

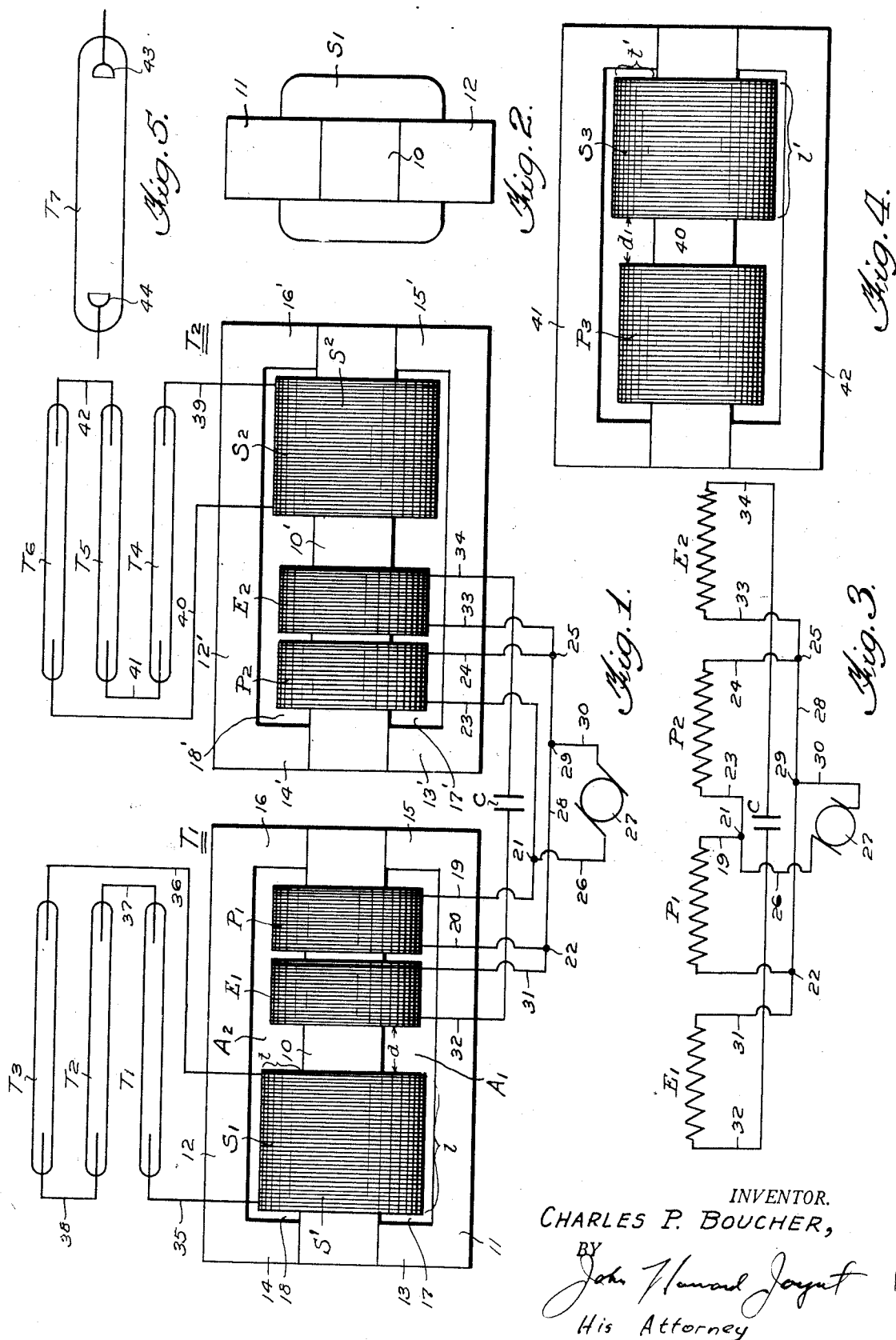
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ILLUMINATING TUBE SYSTEM

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ILLUMINATING TUBE SYSTEM

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My invention relates to lighting systems employing fluorescent gas discharge tubes, particularly systems of this general type adapted for outdoor use under adverse weather conditions, and more especially concerns power units for energizing lighting systems of this general class.

One object of my invention is to produce a high leakage reactance transformer unit which, while complying with all requirements of the Fire Underwriters, is simple, compact and rugged of construction; which requires simple, inexpensive stampings and the employment of a minimum of iron and copper; which is highly efficient and reliable under all operating conditions; and which is characterized by its low operating and maintenance costs.

Another object is to produce a fluorescent tube lighting system powered by one or more transformer units aforesaid, which complies with the requirements of the Fire Underwriters, is simple, compact, sturdy, efficient, and of low first cost; which is admirably suited for outdoor operation; which possesses good operating characteristics, including good wave form, and is characterized by low operating and maintenance costs, long tube life, marked superiority in flood lighting, by adaptability for dimmer operation, and by the requirement of only a small capacity power-factor correcting condenser.

Still a further object is to produce a fluorescent tube lighting system of the type described which produces light of outstanding brilliance, which has low voltage demand per unit of tube length, and which gives rise to long electrode life of the associated tube equipment forming part of the lighting system.

Other objects and advantages in part will be obvious and in part pointed out hereinbefore in connection with the following description taken in light of the accompanying drawing.

Accordingly, my invention resides in the several elements, features of construction and operational steps, and in the relation of each of the same to one or more of the others, all as described and illustrated herein, the scope of the application of which is indicated in the appended claims.

In the drawing,

Figure 1 is a schematic elevational view, showing a fluorescent tube lighting system according to my invention, and as well disclosing certain novel details of my new transformer power units;

Figure 2 is an end view of the transformer power unit according to Figure 1.

Figure 3 is a schematic circuit diagram illus-

trating the primary and extension windings as employed in Figure 1; Figure 4 discloses a modified form of transformer unit of my invention, while Figure 5 is a view showing certain features of an outdoor fluorescent tube which I prefer to employ in connection with my new system.

As conducive to a more thorough understanding of certain features of my invention, it may be noted at this point that fluorescent tube lighting systems in recent years have come more and more into widespread acceptance in the illumination field. They produce some two and one-half times as much light per unit of power input as do incandescent lamps and, at the same time, operate at relatively low temperatures. Through their use, light of widely varied spectral composition has been achieved in a number of widely diversified fields, including household lighting, ornamental and display lighting in retail stores, and in factories and other industrial installations. The basic spectrum characteristic of fluorescent lighting in general has been found to be such that the light emitted is quite penetrating and extends to points considerably distant from its source. In short, fluorescent tube lighting illuminates a comparatively large area, with light of uniform distribution, and has been found in most cases to be appreciably more satisfactory than are the incandescent bulbs heretofore in use.

Certain heretofore known fluorescent lighting systems however, display high first cost, along with other well known disadvantages, in that a large number of auxiliaries are required including compensators, reactor coils, starters, ballasts, and the like. This equipment in use requires repair and frequent replacement, the cost of which also is found to be excessively high. On the other hand, this type of lighting equipment, despite its disadvantages, has been instrumental in leading to the development of fluorescent lighting as a whole. There are, for example, at present, fluorescent lighting systems in the art which are energized by a transformer source of power. It is realized by those well versed in the art that the transformer itself represents an item wherein over-all initial and maintenance costs may be reduced, and through which an improved character of illumination may be achieved.

An important object of my invention, accordingly, is the provision of a transformer power unit adapted for energizing fluorescent space discharge tubes, which is compact, employing minimum iron and copper content, and which possesses high leakage reactance, whereby, upon en-

energization of the tube load, only calibrated quantities of primary magnetic flux interlink the secondary winding.

Experience quickly discloses that energizing voltages suitable for operating discharge tubes under ideal weather conditions, such as for example, as maintain in the case of interior illumination, are insufficient to insure proper tube operation under severe weather conditions as encountered in the operation of outdoor displays, including flood-lighting and the like. Low tube-energizing voltages are found to result in slow striking of the tube or even refusal to strike under low temperature conditions, and in flickering and unstable operation even when the tube strikes. It has heretofore been thought impossible, in those instances where high voltages necessary for stable outdoor operation are required, to achieve economical transformer construction and to obtain proper energization of tube lighting equipment in the absence of expensive and cumbersome auxiliary equipment. By consequence, known power units for operation under adverse weather conditions are relatively cumbersome and expensive, and their employment is attended by the use of a number of auxiliaries.

A further object of my invention, therefore, is to provide a high voltage fluorescent lighting system which is comparatively inexpensive, which includes a calibrated, high leakage reactance transformer for restricting within definite limits the currents available across the associated fluorescent tube load, and which may be used for exterior lighting without necessary addition of auxiliary equipment.

Finally, it may be noted that fluorescent tube lighting systems, of the general type referred to herein, ordinarily possess inductive characteristics so that lagging power factor maintains. Consequently, the user not only suffers a financial loss due to waste power consumed but, additionally, is unable to take advantage of lower rates which electrical utilities frequently make available for approximately unity power factor loads. Where economical utilization of electrical energy is imperative, power losses are, of course, to be suppressed wherever possible. Accordingly, the practice has arisen of inserting power-factor-correcting condensers in such tube lighting systems, of sufficient capacity to insure the maintenance of approximately unity power factor. Such condensers represent comparatively important items of investment, and should be reduced to a minimum size consistent with good power factor regulation.

Accordingly, a further object of my invention is to produce a fluorescent tube lighting system in which the size and hence cost of the power-factor-correcting condenser employed is reduced to a minimum consistent with proper functioning.

Referring now more particularly to the practice of my invention, in the construction disclosed in Figure 1 of the accompanying drawing, it will be seen that two like transformer units indicated broadly at T1, T2 are disposed closely adjacent to each other in substantially magnetically separate relationship. These two transformer units are energized either in parallel or series relation from a suitable source of power, while a power-factor-correcting condenser C is disposed symmetrically across both such units. Having attention to the unit T1 disposed at the left in Figure 1, it will be observed that this unit, constructed of laminations of magnetic iron, for example, has a central longitudinally extending

leg 10, paralleled on opposite sides by spaced outer legs 11, 12 respectively. End pieces 13, 14, and 15, 16 extend transversely across the ends of the central and outer legs, forming therewith a pair of substantially like closed magnetic circuits. One of the circuits comprises the central leg 10, end piece 13, outer leg 11 and end piece 15; while the other parallel magnetic circuit includes central 10, end piece 14, outer leg 12 and end piece 16. The interconnected core members of the several magnetic circuits provide closed spaces 17, 18 therebetween. Primary winding P1 and extension winding E1, constituting one winding unit, and secondary winding S1, constituting a second winding unit, are disposed about central leg 10 in spaces 17, 18, the two winding units being spaced a predetermined distance from each other as will be more fully pointed out hereinafter.

The second transformer unit, T2, shown at the right in Figure 1, comprises central leg 10', outer legs 11', and 12', and end pieces 13', 14', 15', 16'. Spaces 17', 18' are provided by the interrelation of the central and outer legs and the end pieces. The construction preferably is identical in all respects with that of the first transformer unit. A winding unit consisting of primary winding P2 and extension winding E2 is disposed on central leg 10' within end spaces 17', 18', in spaced relation to secondary winding unit S2. For purposes of symmetry I prefer to construct the windings of this second unit in close identity with those of the first transformer unit, although this is not absolutely essential since, as will be disclosed hereinafter, the fluorescent tube lighting loads of the several secondary windings are independent of each other.

Primary winding P1 has leads 19, 20 extending therefrom, lead 19 being connected to junction 21, and lead 20 to junction 22. Similarly, leads 23, 24 extend from primary P2, lead 23 in the instance under discussion extending to junction 21, while lead 24 extends to junction 25. A lead 26 connects junction 21, common to leads 19, 23 of primary windings P1, P2, to the left-hand terminal (Figure 1) of a suitable source of alternating electrical energy, indicated generally as constituting a generator 27. Similarly, a lead 28 interconnects junctions 22, 25, thereby interconnecting leads 20, 24 of primary windings P1, P2. This lead 28, by means of junction 29, connects with lead 30, extending to the right-hand terminal of generator 27. It will be seen, therefore, that the connections illustrated are such as to dispose the primary windings in parallel-aiding relation. It is, however, within the scope of my invention to dispose the primary windings in parallel-opposed or series relation. With parallel connection, there is imparted across each primary winding the full potential of the generator 27 or other source of electrical energy. Should series-connection of the primary winding be employed, however, each such winding would have one-half of the terminal voltage of generator 27 imparted thereto. Thus, it is apparent that for a given number of turns in the secondary winding, twice the number of turns are required in the case of parallel-connected primary winding as are demanded for series-connected primaries, to produce equal volts-per-turn in the two hook-ups.

As has been discussed briefly at an earlier point in the course of this description, the transformer units and associated tube loads have inductive characteristics, so that in the absence of some provision for correcting the same, the system

takes a lagging power-factor load. This results, also as has been stated hereinbefore, in waste power, and in financial loss due to inability of the consumer to take advantage of lower rates frequently made available by the electrical utilities for approximately unity power-factor loads.

In the present instance provision is made for restoring the system power-factor to approximately unity value by supplying a power-factor correcting condenser C, disposed symmetrically across the primary circuit. I have realized that by increasing the voltage across this condenser C, its regulatory action is maintained unimpaired upon reduction of its electrical capacity, and hence of its size and attendant first cost. Additionally, upon break-down of the condenser in operation, its replacement does not represent so great an investment. Appreciable economies thus, are achieved.

I make available the required elevated voltage by providing an extension winding E1, E2 associated with primary windings P1, P2, respectively. While for purposes of illustration, I disclose the extension windings at the side of and closely adjacent the corresponding primary windings, the primary and extension windings may be disposed one atop the other or may be interwound to reduce reactance losses to a minimum.

A primary charging circuit may be traced for winding P1 during any given half-cycle of alternating current flow, from left hand terminal of generator 27, over lead 26, junction 21, lead 19 through winding P1, lead 20, junction 22, lead 28, junction 29, and back through lead 30 to the other side of the generator 27. A similar parallel circuit for primary winding P2 can be traced from left-hand terminal of generator 27, over lead 26, junction 21, lead 23, through primary winding P2, lead 24, junction 25, lead 28, junction 29, and lead 30, back to the other side of generator 27. Of course during the next subsequent half-cycle of current flow, the direction in which the circuits are traced are exactly opposite of those just described.

Preferably I employ autotransformer connection of the primary and extension windings in achieving high voltage transformer output. Thus, primary and extension windings P1, P2 and E1, E2 are in autotransformer circuit, and such circuit is traced conveniently from primary winding P1 over lead 20 to junction 22, over leads 28 and 31 through extension E1, thence across lead 32 through condenser C, lead 34 through extension E2, and over lead 33 to junction 25, lead 24 through winding P2, across lead 23 to junction 21, and thence over lead 19 through winding P1 back to the point of beginning.

Each secondary winding energizes a fluorescent gas discharge tube load which is separate and independent of that across the other secondary winding. For example, secondary winding S1, is connected by lead 35 to the left-hand end of fluorescent gas discharge tube T1, and by lead 36 to the right-hand end of discharge tube T3. Tube T1 is series-connected to tube T2 by lead 37, while tubes T2 and T3 are series-connected by lead 38. Similarly, secondary winding S2 is connected by leads 39 and 40 to tubes T4 and T6. Lead 42 series-connects the right-hand ends of tubes T6 and T5 while lead 41 series-connects the left-hand ends of tubes T5 and T4.

A series circuit may be traced through the tube load of winding S1 for a given half-cycle of current flow as follows: From the left-hand ter-

5 minial of winding S1 through lead 35, across tube T1 to the right in Figure 1, through lead 37, across tube T2 to the left, over lead 38, across tube T3 to the right and back through lead 36 to the right-hand end of winding S1. Likewise, a circuit may be traced from the right-hand end of winding S2, over lead 39, across tube T4 to the left, over lead 41, across tube T5 to the right, through lead 42, across tube T6 to the left, and back through lead 40 to the left-hand end of winding S2. In the next succeeding half-cycle of current flow, the direction in which circuit traverses these two independent circuits is exactly the reverse of that just traced.

15 Having described certain preferred features of the physical structure constituting my invention, it is convenient at this point, before giving further attention to the details of the system as an entirety, to complete the detailed discussion of the independent transformer units.

20 Accordingly, having attention again to the transformer units, for example, transformer T1, disclosed at the left in Figure 1, let us assume that the instantaneous direction of current flow through primary winding P1 is such that a primary flux is generated which tends to course to the left in Figure 1 along central leg 10. Let us further assume that at the beginning of this half-cycle of current flow (60 or 25 cycle current being assumed to maintain, although any other frequency within reasonable limits will be satisfactory, such as for example 60 cycle current) this primary flux at first encounters no counter magnetomotive force, since the tube load across winding S1 has not yet become energized. So far as the magnetic reluctance of winding E1 is concerned, it is immaterial whether or not the latter be energized; that is, whether it is charging condenser C or is at rest. This is because of the intimate physical relationship of the primary and extension windings as described hereinbefore.

45 Linking winding S1, the primary flux courses to the left to the end of leg 10, and there splits in two directions. The flux, after splitting, courses, in part, down end piece 13 to the right in Figure 1 along outer leg 11, and up end piece 15 to leg 10 and, in part, up end piece 14 to the right along leg 12 and down piece 16 to leg 10. The flux reunites at the right-hand end of leg 10, and courses back along leg 10 to primary winding P1.

50 During the corresponding portions of the next subsequent half cycle, the primary magnetic flux courses in a direction exactly the contrary of that just described. Thus, the flux courses from winding P1 to the right along leg 10 and at the end of that leg splits in two directions. In splitting, the flux courses in part down along end piece 15, to the left along leg 11, up end piece 13 to the left-hand end of leg 10 and, in part, courses up end piece 16 to the left along leg 12 and down end piece 14 to leg 10. The flux reunites at leg 10 and courses to the right along the same leg, interlinking windings S1 and E1, back to winding P1.

55 It is to be noted that since the transformers provided energize fluorescent tube lighting equipment adapted for outdoor use, that is to say, since they supply high voltages and high density currents to loads of negative resistance characteristics, special problems are involved in providing means for limiting the current flow through the secondary windings and their associated loads when the loads are rendered luminous. Because of the absence of such current-limiting means in

certain transformer equipment heretofore employed, it has been necessary to provide auxiliary ballast means. Besides involving additional complication from the standpoint of mounting and connecting these ballasts, an appreciable item of investment and maintenance is presented which reflects most unfavorably on economy.

In effectively controlling secondary voltages and currents during the period of tube luminosity, I rely upon magnetic leakage over air-spaces between central legs and parallel-extending outer legs of the transformers. In transformer T¹, for example, air-space A¹ formed between winding units P¹, E¹, and S¹ and between legs 10 and 11, and the similarly disposed space A² between legs 10 and 12, are of such high reluctance that practically no primary flux traverses these two air-spaces prior to energization of the tube load across winding S¹. The situation, however, radically changes when the arcs strike across the tube load of winding S¹, and the latter becomes energized. Instantly upon the occurrence of this phenomenon, a back magnetomotive force is generated in winding S¹ opposing the passage of primary flux. The air-spaces A¹, A² hitherto having substantially higher reluctance than the winding S¹, now display lower reluctance than does the winding. The primary flux, seeking the path or paths of least reluctance, now in large measure avoids winding S¹, and courses the air spaces A¹, A². The design and dimensioning of the transformer unit preferably is such that during energization of winding S¹, just sufficient primary flux interlinks this latter to maintain the energization of the tube load.

In providing air-spaces of proper reluctance between winding units of a shell-type transformer, the thickness t (see Figure 1 where the transformers are drawn to scale to illustrate preferred proportions) of the secondary winding does not exceed more than one-third the length l of the same winding. The outer core legs, such as legs 11 and 12 of transformer T¹, closely confine the winding unit mounted on the inner core leg, such as units P¹, E¹ and S¹ on the inner core leg 10. The primary and extension winding unit and the secondary winding unit preferably are spaced apart on the inner core leg at a distance d ranging from about $\frac{1}{4}$ to $\frac{1}{2}$ length l of the secondary winding.

It will be understood that the flux leakage feature of my invention may be applied to a shell type transformer wherein the extension coil is omitted. Such shell-type transformer, drawn to scale in Figure 4 to illustrate desired proportions, has a primary winding P³ and a secondary winding S³ mounted on its central leg 40. The windings are spaced apart a distance d^1 which preferably ranges from $\frac{1}{4}$ to $\frac{1}{2}$ length l^1 of the secondary winding, assuming that thickness t^1 of the secondary winding does not exceed about $\frac{1}{3}$ the length l^1 , and that the outer core legs 41 and 42 are closely adjacent to the windings.

A transformer, either with or without extension windings, but having the voltage and current control features described hereinbefore, need not be used with another such transformer, as in Figure 1, but may be employed strictly above in energizing a fluorescent gas discharge tube or tubes. It will be further understood that although I prefer to apply my voltage and current output controlling feature to shell type transformers, and obtain best results by doing so, the feature may be applied, with proper adjustment and allowances, to core type transformers.

To illustrate the control which I achieve over transformer output, it is again assumed that current flows through primary winding P¹ in a direction such that primary flux courses to the left in Figure 1 along leg 10. This primary flux interlinks extension winding E¹ without restraint due to the fact that the latter is closely associated physically with the primary winding. As the flux continues its passage to the right, however, it comes opposite air-spaces A¹, A², which are now, energization of secondary winding S¹ being assumed, of lower reluctance than the secondary winding. The flux, accordingly, courses in part across air-space A¹, to the right along leg 11, up end piece 15 and back through leg 10 to winding P¹, and in part courses up across air-space A² and to the right along leg 12, down end piece 16, and back along leg 10 to the primary winding. Small quantities of primary flux continue to the left along leg 10 so as to link winding S¹. This flux in part courses downwardly through end piece 13, along leg 11 and end piece 15, back to leg 10; and in part courses up through end piece 14, along leg 12 and end piece 16, back to leg 10. In the next subsequent half cycle of primary current, it will be understood that the direction of primary flux is just the reverse of that traced. To illustrate, the primary flux courses to the right from primary winding P¹, along leg 10 and to the end of the latter. It then splits and courses over end pieces 15 and 16 to the left along legs 11 and 12. A major part of the flux courses across air spaces A¹, A², back to leg 10. A small quantity of primary flux for maintaining energization of winding S¹ continues along legs 11 and 12, across end pieces 13, 14 and to the right along leg 10. All primary flux re-unites in leg 10 and returns to the left along that leg to winding P¹, and in so doing interlinks winding E¹.

It will no doubt be helpful to state certain dimensions which I employ in one of my transformer units. Such dimensions, however, are given not by way of limitation, but are intended primarily to disclose the proportions employed in an illustrative embodiment embracing my invention. Such transformer, assumed for the present to be rectangular, possesses a length, width, and depth of approximately $9\frac{1}{2}$, 6, and $1\frac{3}{4}$ inches, respectively. All outer core legs are about $\frac{1}{8}$ inch wide; the inner or central core leg being around $1\frac{3}{4}$ inches wide and disposed approximately equidistant from the outer core legs which are substantially parallel thereto. The primary and extension windings combined as a unit have a length of about 3 inches measured longitudinally of the central core leg, while the secondary winding unit likewise has a length of about 3 inches. A spacing of approximately $1\frac{1}{8}$ inches is provided between the primary and extension unit and the secondary winding unit, which distance also is measured along the central core leg. A spacing of about $\frac{1}{8}$ inch exists between the primary winding unit and the adjacent outer core legs, while the corresponding width between the secondary winding and the outer legs is approximately $\frac{3}{8}$ inch. The secondary winding, accordingly, has a thickness of approximately one inch.

Transformer units of the general type according to my invention display important advantages in powering outdoor tube lighting systems. While the Fire Underwriter's requirements sharply limit auto-transformers to 600 volts secondary terminal potential, it is possible while abiding by the requirements of that body, and entirely feasible

from a practical standpoint, to provide 5000 volts or higher secondary potentials in transformer equipment such as I have disclosed. While 600 volts potential is entirely satisfactory for indoor operation when no extremes of temperature are encountered, experience has demonstrated that for satisfactory outdoor operation with prevailing low temperatures, appreciably higher secondary voltages are required. In this connection, systems according to my invention operate satisfactorily under temperature conditions, as low as 0° F.

My experience is that hot-cathode tubes customarily employed in inside lighting systems are not satisfactory for use outdoors. When such tubes are employed with hot-cathode connection in outdoor uses, their efficiency is appreciably lowered and the tubes are found to last not more than 500 hours. It is consistent, therefore, to discuss at this point the type of tube which I find best suited for the practice of my invention.

Fluorescent gas discharge tubes may be defined as elongated transparent glass tubes lined interiorly with a suitable fluorescent material, known generally as a "phosphor," such as zinc silicate, calcium tungstate, and the like. Electrodes are provided at each end of the tube, spaced from each other, and forming a discharge path therebetween. A gas or vapor filling is provided in the tube, of composition and pressure such that the major part of the energy across the arc is converted into ultraviolet radiation at what is known as the resonance line 2537A. Tubes of this type may have electrodes either of the incandescible type, or of the cold, solid electrode type. While the incandescible filament type of electrode is admirably adapted to emit copious quantities of electrons, thus facilitating ready striking and maintenance of the arc under low voltage conditions required in interior operation, these tubes do not display requisite sturdiness and long life when used in outdoor installations. Particularly is this the case when extreme weather conditions maintain. Even when these hot-cathode tubes are operated with short-circuited electrodes, that is, on cold-cathode operation, the life is found to be not in excess of 2000 hours. Additionally, when hot-cathode tubes are employed at elevated voltages such as are maintained in outdoor installations, then even with short-circuited terminals, it is found that the high voltages encountered result in sputtering and deterioration of the filaments and electrodes. With the cold cathode tubes employed in carrying out my present invention, however, such for example, as shown at T7 in Figure 5, with opposed, generally cup-shaped electrodes 43, 44, the life of the tubes is found to be many times greater than is the life of the short-circuited hot-cathode tubes, and is of the order of say 20,000 to 40,000 hours.

As one instance of a tube having electrodes of this general type, attention is directed to the disclosure of my previously issued United States Letters Patent No. 2,117,054, issued May 10, 1938. A tube of the general type disclosed therein proves entirely satisfactory when employed as part of my new assembly. Such tubes on outdoor operation display stable operating qualities together with long life, and have given entirely satisfactory operation at zero temperature, Fahrenheit.

In an illustrative installation according to my invention, the tubes employed have a gas pressure of 5-10 mm. of mercury, 6-8 mm. pressures frequently being used. I prefer to employ these

pressures, which are somewhat higher than those ordinarily maintained in hot-cathode tubes adapted for interior use, to obtain a more uniform pattern of the arc across the tube discharge path. The tube filling is, for example, of argon, neon, or other monatomic gas, or mixtures thereof, together with mercury.

While the fluorescent tubes employed may be of any desired diameter, my experience directs that for outdoor operation a tube having a diameter of 25 millimeters is preferable. Required energy input can be supplied such tubes at smaller current intensities. An additional advantage follows upon the use of small-diameter tubing in that it is readily provided in a variety of different shapes and configurations, lending itself admirably to complex and novel outdoor displays. I find that best efficiency is obtained using current intensities of about 250 milliamperes. In practice, however, the current across the tube will frequently be found to range from about 125 milliamperes to about 180 milliamperes.

In way of further illustration of my invention, the transformer secondary windings S1 and S2 are constructed to have terminal potentials of either 3000 or 5000 volts and the number and length of the tubes T1-T3 connected thereacross is sufficient to consume the entire terminal voltage. In practice, the 3000 volts terminal output will energize about 32 feet of 25 mm. tubing, while with 5000 volts terminal output, about 64 feet of 25 mm. tubing can be energized. The tubing usually is provided in lengths of 6 or 12 feet. It may be noted in this regard that a 6 foot tube of 25 millimeter diameter, when operating at temperature of 0° F., will require about 60 milliamperes current, as contrasted with the requirement of about 80 milliamperes when operating at 70° F.

One of the most important problems heretofore confronting the designer of fluorescent tube lighting equipment has been the question of obtaining good wave form across the secondary winding of the transformer. The disadvantages of poor wave form display themselves in reduced tube life, punctured insulation, and other defects incident upon high voltage phenomena. Such defects and disadvantages are avoided, however, and the wave form is appreciably improved, approaching the ideal sine-wave, with the power system according to my invention. This is due in large measure to the disposal of the primary and secondary windings of the several power units in separate substantially independent magnetic circuits, the several power units being only in electrical connection with one another. Due to this construction, high-voltage harmonics or other transient phenomena encountered in one power unit are dissipated in the secondary, extension and primary windings of that unit before they are transferred over electrical connection to the windings of the neighboring power unit. This contributes to long, useful life of both the power units and of the tubes employed.

By the use of secondary terminal voltages substantially in excess of those required to strike and re-strike the arcs across the tubes in successive half-cycles of current flow, these last-mentioned voltages being known as "striking" potentials, the possibility exists of diminishing this terminal voltage and still having it substantially in excess of the striking potential. This diminishing of voltage flattens the voltage wave form across each secondary winding and moves the

point at which momentary voltage reaches striking potential to a later moment in each current half-cycle. By virtue of the same adjustment, the voltage falls off earlier to a value where it is no longer able to sustain the tube arc. In other words, there is a change in time of striking and extinguishing the tube arc, with resultant decrease in the span of time in each current half-cycle during which the tube is energized and light is emitted therefrom. The eye accepts this phenomenon as a reduction in the total quantity of light emitted, it appearing to the observer that a dimming action has been brought about. This possibility of variation in the total light output has not been available with indoor fluorescent tube lighting equipment as obtainable on the market. The line voltages impressed across tubes in such systems so closely approximates striking potential that further potential decrease results in complete de-energization of the tubes.

It will be noted that while simple and compact, my new transformer is extremely powerful and is admirably suited for energizing associated cold-cathode tube lighting equipment of appreciable power demand under the most adverse weather conditions. High leakage reactance is provided between the primary and secondary windings of the transformer units in a most effective and ingenious manner, whereby the transformer output is always maintained within safe limits and close voltage regulation is obtained. Simple in design and in construction, the transformer is characterized by highly satisfactory wave form and by attendant long life of both the transformer unit itself and of the associated equipment. Additionally, the design of my new lighting system is such that effective power regulation, positive operation, and good wave form are obtained in an economical and thoroughly practical manner.

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

I claim:

1. An illuminating system comprising, in combination, a transformer including a shell-type main magnetic core having an inner core leg and two outer core legs disposed in spaced relationship, a primary winding and a secondary winding closely confined between said outer core legs and mounted on said inner core leg, a cold-cathode gas discharge tube connected across said secondary winding, a condenser connected across said primary winding, and a source of power connected across a portion only of the primary winding, said primary and secondary windings being spaced apart such distance as to effect control of current in the tube under conditions of luminosity.

2. An illuminating system comprising, in combination, a transformer including a shell-type main magnetic core having an inner core leg and two outer core legs disposed in spaced relationship, and a primary and extension winding unit and a secondary winding unit closely confined between said outer core legs and mounted on said inner core leg; said primary and extension windings being connected in autotransformer circuit with a power-factor improving condenser; a fluorescent gas discharge tube connected across said secondary winding unit; and

a source of power connected across the primary of the primary and extension winding unit; said winding units being spaced apart so as to permit substantial leakage of flux under load to effect control of current in the secondary winding unit.

3. An illuminating system suited for outdoor low temperature use comprising, in combination, a transformer including a shell-type main magnetic core having an inner core leg and two outer core legs spaced in substantially parallel relationship; and a primary winding and a secondary winding closely confined between said outer core legs and mounted on said inner core leg; a source of power connected across said primary winding, and a cold-cathode gas discharge tube connected across the secondary winding, said secondary winding having a thickness not exceeding $\frac{1}{3}$ the length thereof and being spaced $\frac{1}{4}$ to $\frac{1}{2}$ the length thereof from the primary winding, whereby effective control of current in said tube is achieved under conditions of luminosity, in absence of magnetic core shunts between primary and secondary windings.

4. In an illuminating system, in combination, a transformer unit including primary and extension windings, the primary, secondary winding of the unit being connected across a source of electrical energy and in autotransformer circuit with said extension winding, with a condenser being connected across the primary and extension winding and with said secondary winding being connected to a gas discharge tube load.

5. In an illuminating system, in combination, paired transformer units disposed in substantially magnetically independent relationship, each said transformer including primary, secondary and extension windings, the primary windings of the units being connected across a source of electrical energy and in autotransformer circuit with said extension windings and a power factor improving condenser, and said secondary winding being connected to a gas discharge tube load.

6. An illuminating system suited for outdoor low temperature use, comprising, in combination, paired transformer units in substantially magnetically independent relationship, each said transformer including a main magnetic core and a primary winding and a secondary winding mounted on the core; a source of power connected across said primary windings; and cold-cathode gas discharge tubes individually connected with said secondary windings; said secondary winding having a thickness not exceeding one-third the length thereof and being spaced one-quarter to one-half the length thereof from the primary winding so as to effect control of current in the tubes under conditions of luminosity in absence of magnetic core shunts between primary and secondary windings.

7. An illuminating system comprising, in combination, paired transformer units disposed in substantially magnetically independent relationship, each said transformer including a main magnetic core having primary and extension windings and a secondary winding mounted thereon; a source of power connected across said primary winding, the primary and extension windings being connected in autotransformer circuit with a power factor improving condenser; and gaseous discharge tubes individually connected with said secondary windings; the primary and extension windings and the secondary windings being so spaced apart and dis-

posed with respect to said cores as to effect control of current in the tubes under conditions of luminosity.

8. In combination, a shell type main magnetic core having an inner core leg and two outer core legs disposed in spaced relationship, a primary and extension winding unit and a secondary winding unit closely confined between said outer core legs and mounted on said inner core leg, said extension winding unit being intermediate said primary and secondary units and said winding units being spaced apart so as to permit substantial leakage of flux under load to effect control of current in the secondary winding unit, and a condenser connected across said primary and extension winding unit.

9. In combination, a shell-type main magnetic core having an inner core leg and two outer core legs spaced in substantially parallel relationship, a primary and extension winding unit and a secondary winding unit closely confined between said outer core legs and mounted on said inner core leg, said secondary winding unit having a thickness not exceeding $\frac{1}{3}$ the length thereof and being spaced $\frac{1}{4}$ to $\frac{1}{2}$ the length thereof from the primary and extension winding unit, whereby substantial leakage of flux is achieved under load to control transformer output, and a power-factor correcting condenser connected across said primary and extension winding unit.

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