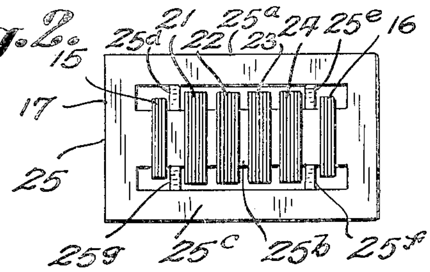
March 13, 1934. C. P. BOUCHER 1,950,396

ELECTRIC LUMINESCENT TUBE SYSTEM AND APPARATUS

Original Filed Dec. 12, 1932

Fig. 2.



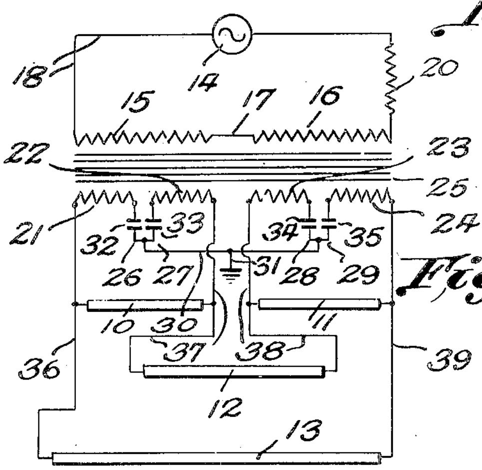


Fig. 1.

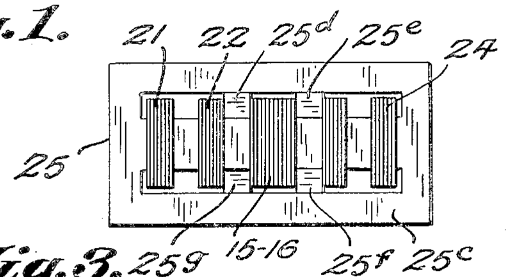


Fig. 4.

Fig. 3.

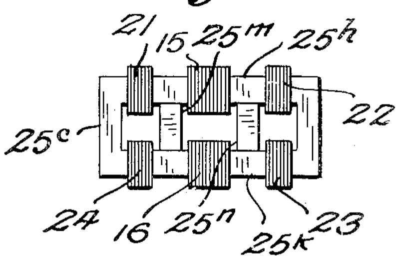
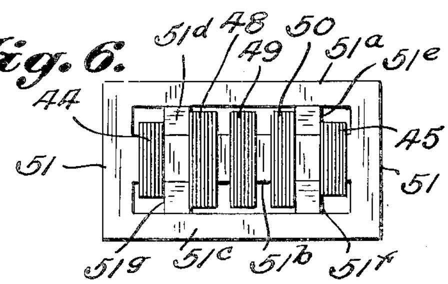


Fig. 6.



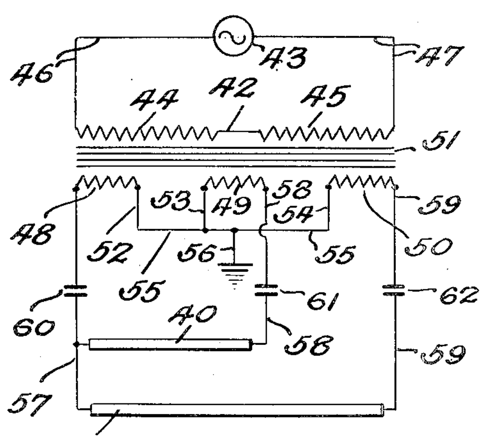


Fig. 7.

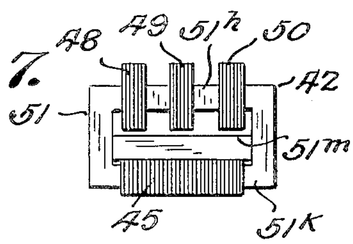


Fig. 5.

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1,950,396

ELECTRIC LUMINESCENT TUBE SYSTEM AND APPARATUS

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Original application December 12, 1932, Serial No. 646,780. Divided and this application June 24, 1933, Serial No. 677,518

13 Claims. (Cl. 176—124)

This invention is a division of my copending application Serial Number 646,780, filed December 12, 1932, entitled Means for operating gas filled luminescent tubes, which is a continuation in part of the invention disclosed in my copending application Serial Number 580,793, filed December 14, 1931, entitled Electrical operating devices for neon and like signs, and relates to a luminescent gas-filled tube electrical sign or display system and apparatus.

One of the objects of my invention is to provide a simple, inexpensive, and thoroughly practical system and apparatus for the highly efficient and reliable operation of luminescent tubes or gaseous conduction devices, such as neon tubes, of various shapes and sizes comprising, for example, a neon electric sign.

Another object is to maintain maximum clear and brilliant operation of luminescent tubes or devices of the character indicated throughout long periods of continuous use at maximum operating efficiency and at minimum expense.

Another object is to assure uniform brilliant operation of the various individual luminescent gas-filled tubes forming part of a single luminescent sign or display in spite of various inequalities and differences in the tubes in matters of size, shape, the nature and pressure of the gas employed and other physical differences which affect the electrical characteristics of the tubes employed.

Other objects in part will be obvious and in part pointed out hereinafter.

The invention accordingly consists in the various combinations of elements, features of construction and arrangements of parts as described herein, and the scope of the application of which is indicated in the following claims.

In the accompanying drawing Figure 1 is a diagrammatic representation of my system and apparatus for operating a number of luminescent tubes comprising a single display, Figures 2, 3 and 4 indicate various embodiments of transformers which may be employed in the system and apparatus of Figure 1, Figure 5 is a diagrammatic representation of a modified system and apparatus for operation of a number of luminescent tubes comprising a single display, and Figures 6 and 7 are embodiments of transformers employed in the system and apparatus of Figure 5.

As conducive to a clearer understanding of certain features of my invention it may be noted at this point that in the operation of luminescent gas filled tubes or devices of the character indicated from a source of alternating current electrical energy the instantaneous resistance of any one tube or device varies greatly from the time when the instantaneous value of the applied potential is insufficient to cause an ionized condition of the contained gas (during which the tube is of high electrical resistance, is non-conductive and is non-luminous) and when the applied potential, in either the alternatively positive or negative portion of the cycle has risen to such a value as to ionize the gas and thus cause the tube to become a good conductor of comparatively low resistance and luminescent. Where the ionized or conductive condition of the tube is established a substantial current flows through the tube until the continuously changing applied potential has fallen to such a low value that the ionized condition of the tube may no longer be maintained. At this time the tube again becomes non-conductive and non-luminous and remains so until the instantaneous value of the applied potential again rises, in following through the cycle of alternations, to a point sufficient to again cause the gas to become ionized, conductive and luminous.

The proportion of the time of a complete cycle of alternations of the source of electrical energy that the gas filled tube is luminescent depends, first, upon the proportionate length of time that the tube is rendered conductive (the proportionate period between the time when the instantaneous potential becomes sufficient to ionize the gas contained in the tube and the time when this potential falls to such a value that the ionized condition may no longer be maintained) and, second, upon the proportion of this proportionate length of time that the current density within the conductive tube (influenced by other elements, such as capacitances, inductances and resistances in the electrical circuit of the gas-filled tube) is sufficient to render the tube luminescent.

It may also be noted that luminescent gas-filled tubes of the class indicated comprising a single luminescent sign or display or of different sizes and shapes conforming to certain designs and configurations so as to give a desired arrangement for a combined effect. Due to the variations in physical dimensions the electrical characteristics of the several tubes vary considerably particularly in the matter of the potential at which the tubes start or become ionized, the potential at which ionization may no longer be maintained, and the electrical conductance (or resistance) during the ionized conductive condition.

As more particularly indicated above, the resistance of any one of the gas-filled tubes of a single display varies greatly for the ionized condition of the gas, during which the resistance is comparatively low; a characteristic which renders the tube inherently unstable and exceedingly difficult to effectively control.

In heretofore known and/or used luminescent sign systems and apparatuses of the class indicated employing a plurality of gas-filled luminescent tubes, great difficulty is experienced in achieving uniform stable operation of the system. Thus, where a plurality of tubes of the class indicated are connected to a source of high potential electrical energy (the tubes are ordinarily connected in parallel in order to prevent the required electrical potential from reaching prohibitive values), due to the necessary variations in the electrical characteristics of the tubes employed as well as the inherent instability of the individual tubes, there is a tendency for the tube of lowest starting potential or of highest conductance to draw such a large part of the instantaneous load current available that the other tubes either fail to start, or, where they do start, draw such light currents that the current densities are wholly insufficient to produce the desired brilliant glow. In addition to non-uniform and wholly unsatisfactory operation of the several tubes when taken as a group or a single luminous display there is the further difficulty of preventing the tube drawing the excessive current from burning out within a comparatively short time.

Thus, in heretofore known luminescent sign systems of the class indicated, the several gas-filled tubes employed, because of the inherent instability and varied individual electrical characteristics thereof as more particularly referred to above, are either energized from individual sources of high potential electrical energy, or supplied with energy from the various phases of a polyphase electrical system, or excited from separate high-potential electrical transforming apparatus connected with a single source of electrical energy. All of these systems and apparatuses are large and cumbersome requiring much expensive apparatus which is costly to maintain and operate and which is generally inefficient and unreliable.

Accordingly, one of the outstanding objects of my invention is to provide a system and apparatus of compact, inexpensive and practical construction for operating luminescent tubes or gaseous conduction devices of the class indicated in an economical and thoroughly reliable manner from readily available alternating current electrical energy to achieve a uniform brilliant display of a desired character.

Referring now more particularly to the practice of my invention, attention is directed to Figure 1 of the drawing wherein a plurality of luminescent gas-filled tubes, 10, 11, 12 and 13 are suitably mounted in a desired arrangement comprising a luminescent display or sign 10—11—12—13. Illustratively, the tubes or devices 10, 11, 12 and 13 are of approximately the same current ratings, but of slightly different ratings in starting potentials. Thus, for example, the tubes 10, 11 and 12 require about the same value of starting potential while the tube 13 requires a somewhat increased potential.

Each of the luminescent tubes, as more fully described in my copending application Serial Number 580,793, preferably comprises an elongated clear glass envelope having sealed-in electrodes at opposite ends. The envelope is filled with a gas, neon for example, at low pressure which has the property of becoming luminescent upon being electrically excited.

As the column of gas contained within the glass envelope is subjected to a high electrical potential applied across the tube electrodes, in a manner more particularly described hereinafter, the gas becomes ionized and the tube, formerly non-conductive, is rendered conductive permitting the flow of an electric current through the ionized gas and the emission of a luminous glow which, for neon, is red-orange in color. The intensity or brilliancy of this glow, as more particularly indicated above, is largely dependent upon the current density within the column of ionized gas; for low current densities (where the flow of current is greatly limited by other elements contained in the electrical current supplying the luminescent tube) the glow is weak and poorly distributed along the length of the tube, but for reasonably high densities the tube gives forth a brilliant luminous glow which is well distributed along the length of the tube. For maximum efficient luminescence reasonably high current densities are desired. Due, however, to the inherently unstable characteristics of the luminescent tubes or gaseous conduction devices, all as more particularly referred to above, special precautions are taken to assure a flow of current which is sufficient to give a desired brilliant operation of the several tubes comprising the luminous display yet which is insufficient to burn out or otherwise damage the tubes.

Referring now back to Figure 1, the various luminescent tubes 10, 11, 12 and 13 are preferably supplied with alternating current electrical energy from a readily available single phase source of electrical energy 14, illustratively 220 volts at 60 cycles per second, which is connected to the luminescent tubes by an electrical system and apparatus more fully described below.

In accordance with the provisions of my invention electrical energy from source 14 is supplied the primary winding 15—16 of a transformer generally indicated at 17 by way of suitable conductors 18 and 19. There is preferably included in the supply conductor 19 an impedance element 20, preferably a resistance unit, the purpose of which will appear more fully hereinafter.

A plurality of coil sections of approximately the same impedance and voltage ratings, illustratively four, 21, 22, 23 and 24, comprise the high voltage secondary winding of the transformer. In order to achieve a maximum possible inductive linkage between primary winding 15—16 and secondary winding 21—22—23—24 during the initial periods of each half cycle both the primary and the secondary windings are mounted on a common magnetic core diagrammatically indicated at 25 (see also Figures 2, 3 and 4). The relative placement of the primary and secondary winding coil sections on the magnetic core in order to achieve desired results appears more fully hereinafter.

One end of each of the various transformer secondary winding coil sections 21, 22, 23 and 24 are preferably connected by way of the respective conductors 26, 27, 28 and 29 to a common conductor 30 which is conveniently grounded as at 31. The connections are made so as to establish a point of common potential for all of the coil sections and to place, preferably, half of the coil sections in phase sequence opposite the remaining half to permit combinations of two of said coil sections in additive or cumulative operation supplying independent loads wherein each coil section supplies two loads, all as appears more fully hereinafter; each coil section being designed to have a current carrying capacity of two of said loads. Thus, for an assumed induced potential in all of the secondary winding coil sections in a direction of from left to right as seen in Figure 1 respecting the point of common potential established by conductors 26, 27, 28, 29 and 30, the coil sections 21 and 23 are in the same phase sequence and are in opposition to coil sections 22 and 24. Both coil sections 21 and 23 may be cumulatively connected to each of the coil sections 22 and 24 to supply a plurality of independent loads as more particularly described below.

There is preferably included in the respective conductors 26, 27, 28 and 29 the capacitive impedance element or condensers 32, 33, 34 and 35 which, in a measure, serve to stabilize the operation of the several luminescent tubes as well as to extend the luminescent periods of these tubes and to improve the power factors of the several tube circuits all as will appear more fully hereinafter.

The several luminescent tubes or gaseous conduction devices 10, 11, 12 and 13 are preferably supplied with high potential electrical energy from combinations of two of the illustratively four transformer secondary winding coil sections; the combination of coil sections connected to any one of the gaseous conduction devices is not repeated but each conduction device is supplied with high potential electrical energy from a combination of series connected coil sections which is not duplicated for any of the others.

For example, luminescent tube or gaseous conduction device 10 is supplied with high potential electrical energy from the transformer secondary winding coil sections 21 and 22 which, as indicated above, are connected together by conductors 26 and 27 and the interposed condensers 32 and 33 to permit a cumulative connection, by way of conductors 36 and 37. Likewise, the luminescent tube 11 is supplied with high-potential electrical energy from the secondary winding coil sections 23 and 24, which are interconnected to permit an additive effect by conductors 28 and 29 and the interposed condensers 34 and 35, by way of conductors 38 and 39. Similarly the tube 12 is supplied with high-potential energy from the coil sections 22 and 23, interconnected to permit an additive effect by conductors 27, 28 and 30 and the included condensers 33 and 34, by the two conductors 37 and 38. And, likewise, the tube 13 is supplied with energy from the coil sections 21 and 24, likewise connected together by conductors 26, 29 and 30 and the interposed condensers 32 and 35, the conductors 36 and 39. Each coil section supplies current to two of the luminescent tubes.

Although the several luminescent tubes 10, 11 and 12 are of approximately the same current and voltage ratings as indicated above, the tube 13 is of a somewhat increased size and voltage rating. The several transformer secondary winding coil sections 21, 22, 23 and 24, for reasons of economy in construction and simplicity in installation, are preferably of like size and rating. In order, then, to assure efficient and reliable operation of the various tubes comprising the luminescent display 10—11—12—13 the potential impressed across the terminals of the several tubes must be as high as that required by the luminescent tube of highest required starting potential, illustratively 13. The magnitude of this applied potential, however, is not so great as to adversely affect the operation of the other luminescent tubes.

Likewise, although the several luminescent tubes are of different conductivities in either the un-ionized or the ionized conditions the relatively complete independence of the circuits supplying electrical current to these tubes effectively prevents a tube of highest conductivity in the ionized condition from drawing an excessive current at the expense of the other tubes in the circuit (and so permitting erratic and non-uniform illumination of the display of luminescent and a very short life of operation of all of the tubes) thus assuring uniform operation of the tubes as well as maximum life.

While maximum electrical potential is impressed across the terminals of the several luminescent tubes by way of the respective supply conductors, illustratively the potential applied across the terminals of the luminescent tube 10 by way of the supply conductors 36 and 37, only one-half of this potential need be insulated against in the construction of the system and apparatus since, as more particularly described above, only one-half of the maximum potential exists between either of these conductors 36 or 37 and ground 31. Thus, for a luminescent tube of a desired starting potential the high potential transformer secondary winding coil sections need be only wound for one-half of the required maximum value, the various interconnecting conductors need be only insulated for one-half the maximum value and direct savings and economies in insulating the various parts of the system and apparatus, the amount and cost of which increases rapidly with the increased value of the potential for which the system and apparatus is to be insulated, are achieved in addition to increased safety to life and property. Or, for a system of a limited permissible value of high potential to ground, the starting potential ratings of luminescent tubes which may be operated from such a system may be doubled without increased danger to property.

In addition to the savings in cost of apparatus and the economies in installation indicated above, by connecting all of the transformer secondary winding coil sections to a common conductor which is preferably grounded there is achieved a balanced transformer secondary system, the advantages of which will later appear.

In the operation of my electrical luminescent sign system and apparatus, as high-potential electrical energy is supplied the various luminescent tubes, all as more fully described above, these tubes become conductive, and hence luminescent, when the instantaneous values of the various applied potentials are sufficient to establish an ionized condition within the respective tubes. For a 60 cycle supply of alternating current electrical energy the tubes are rendered alternatively conductive and non-conductive, and consequently luminescent and non-luminescent, 120 times per second (once for the positive half and once for the negative half of each cycle) Due to the persistence of vision the tubes appear to glow continuously.

As soon as the conductive condition is established the resistance of the various tubes (initially very high) drops to low values. In order to prevent the electric current in the various tubes or gaseous conduction devices from rising to excessive instantaneous values which would soon cause the tubes to burn out, the system and apparatus supplying the tubes with high potential electrical energy is preferably designed to have such poor voltage regulation that the instantaneous applied potentials quickly drop to low values as the instantaneous values of the currents in the several tube circuits tend to rise to prohibitive values.

Preferably, referring back to Figure 1, the transformer 17 is designed to have such a high leakage reactance under load conditions that the secondary winding coil sections, through the interconnecting circuits more particularly referred to above, impress upon the several luminescent tubes but a small proportion of the instantaneous high starting potentials. These reduced values of the initially high starting potentials, while sufficient to maintain the various tubes in the ionized conditions of conductivity and luminosity during a portion of each cycle of alternations of the impressed potentials, are insufficient to cause such a flow of excess current in any one tube during this time as to burn out or otherwise damage the tubes or the related apparatus after the system and apparatus has been operated but a comparatively short length of time.

Thus, referring to Figure 2 of the drawing, between primary windings 15—16 of transformer 17 and the secondary winding comprising coil sections 21, 22, 23 and 24 mounted on the single central leg 25*b* of the transformer core 25, there are interposed the magnetic shunt core sections 25*d*, 25*e*, 25*f* and 25 *g* extending from the central core leg 25*b* to the outer core legs 25*a* and 25*e*. The shunt core sections conveniently abut the central core leg 25*b* and the outer core legs 25*a* and 25*c* providing a short air gap in series with each shunt section thus rendering the shunt magnetic circuit of higher reluctance than the magnetic circuit interlinking the primary and secondary transformer windings under no-load conditions. As the currents in the transformer secondary winding coil sections 21, 22, 23 and 24 tend to increase due to the great reduction in the resistance (and impedance) of the secondary output circuits as the luminescent tubes in these circuits become ionized and hence conductive as described above, the magnetomotive forces produced by these currents likewise tend to increase and oppose the course of the magnetic flux (caused by the flow of current through the transformer winding 15—16) through the transformer core leg 25*b* upon which the secondary winding coil sections are mounted. Due to this opposing force the magnetic flux courses through the shunt core sections 25*d*, 25*e*, 25*f* and 25*g* provided therefor, directly detracting from the flow through that portion of the central core leg upon which the transformer secondary winding is mounted.

Thus, for an assumed current flow in primary winding 15—16 tending to cause a magnetic flux to course through the central core leg 25*b* in a direction from left to right as seen in Figure 2, then outwardly and back along the outer core sections 25*a* and 25*c* and then inwardly to the central core leg to complete the magnetic circuit, as a magnetomotive force opposing this coursing of the magnetic flux through that portion of the central core leg upon which the secondary winding is mounted appears there is a tendency for the magnetic flux linking the primary coil section 15 to take a course along the extreme left end of central core leg 25*b* in a direction from left to right, then outwardly from this core leg along the upper core shunt 25*d* and the lower core shunt 25*g*, then back along the extreme left portions of the outer core legs 25*a* and 25*c* in a direction from right to left then inwardly toward the central core leg to complete the magnetic circuit; similarly there is a tendency for the magnetic flux linking the primary coil section 16 to take a course along the extreme right and of the central core leg 25*b* in a direction from left to right then outwardly and backwardly along the outer core legs 25*a* and 25*c* and then inwardly from these core legs along the upper core shunt 25*e* and the lower core shunt 25*f* toward the central core leg 25*b* to complete this portion of the magnetic circuit.

The magnetic flux coursing through the magnetic core shunts 25*d*, 25*e* and 25*f*, as indicated above, directly detracts from the flux coursing along the midportion of the central core leg linking the transformer secondary winding coil sections 21, 22, 23 and 24 (continuing outwardly and back in a direction from right to left along the outer core legs and then inwardly to complete the magnetic circuit) and to that extent detracts from the total magnetic flux linking the transformer primary and secondary windings. In accordance with the reduction in the total flux linking the primary and secondary transformer windings there is a proportionate reduction in the potentials of the secondary winding coil sections and a consequent reduction in the instantaneous value of potential impressed across the terminals of the several luminescent tubes and a limitation thus imposed upon the flow of currents of excessively high instantaneous values in the several tubes, all as more particularly described above.

It will be understood, in view of the above description, that the extent of the reduction in the potential of the electrical energy supplied the luminescent tubes from the high instantaneous value immediately prior to the establishment of ionized conditions of the several tubes to the relatively low value shortly after the ionized condition of the tubes is established, permitting a flow of current, is largely dependent upon the sectional area and the permeability of the magnetic core shunts.

As a modified construction of transformer 17 as shown in Figure 2 and described above, attention is directed to Figure 3 where primary winding 15—16 is mounted at a mid-section of a central leg 25*b* of a shell type transformer core 25 and the secondary winding coil sections are mounted in two groups 21—22 and 23—24 adjacent the extreme portions of this leg. The magnetic circuit of the core is completed by the outer core legs 25*a* and 25*c*. Magnetic core shunts interconnecting the central core leg 25*b* with the outer core legs 25*a* and 25*c* (by which a portion of the magnetic flux linking primary winding 15—16 is shunted from secondary winding coil sections 21, 22, 23 and 24 as currents in these sections tend to rise to prohibitive values as more particularly described above), are provided at points intermediate the primary and secondary winding coil sections as shown at 25*d* and 25*g*, for primary 15—16 and secondary coil sections 21—22, and at 25*e* and 25*g* for the primary 15—16 and secondary winding sections 23 and 24.

With this construction the paths of the magnetic flux which is shunted from linking the secondary winding coil sections is from a mid-section of the central core leg in an assumed direction from left to right as seen in Figure 3, then outwardly through the magnetic core shunts 25e and 25f, then in a direction from right to left through the mid-section of the outer core legs 25a and 25c, and inwardly along core shunts 25d and 25g to the central leg 25b to complete the shunt path of the magnetic flux (neglecting air leakage) is along the total length of the central core leg 25b from left to right, for an assumed instant, then outwardly and back from right to left along the outer core legs 25a and 25c to the central leg. The flux linking primary and secondary transformer windings is decreased in accordance with the amount of flux shunted along the core sections provided therefor as more fully indicated above with reference to Figure 2.

Good results in the operation of my system and apparatus are also achieved by the use of a core type of transformer as shown in Figure 4 wherein primary windings 15 and 16 are mounted at mid-sections of opposite legs 25h and 25k of a closed magnetic core. The transformer secondary winding coil sections 21 and 24 are mounted near the left extremities of core legs 25h and 25k respectively while the remaining secondary winding coil sections 22 and 23 are respectively mounted on the core legs 25h and 25k near the opposite extremities. Interposed between primary winding coil sections 15 and 16 and secondary winding coil sections 21 and 24 is a core shunt 25n providing a direct path for magnetic flux between the core legs 25h and 25k. Similarly, a shunt 25r interconnecting core legs 25h and 25k is located between primary winding coils 15 and 16 and secondary coils 22 and 23 respectively mounted on core legs 25h and 25k.

A somewhat similar result in the matter of the reduction of the instantaneous values of potentials applied to the several luminescent tubes immediately after the conductive conditions are established (see Figure 1) is achieved by the action of the impedance element 20, illustratively a resistance unit, included in the low voltage circuit supplying the primary windings 15—16 of the transformer 17. As the instantaneous value of the currents in the secondary winding coil sections 21, 22, 23 and 24 tend to increase due to the great reduction in the resistance of the luminescent tubes in the ionized, and conductive, condition the current in the primary windings 15—16 tend to similarly increase.

An increase in the current flow of the transformer primary circuit gives rise to a proportionate potential drop across the impedance element 20 and a corresponding reduction in the available potential applied across the primary windings 15—16 with a consequent reduction in the instantaneous values of the secondary winding coil sections which supply the several luminescent tubes.

While the impedance element 20 may be used in conjunction with the transformer 17 having individual secondary winding coil sections supplying the several luminescent tubes comprising the complete luminescent display, as more particularly described above, it will be understood that good results are achieved where the impedance element is omitted or where the impedance element is employed, but a transformer without a specially designed high leakage reactance under load is used.

To compensate for the individual differences in the electrical characteristics of the several luminescent tubes and permit substantially the same current densities in the various tubes, and thus produce substantially the same intensity of luminousness, capacitive impedance elements, as more particularly referred to above, are preferably included in the transformer secondary circuits supplying high-potential electrical energy to the several tubes. As the instantaneous currents in the several tube circuits tend to rise to prohibitive values the voltage drops across the impedances included in these several circuits increase in proportion so that the values of the instantaneous potentials impressed across the terminals of the several luminescent tubes are proportionately decreased. The current limiting action of the various impedance elements supplements the action of the drooping potential characteristics of the high-potential supply transformer to quickly bring the electrical potentials applied the several tubes, and hence the electric currents, to relatively low sustained values.

The capacitive impedance elements in addition to partially limiting the flow of current in the luminescent tubes or gaseous conductive devices as indicated above, are preferably of such size as to compensate for the high inductive impedance of the transformer secondary winding coil sections and so permit a flow of current of sufficiently high density in each of the various tubes over a maximum proportion of the length of time during which the tubes are rendered conductive so as to give prolonged luminescence which directly contributes to the desired brilliant operation of the luminescent tubes, all as more fully described in my copending application Serial Number 580,793.

In addition to the above, the capacitive impedances indirectly improve the power factor of the load supplied with electrical energy from the source of supply and make for efficient and economical operation of the system and apparatus as a whole.

Although as described above in connection with Figure 1, maximum efficient and reliable operation of a plurality of luminescent tubes from a source of single phase electrical energy is achieved by employing a transformer of high leakage reactance under load conditions having an even number of secondary winding coils connected to the several tubes so as to give a uniform balanced load on the transformer, highly satisfactory operation of a plurality of tubes is achieved even where a transformer having an uneven number of secondary winding coil sections supplies high potential electrical energy to an unbalanced load.

Referring to Figure 5 of the drawing, a plurality of luminescent gas-filled tubes 40 and 41, illustratively of different current and voltage ratings, are supplied with high potential electrical energy from a transformer 42 connected to a source of standard 220 volts, 60 cycles, single phase energy, diagrammatically shown at 43. Electrical energy from source 43 is supplied the primary winding coil sections 44 and 45 of transformer 42, by way of conductors 46 and 27, the high potential secondary winding of which is divided, illustratively, into the three coil sections 48, 49 and 50 of approximately the same size and current and voltage ratings mounted on a magnetic core 51 common to both primary and secondary windings. Where desired the coil section 48 may be of double current carrying capacity since this coil section supplies current to both luminescent tubes 40 and 41 as appears more fully hereinafter.

One end of each of the secondary winding coil sections 48, 49 and 50 is preferably connected by way of respective conductors 52, 53 and 54 to a common conductor 55, establishing a point of common potential and placing one of the coil sections, 48, in opposite phase sequence to the other two, 49 and 50. The interconnected ends of the coil sections are conveniently grounded as at 56. The opposite end of one of these coil sections, for example section 48, is connected by way of conductor 57 to one terminal of the luminescent tubes 40 and 41. The opposite ends of the other coil sections 49 and 50 are respectively connected to the opposite terminals of the respective tubes 40 and 41 by way of the conductors 58 and 59. Coil sections 48 is connected in series with each of the coil sections 49 and 50 and supplies current to both of the luminescent tubes 40 and 41.

High potential electrical energy of coil sections 48 and 49, connected in series aiding or cumulatively by conductors 52, 55 and 53, is impressed across the terminals of the luminescent tube 40 by way of conductors 57 and 58 to cause this tube to become ionized, conductive and luminescent all as more particularly described above in connection with the operation of the system shown in Figure 1. Similarly the luminescent tube 41 is supplied with high potential electrical energy from the secondary winding coil sections 48 and 50, connected in series by conductors 52, 55 and 54 by way of conductors 57 and 59 connected to opposite terminals of this tube and the tube is rendered luminescent as above described.

While maximum high-potential electrical energy is impressed across the terminals of the tubes 40 and 41 only one-half of this value need be insulated against, since, as referred to above in connection with the description of the balanced system shown in Figure 1, only one-half of the maximum value is produced by any one coil section and it is this potential difference which exists between the high-voltage supply conductors and ground. This of course permits direct savings in cost of equipment.

The transformer secondary winding coil sections are of such potential rating that the total potential impressed across the luminescent tubes is sufficient to consistently and reliably start the tube of highest required starting potential.

In order that the current supplied the luminescent tubes may be limited to desired values during the conductive portion of each positive and each negative part of each cycle of the impressed high potential electrical energy so as to give desired current densities within the tubes and hence desired uniform brilliant operation, transformer 42, see also Figure 6, is preferably designed to have a high leakage magnetic flux under load so as to give a great reduction in the value of the potential impressed on the tubes during the intermittent conductive periods.

As the instantaneous values of the currents in the secondary coil sections 48, 49 and 50, conveniently mounted on a central core leg 51*b* of the transformer core 51, tend to rise the corresponding magnetomotive forces oppose the course of magnetic flux linking these coil sections with the primary winding coil sections 44 and 45, likewise mounted on the central core leg 51*b*, so that the magnetic flux linking the primary winding coil sections is shunted away from the secondary winding coil sections along magnetic shunts 51*d* and 51*g* interposed between primary coil section 44 and the secondary winding coil sections and shunts 51*e* and 51*f* located between primary coil 45 and the secondary coils; the magnetic shunts preferably extend between the central core leg 51*b* and the outer ion legs 51*a* (for shunts 51*d* and 51*e*) and 51*c* (for shunts 51*f* and 51*g*).

The action of transformer 42 under operating conditions is in all respects similar to that of the transformer shown in Figure 2 and more particularly described above.

Good results in the operating of my system and apparatus are achieved where a core type of transformer as shown in Figure 7 is employed instead of the shell type of transformer shown in Figure 6 and described above. As the currents in the several transformer secondary coil sections 48, 49 and 50 mounted on core leg 51*h* tend to rise the corresponding magnetomotive forces tend to increase and oppose the course of the magnetic flux around the magnetic core 51 linking the primary winding 44—45 mounted on core leg 51*k* and the secondary coil sections 48, 49 and 50 so that a large portion of the total magnetic flux is shunted away from the secondary winding by way of the core shunt 51*m* provided for this purpose. Thus for an assumed portion of the cycle where the magnetic flux is coursing around the core 51 in a counter-clockwise direction as seen in Figure 7, as the current in coil sections 48, 49 and 50 increase, giving rise to an increasing opposing magnetomotive force, the magnetic flux from core leg 51*k* increasingly courses along the shunt path 51 in a direction from right to left and then down and back through the leg 51*k* in a direction from left to right to complete the magnetic circuit. The magnetic flux linking the primary and secondary transformer windings is reduced in proportion.

In accordance with the reduction in the magnetic flux linking the primary winding 44—45 and the secondary winding coil sections 48, 49 and 50 there is a reduction in the instantaneous potential appearing across the terminals of the secondary windings and a proportionate reduction in the potential difference impressed across the terminals of the luminescent tubes.

The core type of transformer of high leakage reactance under intermittent load conditions in addition to giving efficient and reliable operation of my system and apparatus is of a simple, practical and economical construction permitting direct savings in the cost of apparatus.

In order to further limit the flow of current in the luminescent tubes, after the conductive condition of these tubes is established, to desired values in spite of slight differences in the electrical characteristics of the tubes employed, the impedance elements 60, 61 and 62, preferably condensers, are included in the respective high-potential supply conductors 57, 58 and 59. These condensers, in addition to limiting the current in the luminescent tubes, extend the duration of desired current densities during the conductive periods of the tubes by aiding the current to flow immediately after the conductive conditions are established all as more particularly described above to give brilliant operation of the tubes. Furthermore the condensers improve the power factor of the energy supplied individual luminescent tubes thereby reducing the out-of-phase current to a minimum, proportionately decreasing the losses and generally making for high efficient and economical operation of the luminescent tube system and apparatus described.

Thus it will be seen that there is provided in this invention a system and apparatus in which the various objects hereinbefore noted together with many thoroughly practical advantages are successfully achieved. It will be seen that the system and apparatus is simple, economical and highly efficient in construction and use and that uniform brilliant operation of a plurality of luminescent tubes is reliably achieved with a minimum of expensive and cumbersome apparatus.

As many possible embodiments may be made of my invention and as many changes may be made in the embodiments hereinbefore set forth it will be understood that all matter described herein, or shown in the accompanying drawing, is to be interpreted as illustrative, and not in a limiting sense.

I claim:

1. In an electrical luminescent tube system, in combination, a source of alternating current electrical energy, a transformer having a primary winding and a secondary winding comprising a plurality of individual coil sections, means connecting the primary winding of said transformer to said source, a plurality of luminescent gas-filled tubes, means for connecting individual tubes to non-repetitive combinations of a plurality of said transformer secondary winding coil sections whereby said tubes are independently supplied with electrical energy, and means interlinking said primary and secondary windings for uniformly controlling the potential of the energy supplied said tubes, so as to maintain the electric current flow in each of said tubes substantially constant over a portion of each half cycle of the alterations of said source of supply.

2. In an electrical luminescent tube system, in combination, a source of alternating current electrical energy, a transformer having a primary winding and a secondary winding comprising a plurality of individual coil sections, means connecting the primary winding of said transformer to said source, a plurality of luminescent gas-filled tubes, means for connecting individual tubes to non-repetitive combinations of a plurality of said transformer secondary winding coil sections whereby said tubes are independently supplied with electrical energy, and means comprising a magnetic path of high leakage under load conditions interlinking the primary and secondary windings of said transformer whereby the current flow in each of said tubes may be effectively controlled.

3. In an electrical luminescent tube system, in combination, a source of alternating current electrical energy, a transformer having a primary winding and a secondary winding comprising a plurality of individual coil sections, means including an impedance element connecting the primary winding of said transformer to said source, a plurality of luminescent gas-filled tubes, means for connecting individual tubes to non-repetitive combinations of a plurality of said transformer secondary winding coil sections whereby said tubes are independently supplied with electrical energy, and means comprising a magnetic path of high leakage under load conditions interlinking the primary and secondary windings of said transformer whereby the current flow in each of said tubes may be effectively controlled.

4. In an electrical luminescent tube system, a source of alternating current electrical energy, a transformer having a primary winding and a secondary winding comprising a plurality of individual coil sections, means including an impedance element connecting the primary winding of said transformer to said source, a plurality of luminescent gas-filled tubes, and means including capacitive impedance elements for connecting individual tubes to individual combinations of a plurality of said transformer secondary winding coil sections whereby said tubes are independently supplied with electrical energy the potential of which is singly controlled for all of said tubes by the impedance element in said means interconnecting the primary winding of said transformer and said source and individually controlled for each of said tubes by the capacitive impedances included in said means interconnecting the secondary coil sections of said transformer and said tubes.

5. In an electrical luminescent tube system, in combination, a source of alternating current electrical energy, a transformer having a primary winding and a secondary winding comprising a plurality of individual coil sections, means connecting the primary winding of said transformer to said source, a plurality of luminescent gas-filled tubes, means including current controlling elements for connecting individual tubes to non-repetitive combinations of a plurality of said transformer secondary winding coil sections whereby said tubes are independently supplied with electrical energy, and means comprising a magnetic path of high leakage under load conditions interlinking the primary and secondary windings of said transformer, whereby the current flow in each of said tubes is effectively controlled both as to duration and as to maximum values.

6. In an electrical luminescent tube system, in combination, a source of alternating current electrical energy, a transformer having a primary winding and a secondary winding comprising a plurality of individual coil sections, means including an impedance element connecting the primary winding of said transformer to said source, a plurality of luminescent gas-filled tubes, means including power factor corrective elements for connecting individual tubes to non-repetitive combinations of a plurality of said transformer secondary winding coil sections whereby said tubes are independently supplied with electrical energy, the power factor of which is maintained at high value for each tube, and means comprising a magnetic path of high leakage under load conditions interlinking the primary and secondary windings of said transformer whereby the current flow in each of said tubes may be effectively controlled.

7. In a system and apparatus of the character described, in combination, a plurality of gas-filled tubes, a transformer core, a transformer primary winding mounted on said core a transformer secondary winding comprising a plurality of coil sections, mounted on said core and connected in non-repetitive combinations to said tubes, and one or more transformer core shunts for shunting magnetic flux around said secondary winding coil sections whereby the total flux linking said transformer primary winding and said transformer secondary winding coil sections may be reduced.

8. In a system and apparatus of the character described, in combination, a plurality of independent loads of negative resistance characteristics, a transformer having a primary winding and a secondary winding comprising a plurality of coil sections mounted on a core, conductor means interconnecting said loads and said secondary winding coil sections in non-repetitive combinations, and means operatively associated

with said core for substantially instantaneously altering the magnetic flux interlinking said transformer windings in accordance with sudden alterations in said loads.

9. In a system and apparatus of the character described, in combination, a plurality of independent loads of negative resistance characteristics, a transformer having a primary winding and a secondary winding comprising a plurality of coil sections mounted on a core, conductor means including capacitive impedance elements interconnecting said loads and said secondary winding coil sections in non-repetitive combinations, and core shunt means for substantially instantaneously altering the magnetic flux interlinking said transformer windings in accordance with sudden alterations in said loads.

10. In single phase electrical transformer apparatus operating a plurality of independent loads of negative resistance characteristics, in combination, a transformer core, a primary winding linking said core, a secondary winding having three or more coil sections linking said core, said coil sections having current carrying capacities of two of said loads, means interconnecting said secondary winding coil sections and establishing a point of common potential therefor, and three or more corresponding conductor means connected to said coil sections for supplying current to an output circuit comprising said plurality of independent loads connected so that each of said coil sections supplies current to two of said independent loads.

11. In a single phase electrical transformer apparatus operating a plurality of independent loads of negative resistance characteristics, in combination, a transformer core, a primary winding linking said core, a secondary winding having three or more coil sections linking said core, said coil sections having current carrying capacities of two of said loads, means interconnecting said secondary winding coil sections and establishing a point of common potential therefor, three or more corresponding conductor means connected to said coil sections for supplying current to an output circuit comprising said plurality of independent loads connected so that each of said coil sections supplies current to two of said independent loads, and means operatively associated with said core for substantially instantaneously altering the magnetic flux interlinking said transformer primary and secondary windings in accordance with the instantaneoeus variations of said loads, thereby substantially uniformly altering the transformer secondary potentials applied thereto.

12. In single phase electrical transformer apparatus operating a plurality of independent loads of negative resistance characteristics, in combination, a transformer core, a primary winding linking said core, a secondary winding having three or more coil sections linking said core, said coil sections having current carrying capacities of two of said loads, means interconnecting said secondary winding coil sections and establishing a point of common potential therefor, three or more corresponding conductor means connected to said coil sections for supplying current to an output circuit comprising said plurality of independent loads connected so that each of said coil sections supplies current to two of said independent loads, and a plurality of capacitive impedance elements operatively associated with said secondary winding coil sections for controlling the current supplied said loads.

13. In single phase electrical transformer apparatus operating a plurality of independent loads of negative resistance characteristics, in combination, a transformer core, a primary winding linking said core, a secondary winding having three or more coil sections linking said core, said coil sections having current carrying capacities of two of said loads, means interconnecting said secondary winding coil sections and establishing a point of common potential therefor, three or more corresponding conductor means connected to said coil sections for supplying current to an output circuit comprising said plurality of indepenedent loads connected so that each of said coil sections supplies current to two of said indepenedent loads, and core shunt means for substantially instantaneously altering the magnetic flux interlinking said transformer primary and secondary windings in accordance with the instantaneous variations of said loads, thereby substantially uniformly altering the transformer secondary potentials applied thereto.

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