

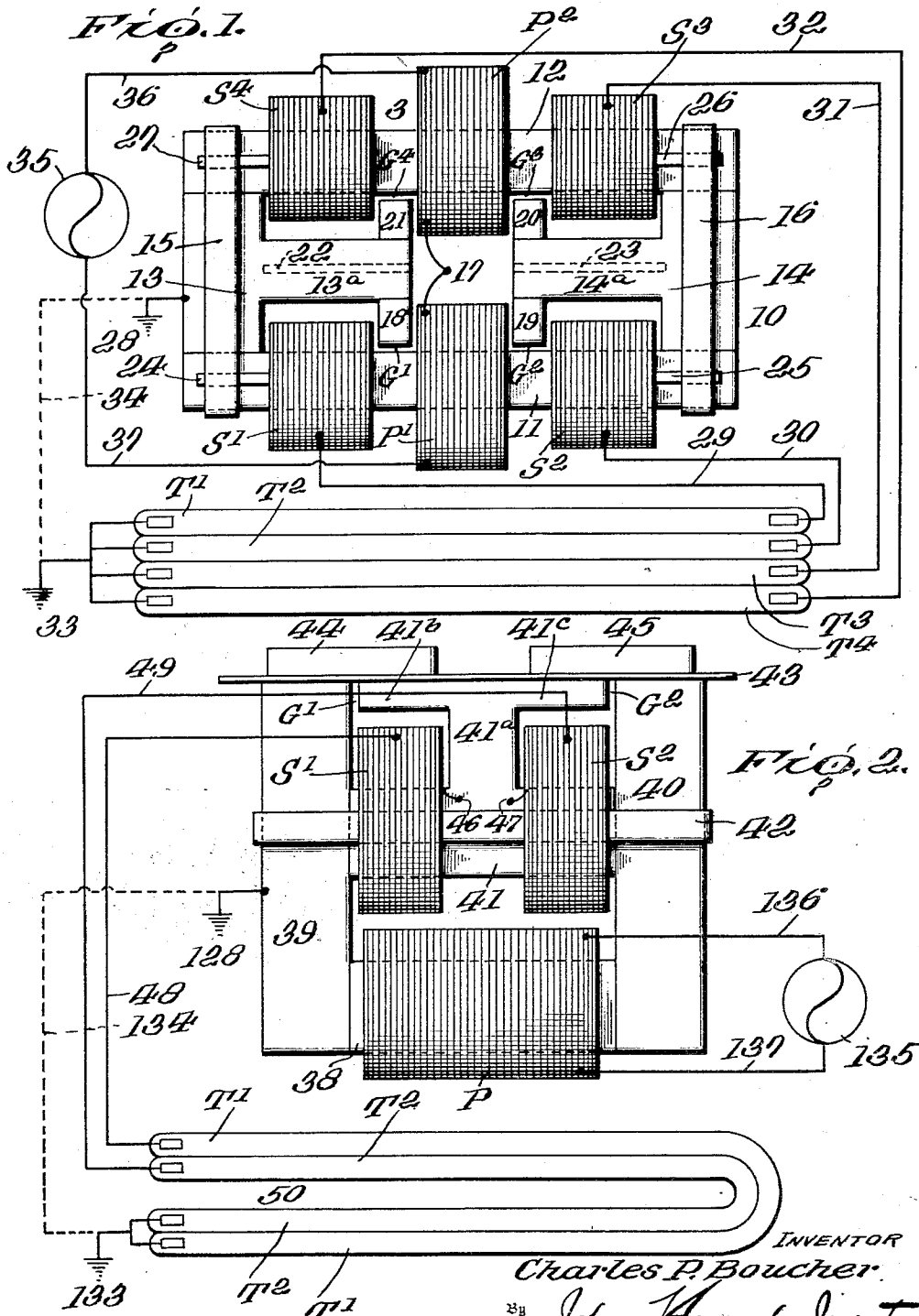
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FLUORESCENT TUBE SYSTEM AND APPARATUS

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FLUORESCENT TUBE SYSTEM AND
APPARATUS

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My invention relates to fluorescent luminous tubes for illumination purposes and more particularly to a system and apparatus for energizing such tubes.

One of the objects of my invention is to provide an economical and efficient source of light which is concentrated in a small area and which utilizes inexpensive energizing equipment and apparatus.

Another object is to provide a system and transformer apparatus which will operate two or more luminous tubes in close proximity to give a concentration of light without danger of flash-over or break-down across the tubes.

Another object of my invention is to provide a system in which a minimum of high tension cable connection is necessary and maximum simplicity and economy is enjoyed in installation and replacement.

A further object of my invention is to provide a system which simultaneously operates tubes of either equal or unequal resistances from a single transformer.

Another object is to provide simple, efficient and inexpensive transformer apparatus for use in the system noted which is readily installed and which is well calculated to serve under the many varying conditions of actual practical use.

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

My invention therefore consists in the combination of elements, features of construction and arrangement of parts, as described herein, the scope of the application of which is indicated in the following claims.

In the accompanying drawing illustrating certain features of my invention:

Figure 1 is a diagrammatic representation of a transformer tube system in which four fluorescent luminous tubes, each connected to a corresponding secondary coil on the transformer, are placed with their sides closely adjacent to each other.

Figure 2 is a diagrammatic representation of a similar arrangement except that the tubes are of greater length, two such tubes being illustrated.

As conducive to a clearer understanding of certain features of my invention, it may be noted that in the use of fluorescent luminous tubes, as now practiced, the efficiency of light emission per unit of power input is much higher than of incandescent lamps. That is, the brilliancy of such a tube in lumens, for each watt of power input, is higher. However, the light emitted from a single tube is not sufficient to give a satisfactory

total of light so as to be an adequate substitute for a single incandescent lamp

Accordingly, it is desirable to group together two or more luminous tubes so as to produce a satisfactory total light emission and, furthermore, it is desirable to have said light emanate from an area small enough that there is a satisfactory concentration of the light.

Another purpose for which it is required to have close grouping of tubes is in connection with the use of gas discharge tubes containing neon or other gases where it is desirable to blend the different colors of two or more tubes.

Numerous arrangements have been designed to achieve the desired concentration of light from gas discharge tubes. Some of these arrangements require costly fixtures and are undesirable from that standpoint. Others are objectionable in that the tubes cannot be assembled in close enough proximity to give the desired concentration of light without there being sparking exteriorly across the electrodes of different tubes.

The light emission per unit area of a fluorescent luminous tube varies directly as the amount of current flowing through it and inversely as the diameter of the tube. It would therefore seem possible to obtain a higher concentration of light in a given area by increasing the tube diameter somewhat and increasing the density of the current within it. A higher total light emission would result with only a slight increase in the area of emission and hence there would be a higher concentration of light. Such an arrangement, however, would require a transformer having a core of greater cross-sectional area and a secondary winding of heavier wire to accommodate the increased current load. The increase in coil size quickly becomes prohibitive since it rises in accordance with the square of the current. These changes in equipment would mean that the transformer would become prohibitively expensive.

In order to take advantage of the economy of using inexpensive transformer equipment and to give a maximum economy of operation, it is the present practice to use fluorescent luminous tubes of relatively small diameter. Attempts have been made to group two or more of these small diameter tubes closely together in order to produce a satisfactory concentration of light. These attempts have not been successful, however, because large potential differences have existed between adjacent terminals of different tubes. As a consequence, the tubes have been short-circuited by exterior spark discharges between their

terminals or by a flash-over between tubes somewhere along their lengths. It has thus far been impossible to successfully insulate the tubes from one another so as to fully prevent such sparking.

Accordingly, one object of my invention is to overcome the difficulty heretofore encountered in the exterior sparking between closely adjacent tubes and provide a tube-transformer system in which economical small diameter tubes and inexpensive transformers are so combined as to give adequately high voltages to operate the tubes and yet the potential difference between tubes closely adjacent to each other is too small to cause a spark discharge between them.

Referring now more particularly to the practice of my invention, attention is invited to Figure 1 of the drawing in which there is shown a transformer, generally indicated by the number 10. This transformer has a core, preferably of laminated magnetic steel, which comprises two longitudinal bars 11 and 12 between which T-shaped core pieces 13 and 14 of magnetic material are held by core hands 15 and 16 which are also preferably of magnetic material.

The core pieces 13 and 14 lie in the plane of the bars 11 and 12 and have inwardly extending legs which are parallel with said bars.

Primary coils P1 and P2 are mounted at the centers of core bars 11 and 12, respectively. They are connected in series at 17. On the core section 11 on either side of primary coil P1 are positioned the secondary coils S1 and S2 respectively. Likewise, secondary coils S3 and S4 are mounted on core bar 12 on either side of primary coil P2. The secondary coils S1 and S2 on the one hand and S3 and S4 on the other are spaced from the primary coils P1 and P2 respectively to provide room for shunt pieces. The shunt pieces 18 and 21 of magnetic material are mounted on the sides of portion 13a of core piece 13 and extend toward but short of the bars 11 and 12 respectively, forming air gaps, of comparatively high magnetic reluctance, G1 and G4 with said bars. Similarly shunt pieces 19 and 20 are of magnetic material and are mounted on portion 14a of core piece 14 and form air-gaps G2 and G3 with the bars 11 and 12 of the main core. Where desired, shunt pieces 18 and 21, and 19 and 20, may be integral with the respective core pieces 13 and 14 in order to eliminate the indefinite reluctances of the butt-joints and to largely limit the reluctance of the shunt paths to that of the included air-gaps.

Portions 13a and 14a of core pieces 13 and 14 may be of larger cross section than shunt pieces 18, 19, 20 and 21, in order to afford a ready flux by-pass around a secondary coil which is operating under short-circuit conditions and to thus limit the current flow in that coil. Ordinarily, however, portions 13a and 14a of the two core pieces need be of only the same sectional areas as the shunt pieces 18, 19, 20 and 21, as appears more fully below. Core pieces 13 and 14, however, may be split longitudinally by slots 22 and 23 as shown by dotted lines, in which event the total sectional area of each core piece must be double that of each shunt in order that the part of the core piece on each side of the slot may accommodate the flux of the associated shunt piece. Each core piece will then operate as two independent shunts. Where the slotted construction is employed, the shunt pieces 18 and 21 on the one hand, and 19 and 20 on the other, preferably are made integral with the associ-

ated slotted core pieces 13a and 14a respectively. In effect the shunt construction then would be two C-shaped shunt members in a back-to-back relationship.

Shunt pieces 18, 19, 20 and 21, may be made movable and mechanically controlled, as described, for example, in my copending application, Serial Number 303,886, so as to change the current output of the transformer.

Like terminals of the secondary coils S1, S2, S3 and S4 are individually grounded to the core by metal strips 24, 25, 26, and 27 respectively, which are held tightly against the core by core bands 15 and 16 above-referred to. Each strip is connected to the inner end of one secondary coil. The core itself is grounded, as at 28.

Each of the other terminals of the secondary coils S1, S2, S3 and S4 is connected to a terminal of one of the luminous tubes T1, T2, T3 and T4 by leads 29, 30, 31 and 32. The other terminals of the tubes are grounded at a single point 33. The core ground 28 may or may not be connected to the tube ground 33 by a conductor 34. This connection is made if either ground 28 or 33 is unreliable.

In the operation of my device, primary coils P1 and P2 are energized by a suitable source of alternating current 35, such as a standard single-phase 60-cycle source of supply at 110 volts, through leads 36 and 37. The primary coils are so disposed on the core 10 as to work in series-aiding relation in generating a magnetic flux in the core. The flux induces an electromotive force in coils S1, S2, S3 and S4. The electromotive force in coils S1, S2, S3 and S4, is impressed across the terminals of luminous tubes T1, T2, T3 and T4, respectively, through leads 29, 30, 31 and 32 on one side and through strips 24, 25, 26 and 27, core 10 and grounds 28 and 33 on the other side.

When the potential across the terminals of one of the tubes T1, T2, T3 or T4 reaches a value great enough to strike an arc across that tube, a current immediately flows through that tube and its secondary coil. Assuming, for example, that an arc has been struck in tube T1, a current will flow through that tube and its secondary coil S1. This current generates a magneto-motive force which opposes the coursing of the main flux through the core bar 11. Consequently, the main flux seeks a path of less reluctance and finds it through core piece 13, shunt piece 18, air-gap G1, bar 11, core piece 14 and bar 12. Thereupon, the voltage induced in coil S1 will decrease in value, but will still be high enough to energize the tube T1 until the electrical potential from source 35 applied across the primary coils P1 and P2 decreases almost to zero near the end of its half cycle. Upon further decrease in potential in following through its cycle, the tube becomes extinguished.

Thus an excessive flow of current in coil S1 and tube T1 is prevented. Furthermore, the flux interlinking coil S4 remains substantially undiminished in value. Accordingly, coil S4 is able to thereafter have induced in it a voltage sufficient to strike tube T4.

Likewise, as arcs are struck across the other tubes T2, T3 and T4, currents flow in their respective secondary coils S2, S3 and S4 and counter magnetomotive forces are generated which divert the main flux across the shunts 19, 20 and 21, and the corresponding included air-gaps G2, G3 and G4. Thus if the tube T2, T3 or T4 strikes first, the core flux will be diverted around

the corresponding shunt path 19, 20 or 21 and the included air-gap.

When two tubes are lighted together, for instance if tubes T1 and T4 are ignited, the flux path will be through bar 11, core piece 14, bar 12, air-gap G4, shunt piece 21, core piece 13, shunt piece 18, and air-gap G1, back to bar 11. It will be noted here that substantially no flux courses bar 13a. Where a slotted core piece 13 is used, the flux courses from shunt piece 21 longitudinally of portion 13a of the core piece 13 until it reaches the end of slot 22, when it returns to pass through shunt piece 18.

Likewise, when tubes T2 and T3 are both operating, and tubes T1 and T4 are not lighted, the flux courses through bar 11, air-gap G2, shunt piece 19, core piece 14, shunt piece 20, air-gap G3, bar 12 and core piece 13 back to bar 11. Where the core piece 14 is slotted at 23, the flux courses longitudinally of the portion 14a to pass around the slot.

When all four tubes T1, T2, T3 and T4, are illuminated, the flux takes a short path through bar 11, air-gap G2, shunt piece 19, core piece 14, shunt piece 20, air-gap G3, bar 12, air-gap G4, shunt piece 21, core piece 13, shunt piece 18, and air-gap G1, back to bar 11. Of course, when the core pieces 13 and 14 are slotted at 22 and 23, the flux travels around the slot.

When the primary current has alternated to its other half cycle, the tubes meanwhile having become extinguished, as each tube strikes, the paths of magnetic flux in the core will be the same as those outlined above, except that the flux will course in the opposite direction. Thus, if tube T1 ignites first, the flux will course through bar 11, air-gap G1, shunt piece 18, core piece 13, bar 12, and core piece 14, back to bar 11. Likewise, when two or more tubes are operating at the same time in the second half cycle, the flux paths will be the same as those outlined above, except that the flux will be coursing in the opposite direction.

In the event one of the tubes should become short-circuited, as by a film of moisture, packed insect bodies, etc., about the terminals, the operation of the transformer will not be impaired but will be similar to the condition existing where that tube is ignited. Thus, if tube T1 is short-circuited, its secondary coil S1 will, from the beginning of the half-cycle of applied potential, commence to develop a strong counter magnetomotive force which will cause the main body of flux to pass around it through core piece 13, shunt piece 18, and air-gap G1. Likewise, when any one or more of the other tubes is shorted, the main transformer flux will be diverted around the corresponding secondary coil or coils through the shunt pieces and across the air-gaps.

On the other hand, when one or more of the tubes is open-circuited, as by the breaking of the tube or a substantial reduction in its vacuum, there will be no need to divert flux around the secondary coils. Thus, if tube T1 is open-circuited, there is no current flowing through the coil S1 and accordingly no counter magnetomotive force is developed therein. Hence, in open-circuit condition, the flux continues to course the bar 11 directly to the bar 13 without passing through the air-gap G1 and the shunt piece 18. Likewise, when any other tube or tubes is open-circuited, the corresponding secondary coil or coils is not by-passed by the flux, but on the contrary the flux continues to course through that coil or those coils.

I prefer to have primary coils P1 and P2 of the same number of turns in order that the flux generated may be equally distributed through the core legs. I also prefer to have secondary coils S1, S2, S3 and S4 of the same number of turns in order that the voltages induced in them may be substantially equal. Of course, if it is desired to use tubes having different striking potentials, secondary coils of correspondingly different voltage ratings may be employed. The objects of my invention are best enjoyed, however, where the coil sections and the tubes are all of like ratings so that the tubes strike simultaneously and like potential conditions obtain along their lengths. In this connection, it is to be noted that in the transformer apparatus of my invention primary and secondary coils are symmetrically positioned on the core and with respect to the core shunts employed. The symmetrical construction assures a compact, efficient and balanced unit. Minimum core iron is necessary because uniform flux conditions are maintained. Direct savings therefore are realized in the core construction which incidentally permits savings in the construction of the coils and in the insulating materials used. Like savings are realized in the casing by virtue of the reduction in size of the transformer unit. The location of primary and secondary coils in spaced relation assures good heat distribution and dissipation. Moreover, in my transformer, the internally located shunts, that is shunts internally of the main magnetic path, minimize the extraneous effect of the transformer casing or housing, which commonly is formed of iron.

If tubes and coils of different voltage ratings are employed, the corresponding shunt pieces 18, 19, 20, and 21, are changed in size or they are adjusted to regulate the lengths of the air-gaps G1, G2, G3 and G4. The adjustment is made so that the magnetic reluctance of each shunt path is high if the secondary coil it by-passes has a high voltage rating, or low, if the corresponding secondary coil has a low voltage rating. An increase in the reluctance of the shunt path is had through a reduction in the sectional area of the shunt or by increasing the length of the included air-gap. Similarly, the reluctance of the shunt path is decreased by increasing the sectional area of the shunt or by shortening the air-gap.

Inasmuch as the one ends of tubes T1, T2, T3 and T4, are grounded, it will be seen that no high tension cable is required for connecting those ends of the tubes with their secondary coils. Accordingly, only the other ends of the tubes require high tension cables for their connections. This feature of my invention effects a substantial saving in cost, as high tension cables and bushings are expensive.

Considering now another embodiment of my invention, attention is directed to Figure 2, in which I have shown a transformer of the type disclosed in my pending application Serial Number 303,886, entitled Fluorescent tube system and apparatus. The core comprises a laminated bar 38 of magnetic material having abutting legs 39 and 40, which also abut the cross leg 41. A core band 42 may be secured around the main core legs 39 and 40 and the cross leg 41 to maintain them in fixed relationship. Cross leg 41 is H-shaped, having a central part 41a and shunt arms 41b and 41c, all of which lie in the plane of the main core. The shunt arms 41b and 41c extend at right angles to the central part 41a and are substantially parallel to the bar 38. These shunt arms

form with the legs 39 and 40 air-gaps G1 and G2, respectively.

Extending across the extremities of legs 39, 40, air-gaps G1, G2 and shunt arms 41b, 41c, is a dielectric membrane 43 separating from the core parts the adjustable bridging pieces 44 and 45. As disclosed in the application above referred to, the purpose of the bridging pieces is to afford a means for adjusting the reluctance of the shunt paths around the air-gaps G1, G2 respectively, so as to vary the amount of flux which will be by-passed around the secondary coils and thus vary the voltage and resultant current induced in those coils.

Mounted on the central part of core bar 38 is a primary coil P which is energized through leads 136 and 137 from a suitable source of alternating current 135 similar to the source 35 of Figure 1.

On the extremities of core cross leg 41 and in symmetrical position with respect to the primary winding P and the other core legs are mounted secondary coils S1, S2 with their like terminals grounded to the core at 46, 47 respectively. At their other ends, coils S1, S2 are connected to fluorescent luminous tubes T1, T2 by leads 48 and 49 respectively. The core 38 is itself grounded as at 128 and the other ends of tubes T1, T2 are connected together and grounded, as at 133. The grounds 128, 133 may be connected together by a conductor 134 especially if one of them is unreliable.

The usual high tension cable leads and/or porcelain bushings are employed between the high tension side of each secondary coil and the corresponding tube electrode. Since one end of each tube is connected to the ground, it follows that the lead at that end need not be a high tension cable. Therefore, instead of requiring two high-tension cables and/or bushings per tube as present systems do, by my invention only one high-tension cable and/or bushing is required for each tube, thus effecting a direct saving in apparatus cost.

The transformer proper may or may not be enclosed in a container depending upon its location. For indoor use, this is generally unnecessary. For outdoor use, however, it usually is necessary. Where an enclosure is desired, the container is filled with insulating compound to prevent the destructive effects of moisture and ozone on the core and coils.

The tubes T1, T2 are approximately twice the length of those shown in Figure 1 and therefore about twice as much potential difference must be impressed across their terminals to strike an arc. The tubes are formed in a U-shape and nested one within the other in order to concentrate their light in a small area. To prevent sparking across the opposite terminals and to avoid puncture of the tube glass, a space 50 separates the sides of the opposite legs of the inner tube T2.

As in Figure 1, the secondary coils S1, S2 of Figure 2 are so connected to the tubes T1, T2 and to the ground that the leads 48, 49 and consequently the tube terminals to which they are connected are always at a potential in the same direction, either positive or negative, and of nearly the same value at the same instant. Therefore, the maximum possible potential difference between the adjacent terminals of tubes T1, T2 is the differential between the striking voltage of the last tube to strike and the operating voltage of the first tube to strike. Ordinarily, however, this is negligible because the tubes strike

about simultaneously and the inductance of the circuit prevents an instantaneous drop in the potential applied. Thus, for all practical purposes, where tubes of the same striking potentials are employed and secondary coils of like turns are used, the potential differences between the tubes is negligible throughout the various conditions of operation.

As in the construction of Figure 1, the transformer of Figure 2 is of a symmetrical form which effects uniform flux distribution and resultant savings in the size and cost of core iron, coils, insulating materials, and casing. Furthermore, efficient heat distribution and dissipation is obtained.

The manufacturers of glass tubes have found that a tube four feet in length and of 12 millimeters diameter is the most convenient size to make. A potential of 2000 volts will operate a fluorescent luminous tube of this size under any condition of voltage variation encountered in practice; hence that voltage is most practical. In any event, it is not advisable to operate such tubes at a potential higher than 5000 volts. Where the tubes are of the same size and have been carefully pumped, the maximum difference in their striking potentials has been found to be 200 volts for a 5000 volt circuit. For most practical purposes, this difference is negligible.

I find that where the distance between electrodes is .095", a potential difference of at least 1900 volts is required to cause a spark discharge between them. There is in my parallel tubes, however, a distance greater than .095" between electrodes. Their centers are 12 millimeters or .47" apart. Consequently a potential in excess of 8000 volts would be required to cause a spark discharge between them. Such a voltage difference across like terminals is not encountered in my system.

Where the two tubes are somewhat unequal in striking potentials, I find that after the first tube strikes, there is a large difference in potential between its high voltage terminal and those of the adjacent tubes. Even when operating at a potential of 5000 volts, however, there will not be sufficient potential difference to cause sparking across the high voltage terminals. This is true particularly because of my arrangement whereby the voltages impressed on said terminals are of like phase. Moreover, because of the like phase relationships existing, the potential differences between the conductive columns of the tubes never becomes sufficient to puncture the tubes. At the zero potential ends of the tubes, they are interconnected and clearly there will be no stress likely to cause sparking.

Since each tube is connected to a separate secondary coil, I find that it is possible to simultaneously operate tubes of substantially unequal resistances and striking potentials, as well as those of equal resistances. In my system, no balancing of the voltages across or currents through transformer secondary coils is necessary because, by having the terminals of adjacent tubes always at potentials corresponding in direction or phase, no difference sufficient to cause sparking between them is possible.

Although I have illustrated systems operating four and two tubes in Figures 1 and 2 respectively, it is to be understood that any other number of tubes may be employed. In such systems it will be understood that each tube is operated by a separate secondary coil, all secondary coils

being mounted on a single core energized by a single primary winding.

Thus, it will be seen that there has been provided in my invention a system and apparatus for the illumination of fluorescent tubes in which the various objects hereinbefore set forth, together with many practical advantages, are successfully achieved. It will be seen that the system is simple and efficient and that it lends itself to ready installation and ready replacement of tubes. Also that it effectively assures high concentration of light with minimum likelihood of flash-over between terminals or rupture of the tube walls in spite of the high potentials employed and the close physical relationship of the tubes.

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

I claim:

1. In luminescent tube systems, in combination, a tube unit comprising a plurality of luminescent tubes grouped together with their sides in adjoining relationship substantially along their entire lengths and having their one ends grounded; an electrical transformer for energizing said tubes comprising a primary winding and secondary windings mounted on a main core member in spaced relation, shunt core members associated with said main core member and extending between said primary and secondary windings; the secondary windings being equal in number to said plurality of tubes and having

their one ends grounded; and individual conductor means interconnecting the other ends of said secondary windings and the free ends of said tubes.

2. In luminescent tube systems, in combination; a tube unit comprising a plurality of luminescent tubes grouped together with their sides adjoining along a major portion of their lengths; an electrical transformer for energizing said tubes comprising primary winding means and secondary windings mounted on a main core member in spaced relation; and shunt core means associated with said main core member and extending magnetically between said primary winding means and the secondary windings, the secondary windings being equal in number to said plurality of tubes and each of said secondary windings being connected across one of said tubes.

3. In luminescent tube systems, in combination; a tube unit comprising a plurality of luminescent tubes grouped together with their sides adjoining along a major portion of their lengths and having their one ends grounded; an electrical transformer for energizing said tubes comprising primary winding means and secondary windings mounted on a main core member in spaced relation; shunt core means associated with said main core member and extending magnetically between said primary winding means and the secondary windings, the secondary windings being equal in number to said plurality of tubes and having their one ends grounded; and individual conductor means interconnecting said secondary windings and the free ends of said tubes.

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