied over a definite but adjustable period of time by a network including a transistor 310 having an emitter 312, base 314 and collector 316. The emitter 312 is coupled through a diode 318 to a first end of the control winding 306.

A variable resistor 320 connected between the collector 316 and the second end of the control winding 306 completes the series electrical circuit through the diode 318, the transistor 310 and the resistor 320 connecting the first end 306' of the control winding 306 with the second end. The base 314, the control electrode of the transistor 310, is coupled to the second end 306'' of the control winding 306 through the parallel combination of a capacitor 322 and a semiconductor trigger 324, to the emitter 312 through a resistor 326, and to the collector 316 through a resistor 328.

In the operation of the above-described circuitry associated with the control winding 306, a certain amount of current flow will be induced in the winding 306 by the AC input signal applied at the terminals 22, 24. To the extent that input power to the magnetic amplifier at the terminals 22, 24 is inductively coupled to the control winding 306, it is not inductively coupled to the control winding 304; or in other words, the amount of power dissipated in the circuitry coupled to the control winding 306 is subtracted from the amount of AC input power that might otherwise be inductively coupled to the output winding 304 and thence ultimately to the tube 10. At a time when the capacitor 322 has no charge in it and thus no voltage drop across it, the emitter 312 of the transistor 310 will be higher in voltage than the base 314 to an extent that the transistor 310 will be fully conductive and the tube 10 will be unlighted. Current from the collector 316 will flow to the second end 306'' of the winding 306, both through the resistor 328 and the capacitor 322 in series and through the variable resistor 320 in parallel therewith. As the capacitor 322 charges, the voltage on the base 314 of the transistor 310 rises toward the value of the voltage on the emitter 312 of the transistor 310 and the transistor, therefore, becomes less conductive so that less current flows through the winding 306. This will result in more power being coupled to the winding 304 of the magnetic amplifier 300 and thus to the circuitry centered about the SCR 120 and the transformer 12, where electrical signal necessary to achieve the writing effect in the tube 10 would be produced in the manner described above.

The time constant of the writing cycle in the FIGURE 3 type of circuitry depends mainly on the values of the capacitor 322 and the resistor 328 and on the adjusted value of the variable resistor 320 in parallel therewith. The writing cycle ends when the voltage across the capacitor 322 exceeds the breakdown voltage of the trigger 324, so that the trigger becomes conductive and discharges the capacitor 322 by dissipating its power through the resistor 323. With the trigger 324 fully conductive, of course, the current through the winding 306 rises to a relatively high value even though the transistor 310 would be in its off condition because of the current path between the first end 306' and the second end 306'', comprising the series combination of the trigger 324 and the resistor 326.

It should be noted that the circuitry associated with the winding 306 can easily be varied to provide the writing effect starting either with the tube 10 fully illuminated or with the tube unilluminated. In the former case, the illuminated portion of the tube then diminishes or retreats toward the anode of the tube until the tube is finally unilluminated (unless the cycle is cut off before); while in the latter case, the tube begins totally unilluminated and then the illuminated portion proceeds from the anode until it reaches the cathode or until the writing cycle is stopped whichever happens first. As explained above, the circuitry as shown in FIGURE 3 will produce

the writing effect starting from the unilluminated state. In order to start from full illumination and then diminish the length of tube illuminated, it would be necessary, of course, to arrange the circuitry in such manner that no current flowed through the winding 306 at the beginning of each cycle and then current flow became progressively greater. This can be accomplished merely by reversing the direction of the diode 318 and reversing the positions of the emitter 312 and collector 316 of the transistor 310 so that the collector 316 is coupled through the diode 318 to the first end 306' of the winding 306 (which is now, in effect, the negative terminal of winding 306), while the emitter 312 is coupled through both the resistor 320 and the series combination of the resistor 328 and the capacitor 322 (and its current limiting resistor 323) to the positive winding 306''. In such a situation, of course, the transistor 310 is not initially conductive, but becomes so only as the capacitor 322 charges to cause the voltage on the base 314 to drop below that on the emitter 312. The result is that at the beginning of each writing cycle, there is no current through the winding 306 and full power coupling to the winding 304 resulting in maximum illumination. Then, as the capacitor 322 charges and causes the transistor 310 to become more conductive, more power is dissipated in the resistor 320 to reduce the amount of power supplied to the tube 10, causing the amount of its length in the illuminated state to progressively decrease toward its anode until no illumination remains or until a new cycle is initiated, whichever comes first.

Thus, applicant's invention sets forth several new principles which in various combinations will achieve the writing effect. First and most important, illumination can be made to progress slowly along the length of a luminescent tube if the input excitation signal has its voltage amplitude, current amplitude and/or frequency increased, the rate of increase governing the rate of "writing." At the same time, the waveform of each cycle of the input excitation signal is so generated by the circuits of FIGURES 1 through 3 that numerous harmonics of the fundamental frequency are applied across the electrode or electrodes of the gas tube and that the potential of the valence electrons of the gas molecules is lowered as much as possible during the negative swing of each cycle. Illumination then occurs by gas ionization, rather than by the usual arcing which can only accomplish complete illumination of the tube between the electrodes excited.

Once illumination by ionization is used in place of arcing, the writing effect can be achieved by polarizing the tube electrodes, as the FIGURE 4 waveform will necessarily do, and then varying input excitation signal current level, voltage, or frequency, or various combinations thereof, to cause the critical ionization level for illumination to be reached at limited lengths of the tube. It should be appreciated that the length of ionization of the tube can be progressively decreased as well as progressively increased by the principles included in this invention.

The lowering of gas pressure in lighting tubes used for writing below the pressure normally used is found to facilitate achievement of the writing effect; for arcing is thereby retarded, while ionization is made easier, both due to the thinning out of electron density. The result of thus thinning the luminescent gas is that the individual valence electrons of the gas molecules have greater freedom of movement and require less energy to ionize or take complete leave of the atomic structure and, accordingly, the power level of the input excitation signal can be lowered. As the diameter of the tube increases, the pressure of the gas in the tube can be correspondingly decreased. For example, with tube diameters of 8, 10, 15 and 25 millimeters, gas pressures of 12, 10, 7 and 4 millimeters of mercury can be used. Furthermore, as the length of the tube is increased, the gas pressure used in the tube should be increased slightly.

Since high excitation voltage causes arcing and since increased excitation frequency agitates the electrons more to give the equivalent of higher pressure, the principle of lowering of excitation voltage while raising current amplitude (to increase lighting level) and frequency gives the ionization and non-arcing type illumination for accomplishing writing, yet at an acceptable level of brilliance. Brilliance can then be increased even more by the provision of metallic particles in the tube glass or vacuum-deposited thereon or by the positioning of a metallic strip along the glass. This causes the metallic material to add its own electron emission in response to that of the luminescent gas. Metallic tube glass, coating or backing also aids in controlling the length of tube illuminated and in providing a sharper light-dark boundary by providing improved conductance between the light-dark boundary to the cathode or electrode at the dark end. Without this improved conductance, the capacitance between light-dark boundary (i.e.—the end of the ionized portion) and the dark end electrode would be a strong factor in the equation of tube reactance to input power, requiring greater voltage which would increase the arcing danger. The use of a tube 10 with metallic glass 500 and/or with a metallic strip 502 is illustrated in FIGURE 5. The metallic glass 500 and/or metallic strip 502 effectively provides a capacitive effect along the ionized portion of the tube 10. This capacitive effect decreases as the ionized length of the tube increases. This causes the capacitance in the tube to decrease with increase in frequency so that a resonant effect is effectively created in the tube. This resonant effect facilitates the ionization of the gas in the tube.

Additional inventive features appear in the circuitry for producing a writing sign input excitation signal from a standard power supply; for nowhere in the prior art can one find the circuitry shown in FIGURES 1 through 3 for supplying the input excitation signals having first means for converting a power supply signal into the polarized waveform of FIGURE 4(b), rich in harmonics of the fundamental, and having a deep negative excursion at one point in each cycle while tending to increase the frequency of the FIGURE 4 waveform as input power is increased. One can also not find second means for varying the input power in the substantially "sawtooth" time-power configuration productive of writing effects.

A circuit according to the schematic of FIGURE 1 was built and operated using the following components:

Power supply:

22-24 ----- 120 volts, 60 c.p.s.

Active elements:

26 -----
56 ----- 4E30-28
104 ----- 4E20-8
120 -----
132 -----

Diodes:

58 -----

Resistors:

Ohms
36 ----- 2.0
38 ----- 20
50 ----- 8.2K
84 ----- 47
86 ----- 1,200
88 ----- 1,000
98 ----- 270
102 (pot) ----- 50K
106 ----- 27
108 ----- 15K
140 ----- 4.3K
142 ----- 390
144 ----- 47
146 ----- 10K

Capacitors:

Microfarads

20 ----- 0.75
54 ----- 0.1
100 ----- 500
110 ----- 100
130 ----- .047

Inductors:

Millihenries

112 -----

The above-specified circuit produced the waveform shown in FIGURE 4(b) with increasing frequency as the amount of power across the terminals 46 and 48 was increased. The output power across the secondary 16 was also increased by increased input power, because the length l and thus the average slope α of the declining portion of the waveform of FIGURE 4(b) are considerably shortened at high frequency, resulting in almost a square pulse. Using a 10 mm. diameter, 26 foot tube in the position 10, writing was achieved by raising the frequency of the waveform of FIGURE 4(b) from 800 c.p.s. to 6,000 c.p.s. for full illumination, while the voltage across the primary of the transformer was varied to approximately 100 volts and the voltage (maximum amplitude of the waveform of FIGURE 4(b)) across the tube was varied from 600 volts to 2,000 volts for full illumination. In comparison, with the approximately 30 milliamps of current at 9,000 volts to light a fluorescent tube at 60 c.p.s. in a conventional system, with the waveform of FIGURE 4(b) delivered at a frequency of 6,000 c.p.s., only 15 milliamps at 2,000 volts was consumed for full illumination. However, fundamental frequencies as high as 23 kilocycles per second have been achieved by the principles of this invention.

The above-described specific circuit should not be taken as a limitation of the scope of the inventive principles; it is merely to aid in thoroughly teaching the practice of the invention. The invention and its protection should extend to all writing sign systems having a lighting tube with a sealed envelope and at least one electrode and having gas in the tube with characteristics of becoming ionized and of obtaining an emission of light upon becoming ionized; circuitry electrically connected to the lighting tube and constructed to apply an AC excitation signal to the lighting tube at variable currents, voltages, and/or frequencies; and automatic, hand-operated or other means electrically connected to the first circuit means for supplying variable input electrical signals to the first circuit means whereby the first circuit means progressively varies at least one of the characteristics of current, voltage or frequency of the AC excitation signal applied to the lighting tube.

The accomplishment of the invention described above and for which protection is claimed is nothing less than the provision of the first time of input excitation signal circuitry capable of causing illumination in selectable portions of the luminescent tube less than the full length thereof; for heretofore there were no known "writing signs" in which illumination could be limited to any closely controlled, small or large portion of the whole lighting tube and could be made to progress along the tube at any desired rate, save, with incandescent bulbs, by progressively switching illumination current to the bulbs along the writing line or, with neon tubes, by constructing a long series of electrodes at 2 or 3 inch intervals along the tube and then progressively switching these electrodes into the lighting circuit. Since these multiple-incandescent and multi-electrode neon writing systems were a poor solution to the writing sign problem, the instant invention supplies, for the advertising trade especially, a great saving in manufacturing and servicing expense. Gone is the necessity of constructing neon writing tubes by penetrating the tube with an electrode every 2 or 3 inches, making manufacturing a very costly process. Even more, the maintenance of writing sign installations will no longer require the constant attention that it did when multi-electrode tubes had such very short

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operating lives because of the uneven temperature gradients and varying stresses produced by the complicated and shifting electrode energization arrangement. Thus, it is a substantial accomplishment of the present invention just to provide a gas tube writing sign in which illumination can be made to progress and regress across portions of the length of the tube merely by varying the characteristics of the input signal being applied to the usual end electrodes found in presently available gas tubes, not to mention the additional power savings and better performance of the inventive system.

The protection warranted for applicant's writing sign technique must cover several new principles which in various combinations will achieve the writing effect, as explained above. First and most important, the variation of the input excitation signal in voltage amplitude, current amplitude and/or frequency, the rate of increase or decrease governing the rate of "writing" forward (toward full illumination) or backward (after starting at full illumination). Also new with the present invention is the use of a waveform for each cycle of the input excitation signal of such shape that numerous harmonics of the fundamental frequency are applied across the electrode or electrodes of the gas tube and that the potential of the valence electrons of the gas molecules is lowered as much as possible during the negative swing of each cycle, whereby illumination can be accomplished by gas ionization, rather than by the usual arcing technique which cannot occur without causing complete illumination of the tube between the electrodes excited. Once illumination by ionization is used in place of arcing, the writing effect can be achieved by polarizing the tube electrodes, as the above-described waveform will necessarily do, and then varying input excitation signal current level, voltage, or frequency, or various combinations of these three, to cause the critical ionization level for illumination to be reached at limited lengths from the anode or positive electrode of the tube.

Another writing sign principle according to applicant's invention is the lowering of gas pressure in lighting tubes used for writing below the pressure normally used, whereby arcing is further retarded and ionization made easier due to the thinning out of electron density. The result of thinning of the luminescent gas is that the individual electrons of the gas molecules have greater freedom of movement and require less energy to ionize or take complete leave of the atomic structure, so that the power level of the input excitation signal can be lowered. Since too high an excitation voltage will cause arcing and since increased excitation frequency agitates the electrons more to give the equivalent of higher pressure, the principles of the invention include the lowering of excitation voltage while raising current amplitude (to increase lighting level) and frequency. This combination gives the ionization and non-arcing type illumination necessary when writing is to be done, yet at an acceptable level of brilliance.

As another important feature of the invention, brilliance and writing clarity can be increased even more by the provision of metallic particles in the tube glass or vacuum-deposited thereon or by the positioning of a metallic strip along the glass so that the metallic material emits secondary electrons under the influence of the free electrons excited from the luminescent gas. Metallic tube glass, coating, or backing also aids in controlling the length of tube illuminated and in providing a sharper delineation or boundary between illuminated and dark portions by improving conductance between the light-dark boundary and the electrode at the dark end (i.e.—the cathode). Without this improved conductance, the capacitance between the light-dark boundary (i.e., the end of the ionized portion of the luminescent gas) and the dark end electrode would be a strong factor in the equation of tube reactance to input power, requiring greater voltage which would increase the arcing danger.

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To summarize, the features of the above-described invention which were unknown in the prior art and entirely new and inventive include neon tube writing by the variation of voltage, current, or frequency, by the use of power supply signals which provide illumination by gas ionization rather than the usual arcing, by the lowering of gas pressure in the tubes and by the use of metallic particles or a metallic electrode to achieve brilliance and sharp delineation. Although the invention has discussed these features with a certain degree of particularity, it should be understood that the present disclosure of preferred methods of practicing the invention has been made only by way of example and that numerous changes in the details of that practice, or of the circuitry of FIGURES 1 through 3, or of the waveshape of FIGURE 4(b) may be resorted to without departing from the spirit and scope of the invention as hereinafter claimed.

What is claimed is:

1. In combination for use with a tube having a sealed envelope and having an electrode disposed within the sealed envelope and having gas disposed within the sealed envelope with characteristics of becoming ionized to produce a luminescent effect:

a lighting tube having a sealed envelope with a particular length and having only a pair of electrodes at opposite ends of the tube and having gas in the tube with characteristics of becoming ionized and of obtaining an emission of light upon becoming ionized;

first means electrically connected to the pair of electrodes for obtaining an ionization of the gas along a portion of the particular length of the tube and an illumination of the tube along the ionized portion of the tube; and

second means for progressively varying the portion of the particular length in which the gas in the tube is ionized.

2. The combination set forth in claim 1 wherein the first means introduce a signal to the tube to ionize the gas in the tube along the portion of the particular length of the tube and wherein the second means vary such signal to obtain progressive variations in the portion of the particular length in which the gas in the tube is ionized.

3. In combination:

a lighting tube having a sealed envelope with a particular length and having a pair of electrodes at spaced positions within the envelope and having gas at a relatively low pressure in the tube with characteristics of becoming ionized and of obtaining an emission of light upon becoming ionized, the pressure of the gas in the tube being less than that for producing arcing of the gas in the tube;

first circuit means electrically connected to the lighting tube and constructed to apply an AC excitation signal to the lighting tube at variable currents, voltages and frequencies to obtain an illumination along progressive portions of the particular length of the tube in accordance with variations in the currents, voltages and frequencies; and

second circuit means electrically connected to the first circuit means for supplying time-variable input electrical signals to the first circuit means whereby the first circuit means varies at least one of the characteristics of current, voltage and frequency of the AC excitation signal applied to the lighting tube in a particular pattern to vary the illumination of the tube along the progressive portions of the particular length in accordance with such particular pattern.

4. In combination:

a lighting tube having a sealed envelope with a particular length and having only a pair of electrodes at spaced positions within the envelope and having gas in the tube with characteristics of becoming ionized and of obtaining an emission of light upon becoming

ionized, the pressure of the gas in the tube being relatively low to provide an ionization of the gas in the tube and an emission of light in accordance with such ionization and to inhibit arcing of the gas in the tube;

first circuit means electrically connected to the pair of electrodes in the lighting tube and constructed to apply an asymmetrical, harmonic-rich AC excitation signal to the lighting tube at variable currents, voltages and frequencies to obtain an illumination of the tube along progressive portions of the particular length in accordance with variations in the currents, voltages and frequencies; and

second circuit means electrically connected to the first circuit means for supplying input electrical signals to the first circuit means at variable levels of power in a particular pattern to cause the first circuit means to vary at least one of the characteristics of current, voltage or frequency of the AC excitation signal applied to the lighting tube for providing variations in the illuminated length of the tube in accordance with such particular pattern.

5. In combination for use with a tube having a sealed envelope and having a pair of electrodes disposed at spaced positions within the sealed envelope and having gas disposed within the sealed envelope with characteristics of becoming ionized and resonant to produce a luminescent effect, the pressure of the gas within the envelope being relatively low to provide an ionization of gas in the envelope and an emission of gas in accordance with such ionization and to inhibit arcing of the gas in the envelope:

first means for providing a first voltage pulse with sharply negative characteristics and with an amplitude for reforming ions into molecules of the gas;

second means operatively coupled to the first means and to the electrode of the tube for producing a second voltage pulse immediately after the formation of the first voltage pulse, with sharply positive characteristics and with an amplitude for obtaining the production of ions from the molecules of the gas and for instituting the resonances of the gas in the tube;

third means responsive to the formation of the second voltage pulse for producing a voltage portion of positive polarity and with a negative slope and a duration dependent upon the frequencies of the resonances in the tube; and

power supply means for supplying input power to the first, second and third means at variable levels of power in a particular pattern to cause progressive variations in the length of that portion of the tube along which ionization occurs in accordance with such particular pattern.

6. In combination:

a tube having a sealed envelope with a particular length and having only a pair of electrodes at spaced positions in the sealed envelope and having in the sealed envelope molecules of gas with characteristics of becoming ionized and of obtaining an emission of light upon becoming ionized, the pressure of the gas within the envelope being relatively low to provide an ionization of gas in the envelope and an emission of gas in accordance with such ionization and to inhibit arcing of the gas in the envelope;

first circuit means electrically coupled to the electrodes in the tube to introduce to the electrodes a voltage having an asymmetrical waveform and having a first portion of a first polarity and a second portion of a second polarity opposite to the first polarity with the first portion of the first polarity having a greater duration than the second portion of the second polarity and with the amplitude of the second portion having a considerable amplitude to obtain an ionization of a

portion of the envelope along the particular length; and

second circuit means electrically connected to the first circuit means for supplying to the first circuit means input signals having characteristics variable in a particular pattern with time whereby the first circuit means varies at least one of the characteristics of current, voltage or frequency of the AC excitation signal applied to the lighting tube in accordance with the variable time characteristics of the input electrical signals to obtain an ionization of progressive portions of the envelope along the particular length.

7. In combination:

a power supply constructed to provide input power; a tube having a sealed envelope of a particular length and having only a pair of electrodes at spaced positions within the envelope and having gas in the tube with characteristics of becoming ionized and of obtaining an emission of light upon becoming ionized, the tube and the gas in the tube having characteristics to provide resonances in the tube at particular frequencies constituting harmonics of one another and to provide ionization of the gas in variable lengths of the tube in accordance with the frequencies of signals applied to the tube and a luminance of the ionized portion of the tube;

first circuit means constructed to operate from variable levels of input power from the power supply and electrically coupled to the electrodes in the tube to provide for the introduction of energy to the tube at a fundamental frequency and a spectrum of harmonics including the resonant frequencies in the tube, the first circuit means including means responsive to the resonant characteristics of the tube and variable according to the input power level from the power supply for adjusting the fundamental frequency and the harmonics of the fundamental frequency supplied to the tube to frequencies and levels for the ionization of the gas in variable portions of the length of the tube in accordance with such frequencies and levels; and

second circuit means electrically connected between the power supply and the first circuit means for controlling in a particular pattern the level of the input power introduced from the power supply to the first circuit means to obtain an ionization of progressive portions of the length of the tube.

8. In combination:

a tube having a sealed envelope of a particular length and having only a pair of electrodes disposed at spaced positions within the envelope for conducting an input electrical signal into the sealed envelope and having in the sealed envelope molecules of a luminescent gas with characteristics of becoming ionized and of obtaining an emission of light upon becoming ionized, the pressure of the gas within the envelope being relatively low to provide an ionization of gas in the envelope and an emission of gas in accordance with such ionization and to inhibit arcing of the gas in the envelope;

first circuit means electrically coupled to the electrodes in the tube to introduce to the electrodes a voltage having an asymmetrical waveform and having a first portion of a first polarity and a second portion of a second polarity opposite to the first polarity with the first portion of the first polarity having a greater duration than the second portion of the second polarity to obtain an ionization of the gas in a portion of the particular length of the tube and a luminescence of the tube in the ionized portion of the tube; and

second circuit means electrically connected to the first circuit means for varying the frequency of the waveform introduced to the electrodes of the tube in a

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particular pattern throughout a range causing progressive light-emission ionization over the length of the tube from a condition of light-emission ionization in a relatively small portion of the particular length of the tube through continuous states of light-emission ionization of progressive portions of the length of the tube in accordance with such particular pattern.

9. The lighting system according to claim 8 with the additional characterization that the voltage level of the waveform introduced to the electrode of the tube is also variable in an individual pattern throughout a range causing light-emission ionization through progressive portions of the length of the tube in accordance with such individual pattern.

10. In combination:

a tube having a sealed envelope of a particular length and having only a pair of electrodes disposed at spaced positions within the sealed envelope for conducting an input electrical signal into the sealed envelope and having in the sealed envelope molecules of a luminescent gas with characteristics of becoming ionized and of obtaining an emission of light upon becoming ionized, the pressure of the gas within the envelope being relatively low to provide an ionization of gas in the envelope and an emission of gas in accordance with such ionization and to inhibit arcing of the gas in the envelope;

first circuit means electrically coupled to the electrodes in the tube to introduce to the electrodes a voltage having an asymmetrical waveform and having a first portion of a first polarity and a second portion of a second polarity opposite to the first polarity with the first portion of the first polarity having a greater duration than the second portion of the second polarity to obtain an ionization of a portion of the particular length of the tube; and

second circuit means for varying the voltage of the waveform introduced to the electrodes of the tube in a particular pattern throughout a range causing light-emission ionization over progressive lengths of the tube in accordance with such particular pattern.

11. The lighting system according to claim 10 with the additional characterization that the current of the waveform introduced to the electrode of the tube is also variable in an individual pattern throughout a range causing progressive light-emission ionization over the variable portions of the length of the tube in accordance with such individual pattern.

12. In combination:

a tube having a sealed envelope of a particular length and having only a pair of electrodes disposed at spaced positions within the tube for conducting an input electrical signal into the sealed envelope and having in the sealed envelope molecules of a luminescent gas with characteristics of becoming ionized in accordance with the characteristics of an electrical current in the tube and of obtaining an emission of light upon becoming ionized, the pressure of the gas within the envelope being relatively low to provide an ionization of gas in the envelope and an emission of gas in accordance with such ionization and to inhibit arcing of the gas in the envelope;

first circuit means electrically coupled to the electrodes in the tube to introduce to the electrodes a voltage having an asymmetrical waveform and having a first portion of a first polarity and a second portion of a second polarity opposite to the first polarity with the first portion of the first polarity having a greater duration than the second portion of the second polarity to obtain an ionization of the gas in a portion of the particular length of the tube and an illumination of the tube in the ionized portion of the tube; and

second circuit means for varying the waveform of the

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current flowing through the tube in accordance with the voltage introduced to the electrodes of the tube in a particular pattern throughout a range causing light-emission ionization over progressive portions of the length of the tube in accordance with such particular pattern.

13. The lighting system according to claim 12 with the additional characterization that the frequency of the waveform introduced to the electrodes of the tube is also variable in an individual pattern throughout a range causing light-emission ionization over progressive portions of the length of the tube in accordance with such individual pattern.

14. The lighting system according to claim 12 with the additional characterization that the voltage and frequency of the waveform introduced to the electrodes of the tube are also variable in an individual pattern throughout a range causing light-emission ionization over progressive portions of the length of the tube in accordance with such individual pattern.

15. In combination:

a tube having a sealed envelope with a particular length and having gas in the sealed envelope at a reduced pressure to produce ionization of the gas in the envelope relative to the pressure for producing arcing of the gas in the tube;

means operatively coupled to the tube for introducing a signal to the tube with characteristics to provide an ionization of the gas along a portion of the particular length of the tube; and

means operatively coupled to the last-mentioned means for varying the characteristics of the signal to vary progressively the length of the tube along which the ionization occurs.

16. The combination set forth in claim 15, wherein:

a pair of electrodes are disposed at spaced positions along the length of the tube to facilitate the ionization of the gas at the reduced pressure in the tube along a length dependent upon the characteristics of the signal introduced to the tube.

17. In combination:

a tube having a sealed envelope with a particular length and having first and second electrodes at spaced positions within the tube and having gas in the sealed envelope and having a reduced pressure of the gas in the sealed envelope to obtain an ionization of the gas in the envelope rather than an arcing of the gas in the envelope;

means operatively coupled to the first and second electrodes of the tube for obtaining an ionization of the gas in the tube along a portion of the particular length of the tube; and

means operatively coupled to the last-mentioned means for obtaining an ionization of the gas in the tube along progressively variable portions of the particular length of the tube in a particular pattern with respect to time.

18. In combination:

a power supply having first and second terminals; power varying means having input, output and control terminals, the first power supply terminal being coupled to the input terminal of the power varying means;

a first gating element having conductive and non-conductive states and having a plurality of electrodes including a control electrode, at least one electrode of the first gating element being coupled to the control terminal of the power-varying means;

means including a photocell electrically connected to the control electrode of the first gating element for supplying gating signals whereby the first gating element is alternately switched between its conductive and non-conductive states;

a transformer having a primary winding and a secondary winding, the primary winding of the transformer hav-

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ing first and second terminals, the first terminal of the primary winding of the transformer being electrically connected to the second terminal of the power supply;

- a capacitor connected between the first and second terminals of the primary of the transformer to form a tank circuit therewith; 5
- a second gating element having conductive and non-conductive states connected between the output terminal of the power-varying means and the second terminal of the primary of the transformer, the second gating element having a control electrode; 10
- means coupled to the control electrode of the second gating element for switching the second gating element between its conductive and non-conductive states in response to the instantaneous magnitude of power between the output terminal of the power-varying means and the second terminal of the transformer; and 15
- a lighting tube having a sealed envelope with a particular length and having only a pair of electrodes disposed at spaced positions within the tube and having gas in the tube at a reduced pressure with characteristics of becoming ionized rather than arcing and of obtaining an emission of light upon becoming ionized, the electrodes being electrically connected to the secondary of the transformer to provide an ionization of progressive portions of the particular length of the tube and an illumination of such progressive portions in accordance with the ionization. 20
- 19. In combination: 30
- an AC power supply having first and second terminals;
- a magnetic amplifier having first and second input terminals, first and second control terminals, and first and second output terminals, the first and second AC power supply terminals being coupled to the first and second input terminals of the magnetic amplifier; 35
- a transistor having emitter, base and collector;
- a rectifying element coupled between the first control terminal of the magnetic amplifier and the emitter of the transistor; 40
- a first resistor coupled between the emitter and the base of the transistor;
- a second resistor coupled between the collector and the base of the transistor;
- the parallel combination of first triggering means and a first capacitor coupled between the base of the transistor and the second control terminal of the magnetic amplifier; 45
- a variable resistor connected between the collector of the transistor and the second control terminal of the magnetic amplifier; 50
- a transformer having a primary winding and a secondary winding, the primary winding of the transformer having first and second terminals, the first terminal of the primary winding of the transformer being electrically connected to the first output terminal of the magnetic amplifier; 55
- a second capacitor connected between the first and second terminals of the primary of the transformer;
- a silicon-control rectifier connected between the second output terminal of the diode-bridge rectifier and the second terminal of the primary of the transformer, the silicon-control rectifier having a plurality of electrodes including a control electrode; 60
- the series combination of a third resistor and a third capacitor connected between the second output terminal of the magnetic amplifier and the second terminal of the transformer; 65
- second triggering means connected from a point between the third resistor and the third capacitor and the control electrode of the silicon-control rectifier; and 70
- a lighting tube having a sealed envelope with a particular length and having only a pair of electrodes disposed at spaced positions within the tube and having 75

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gas in the tube at a reduced pressure with characteristics of becoming ionized rather than arcing and of obtaining an emission of light upon becoming ionized, the electrodes being electrically connected to the secondary of the transformer to provide an ionization of progressive portions of the particular length of the tube and an illumination of such particular portions in accordance with the ionization.

20. In combination:

- an AC power supply having first and second terminals;
- a diode-bridge rectifier having first and second input terminals and first and second output terminals, the first AC power supply terminal being coupled to the first input terminal of the diode-bridge rectifier;
- a first silicon-control rectifier having input, output and control electrodes, the input and output electrodes of the first silicon-control rectifier being coupled between the second terminal of the AC power supply and second control terminal of the diode-bridge rectifier;
- the series combination of a photocell, a first resistor and a first capacitor coupled between the input and output electrodes of the first silicon-control rectifier; triggering means coupled from a point between the first resistor and the first capacitor to the control electrode of the first silicon-control rectifier;
- a light source operatively associated with the photocell such that variations in the intensity of light received from the light source by the photocell vary the electrical resistance of the photocell;
- means including a resistance-capacitance timing circuit electrically connected between the AC power supply and the light source for causing the intensity of the output of the light source to vary cyclically with time;
- a second capacitor coupled across the output terminals of the diode-bridge rectifier;
- a transformer having a primary winding and a secondary winding, the primary winding of the transformer having first and second terminals, the first terminal of the primary winding of the transformer being electrically connected to the first output terminal of the diode-bridge rectifier;
- a third capacitor connected between the first and second terminals of the primary of the transformer;
- a second silicon-control rectifier connected between the second output terminal of the diode-bridge rectifier and the second terminal of the primary of the transformer, the second silicon-control rectifier having a plurality of electrodes including a control electrode;
- the series combination of a second resistor and a fourth capacitor connected between the second output terminal of the diode-bridge rectifier and the second terminal of the transformer;
- second triggering means connected from a point between the second resistor and the fourth capacitor and the control electrode of the second silicon-control rectifier; and
- a lighting tube having a sealed envelope with a particular length and having only a pair of electrodes disposed at spaced positions within the tube and having gas in the tube at a reduced pressure with characteristics of becoming ionized rather than arcing and of obtaining an emission of light upon becoming ionized, the electrodes being electrically connected to the secondary of the transformer to provide an ionization of progressive portions of the particular length of the tube and an illumination of such particular portions in accordance with the ionization.
- 21. In combination:
- an AC power supply having first and second terminals;
- a diode-bridge rectifier having an input terminal, an output terminal, and first and second control terminals, the first AC power supply terminal being coupled to the input terminal of the diode-bridge rectifier;

- a first silicon-control rectifier having input, output and control electrodes, the input and output electrodes of the first silicon-control rectifier being coupled to the first and second control terminals of the diode-bridge rectifier;
- the series combination of a first resistor and a first capacitor coupled between the input and output electrodes of the first silicon-control rectifier;
- a photocell coupled in parallel with the first resistor; triggering means coupled from a point between the first resistor and the first capacitor to the control electrode of the first silicon-control rectifier;
- a second capacitor coupled across the control terminals of the diode-bridge rectifier;
- filtering means coupled between the output terminal of the diode-bridge rectifier and the second terminal of the AC power supply;
- a transformer having a primary winding and a secondary winding, the primary winding of the transformer having first and second terminals, the first terminal of the primary winding of the transformer being electrically connected to the second terminal of the AC power supply;
- a third capacitor connected between the first and second terminals of the primary of the transformer;
- a second silicon-control rectifier connected between the filtering means and the second terminal of the primary of the transformer, the second silicon-control rectifier having input, output and control electrodes;
- the series combination of a second resistor and a fourth capacitor connected between the output of the filtering means and the second terminal of the transformer;
- second triggering means connected from a point between the second resistor and the fourth capacitor and the control electrode of the second silicon-control rectifier; and
- a lighting tube having a sealed envelope with a particular length and having only a pair of electrodes disposed at spaced positions within the tube and having gas in the tube at a reduced pressure with characteristics of becoming ionized rather than arcing and of obtaining an emission of light upon becoming ionized, the electrodes being electrically connected to the secondary of the transformer to provide an ionization of progressive portions of the particular length of the tube and an illumination of such particular portions in accordance with the ionization.
- 22. In combination:**
- a power supply having first and second terminals;
- power-metering means having first and second input terminals and first and second output terminals, the first power supply terminal being coupled to the first input terminal of the power-metering means;
- a first active switching element having conductive and non-conductive states and having input, output and control electrodes, the input and output electrodes of the first active switching element being coupled between the second power supply terminal and the second control terminal of the power-metering means;
- timing means including a photocell and a first capacitor electrically connected to the control electrode of the first active switching element for switching the first active switching element between its conductive and non-conductive states periodically with timing determined by the electrical resistance of the photocell and the capacitance of the first capacitor;
- a light source operatively associated with the photocell such that variations in the intensity of light received from the light source by the photocell vary the electrical resistance of the photocell;
- means electrically connected between the power supply and the light source for causing the intensity of the

- output of the light source to vary cyclically with time;
- a transformer having a primary winding and a secondary winding, the primary winding of the transformer having first and second terminals, the first terminal of the primary winding of the transformer being electrically connected to the first output terminal of the power-metering means;
- a second active switching element connected between the second output terminal of the power-metering means and the second terminal of the primary of the transformer, the second active switching element having a plurality of electrodes including a control electrode;
- the series combination of a resistor and a second capacitor connected between the second output terminal of the power-metering means and the second terminal of the transformer, the control electrode of the second active switching element being electrically connected to a point between the resistor and the second capacitor; and
- a lighting tube having a sealed envelope with a particular length and having only a pair of electrodes disposed at spaced positions within the tube and having gas in the tube at a reduced pressure with characteristics of becoming ionized rather than arcing and of obtaining an emission of light upon becoming ionized, the electrodes being electrically connected to the secondary of the transformer to provide an ionization of progressive portions of the particular length of the tube and an illumination of such particular portions in accordance with the ionization.
- 23. In combination:**
- a power supply having first and second terminals;
- a magnetic amplifier having first and second input terminals, first and second control terminals, and first and second output terminals, the first and second power supply terminals being coupled to the first and second terminals of the magnetic amplifier;
- means coupled across the control terminals of the magnetic amplifier for varying the level of saturation of the magnetic amplifier to cause variation in the power appearing at the output terminals of the magnetic amplifier;
- a transformer having a primary winding and a secondary winding, the primary winding of the transformer having first and second terminals, the first terminal of the primary winding of the transformer being electrically connected to the first output terminal of the magnetic amplifier;
- an active switching element connected between the second output terminal of the magnetic amplifier and the second terminal of the primary of the transformer, the active switching element having a plurality of electrodes including a control electrode;
- the series combination of a resistor and a capacitor connected between the second output terminal of the magnetic amplifier and the second terminal of the transformer, the control electrode of the second active switching element being electrically connected to a point between the resistor and the capacitor; and
- a lighting tube having a sealed envelope with a particular length and having only a pair of electrodes disposed at spaced positions within the tube and having gas in the tube at a reduced pressure with characteristics of becoming ionized rather than arcing and of obtaining an emission of light upon becoming ionized, the electrodes being electrically connected to the secondary of the transformer to provide an ionization of progressive portions of the particular length of the tube and an illumination of such particular portions in accordance with the ionization.
- 24. In combination:**
- a transformer having a primary winding and a sec-

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- ondary winding, the primary winding of the transformer having first and second terminals;
- a first active switching element having a plurality of electrodes including a control electrode and being coupled to the first terminal of the transformer primary;
- the series combination of a resistor and a first capacitor connected across the first active switching element, the control electrode of the first active switching element being electrically connected to a point between the resistor and the first capacitor;
- a lighting tube having a sealed envelope and having at least one electrode and having gas in the tube with characteristics of becoming ionized and of obtaining an emission of light upon becoming ionized electrically connected to the secondary of the transformer;
- a power supply having first and second terminals, the first terminal of the power supply being connected to the second terminal of the primary winding of the transformer;
- a second active switching element having conductive and non-conductive states and having input, output and control electrodes, the input and output electrodes of the second active switching element being coupled between the second power terminal and an electrode of the first active switching element;
- timing means including a photocell electrically connected to the control electrode of the second active switching element for switching the second active switching element between its conductive and non-conductive states periodically with timing varied by the variation in electrical resistance of the photocell; and
- a light source operatively associated with the photocell such that variations in the intensity of light received from the light source by the photocell vary the electrical resistance of the photocell.
- 25. In combination:**
- a power supply having first and second terminals; power-varying means for supplying time-variable electric signals varying in at least one of the characteristics of current, voltage, or frequency and having input, output and control terminals, the first power supply terminal being coupled to the input terminal of the power-varying means;
- a transformer having a primary winding and a secondary winding, the primary winding of the transformer having first and second terminals, the first terminal of the primary winding of the transformer being electrically connected to the second terminal of the power supply;
- a gating element having conductive and non-conductive states and coupled to receive the output electrical signals of the power-varying means and also connected to the second terminal of the primary of the transformer, the gating element having control and other electrodes;
- means coupled to the control electrode of the gating element for switching the gating element between its conductive and non-conductive states in response to the instantaneous magnitude of power between the output terminal of the power-varying means and the second terminal of the transformer; and
- a lighting tube having a sealed envelope with a particular length and having only a pair of electrodes disposed at spaced positions within the tube and having

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- gas in the tube at a reduced pressure with characteristics of becoming ionized rather than arcing and of obtaining an emission of light upon becoming ionized, the electrodes being electrically connected to the secondary of the transformer to provide an ionization of progressive portions of the particular length of the tube and an illumination of such particular portions in accordance with the ionization.
- 26. In combination:**
- a tube having a sealed envelope with a particular length and having gas in the sealed envelope at a reduced pressure in the sealed envelope relative to that for producing arcing to obtain an ionization of the gas in the tube and a luminescence of the tube at the positions of the ionization;
- a metallic element fixedly disposed along the particular length of the sealed envelope;
- means operatively coupled to the tube for introducing a signal to the tube with characteristics to provide an ionization of the gas along a portion of the particular length of the tube; and
- means operatively coupled to the last-mentioned means for varying the characteristics of the signal to vary progressively the portion of the particular length of the tube along which the ionization occurs.
- 27. The combination set forth in claim 26 wherein:** the metallic element includes metallic particles incorporated in the glass envelope of the tube to facilitate the ionization of the gas at the reduced pressure in the tube along a portion of the particular length dependent upon the characteristics of the signal introduced to the tube.
- 28. The combination set forth in claim 26 wherein:** the metallic element includes metallic particles coated on the sealed envelope of the tube to facilitate the ionization of the gas at the reduced pressure in the tube along a portion of the particular length dependent upon the characteristics of the signal introduced to the tube.
- 29. The combination set forth in claim 26 wherein:** the metallic element includes a metallic strip mounted lengthwise on the sealed envelope of the tube to facilitate the ionization of the gas at the reduced pressure in the tube along a portion of the particular length dependent upon the characteristics of the signal introduced to the tube.

References Cited

UNITED STATES PATENTS

2,598,241	5/1952	Elenbaas et al.	
2,696,584	12/1954	Lion et al.	315—357 X
2,736,842	2/1956	Mann	315—335 X
3,016,478	1/1962	Kadell.	
3,265,907	8/1966	Kurata et al.	
3,299,320	1/1967	Kurata	307—252
3,308,342	3/1967	Coradeschi	315—209 X
3,344,311	9/1967	Nuckolls.	

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