

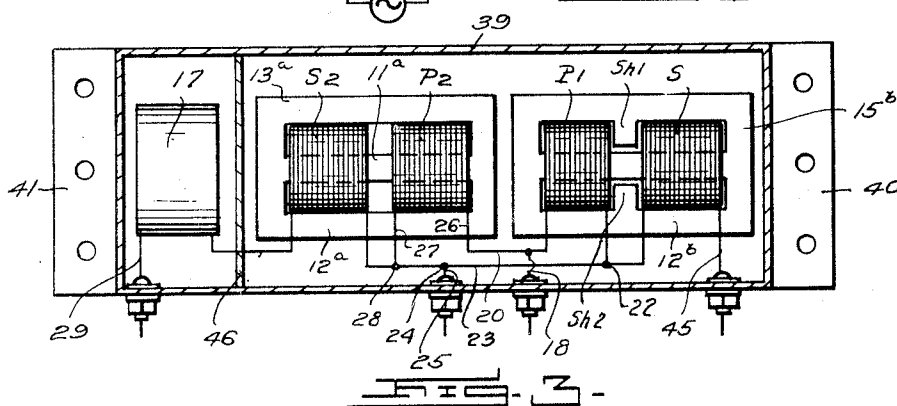
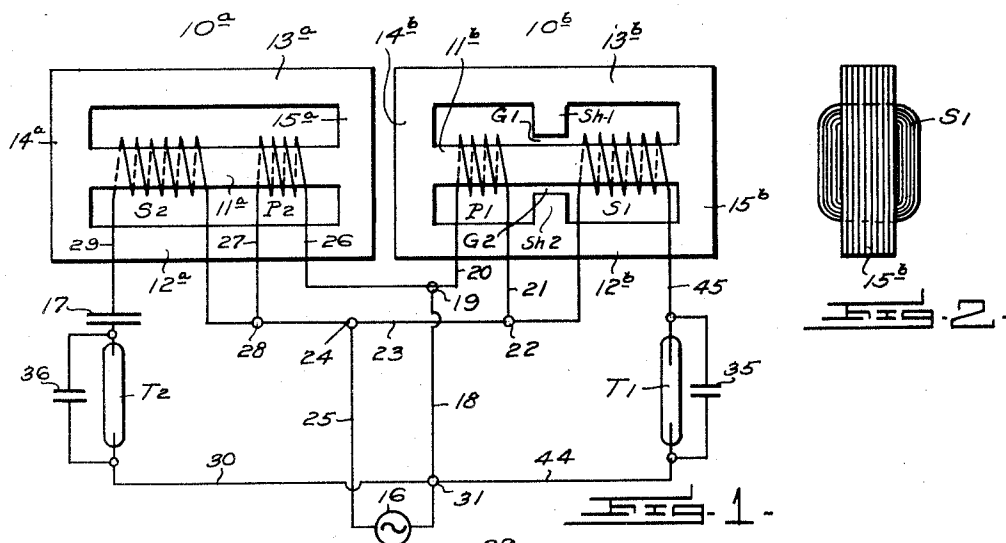
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FLUORESCENT TUBE SYSTEM AND APPARATUS

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## FLUORESCENT TUBE SYSTEM AND APPARATUS

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Our invention is directed to fluorescent tube lighting, and more particularly concerns a new fluorescent tube lighting system, as well as a new transformer for use therein.

One object of our invention is the provision of a multiple tube fluorescent lighting system of the type including a transformer having a plurality of secondary windings which is characterized by vastly improved wave form, by improved life of tubes and condenser employed therein, and by improved light emission; which system is simple, compact, sturdy, reliable, of low cost, both initially and in operation and maintenance; and which has quick, reliable starting characteristics, good voltage regulation and high system power factor.

Another object of our invention is the provision of a split-core transformer unit adapted for fluorescent tube lighting requirements facilitating accomplishment of the aforementioned objects, which new unit is easy to handle and simple to install, and which in operation is both safe and efficient.

Other objects and advantages will be in part obvious and in part pointed out hereinafter in connection with the following description.

Our invention, accordingly, 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 herein, the scope of the application of which is indicated in the appended claims.

In the drawing:

Figures 1 and 2 are front and end schematic elevations of the new transformer according to our invention. Figure 1 additionally discloses, in schematic manner, associated tube equipment and circuits according to our invention;

Figure 3 discloses in plan, the outline of a power unit embodying our invention, the association of related parts being depicted therein;

Figures 4 and 5 disclose facsimiles of oscillograph pictures of improved wave forms achieved through the practice of our new invention.

As conducive to a more thorough comprehension of our invention, a brief resume of the state of the art giving rise to our invention will be helpful. It is noteworthy that in recent years, fluorescent tube lighting systems have come more and more into widespread use in widely varied fields of illumination. Their strong intensity without brilliance permits efficient handling of machines and other equipment in factories. In merchandising, goods are displayed advantageously under any of a variety of desirable and

pleasing white or colored lighting effects, made available, particularly by the use of fluorescent tube lighting equipment. Use of this comparatively new lighting technique has spread rapidly to private residences, where hitherto unheard of lighting arrangements result from the installation of this new equipment.

Until recently, conventional practice has been to employ hot cathode tube lighting systems, the tubes having filamentary electrodes operating at ordinary service potentials, such as 110 or 220 volts. Such systems, however, do not operate satisfactorily under low temperature conditions and cannot produce widely varied intensity of light, as in dimmer operation. The hot cathode tube systems include numerous costly auxiliaries such as ballasts, starting switches, starting compensators, and the like, which lend intricacy and bulk to the systems and which require skilled attention in installation and in maintenance.

Particularly in view of the previously mentioned difficulties, fluorescent lighting systems including a high leakage reactance transformer have been developed. Such systems demonstrate simplicity, compactness, and safety, as salient features. The systems are easily installed and require little maintenance. The associated tube loads strike rapidly, even with severe weather conditions maintaining. Cold cathode operation of the tube loads is made possible, and dimmer operation, i. e., operation at less than full system voltage, is successfully achieved. In short, the use of a high leakage reactance power unit, with tubes functioning on cold cathode operation, promotes very definite and important advantages in the art of fluorescent lighting.

There are, however, certain difficulties still confronting the art, particularly with respect to systems which include a single core transformer of the multiple secondary winding type. In practice, the life of tubes in such systems, while adequate, is substantially shorter than is theoretically predicted. Our studies, conducted over a considerable period of time, finally demonstrate, however, that the shortening of tube life from estimated value, is due in large measure to high frequency, high voltage harmonics impressed on the fundamental of the voltage wave form of the transformer by magnetic reaction between the transformer secondary windings. Such harmonics are prevalent for example, in systems wherein a transformer, illustratively, a double transformer, has its secondary coils connected in individual circuits with tube loads; one of the secondary circuits including a condenser for de-

phasing the tubes of the system and for improving power factor. The condensive side of the system creates periodic flux surges of important magnitude in the transformer core. These surges of flux are responsible for a reaction between the transformer secondary windings and result in distortion of secondary wave form through the production of high potential harmonics. The undesirable phenomenon is mutual and cumulative and quickly builds up to dangerous proportions.

Tubes and other equipment in such systems, we find are impaired both with respect to efficiency and length of life by the harmonic or transient waves. Sputtering of tube electrode material occurs, the tube electrodes slowly disintegrate and voltage drop across the tubes increases. The sputtered electrode material deposits on the glass walls of the tubes, and not only physically impedes passage of emergent light rays through the tube walls, but as well, coats the active fluorescent lining of the tubes, thereby effectively decreasing the intensity of illumination achieved. Gases occluded in this deposit cause hardening of the tubes and tend to displace the spectrum of the generated light from 2537 Å value which, as will be developed, has been found best adapted to energize the fluorescent salts or phosphors lining the tubes. With high voltage harmonic surges, puncturing of the insulation of the tubes and of the related system occurs. Current distribution, moreover, is found to be comparatively poor, due to the momentary voltage surges which force the current unevenly through the lighting system.

An object of our invention is, therefore, to produce a new fluorescent tube lighting system which avoids in large measure substantially all the disadvantages, deficiencies and drawbacks set out in the foregoing, and which gives rise to improved voltage and current wave form, with substantially no harmonics of appreciable value; and in which objectionable tube flicker is diminished appreciably, and life of the tubes is increased appreciably; all without departing from the requirements and standards of the fire underwriters.

In the practice of our invention, we find that a fluorescent lighting system including a transformer of the plural secondary winding type is rendered considerably more effective where the transformer secondary windings are prevented from reacting mutually upon each other. The undesirable harmonics otherwise developed, are avoided in substantial measure, and whatever disturbances remain, due to striking and extinguishing of light tubes of the system, do not and cannot reach alarming proportions. By certain additional precautions, as by inserting small capacity radio-frequency condensers directly across the light tube loads, even these harmonics are substantially damped out.

We, therefore, give considerable attention to the avoidance of detrimental harmonics, with improved secondary wave form, while retaining substantially all of the advantages of compactness, simplicity, reliability and sturdiness, which are attendant upon the use of transformer-energized, cold cathode-operated fluorescent tube lighting systems.

Referring now more particularly to Figure 1, it will be seen that adjacent twin transformer cores, 10a, 10b, are physically spaced end-to-end in substantially separate magnetic relationship. Of course, it is not essential that the cores be physically spaced end-to-end, and in point of

fact, they can be disposed in any convenient manner, as side-by-side, to suit the exigencies of a particular installation, the only requirement being that the two cores be substantially separate magnetically. In the embodiment which we prefer at present, however, we find it convenient from a practical standpoint, to dispose the cores in the physically adjacent, magnetically separate relationship first described. The transformer cores illustratively comprise a central longitudinal leg 11a, 11b, flanked on each side by symmetrically disposed, parallel and spaced outer legs 12a, 12b, 13a, 13b. The ends of the central and outer legs are joined by end pieces 14a, 14b, 15a, 15b disposed normally of said central and outer legs.

Additionally, outer legs 12b, 13b of the second magnetic core are provided, intermediate their lengths, with magnetic shunts Sh1, Sh2 extending toward but short of central leg 11b, providing therebetween air-gaps G1 and G2 of calibrated high reluctance. The purpose of these air-gaps will be developed hereinafter. Except for these intermediate magnetic shunts and associated air-gaps, the second magnetic core is like the first core.

Each core portion 10a, 10b is provided with a primary winding P1, P2 and a corresponding secondary winding S1, S2, respectively. Since the transformer is designed for connection of the primary windings directly across conventional service mains of 110 or 220 volt ratings, while the associated tubes are adapted for operation at elevated voltages of the order of 450 to 600 volts or thereabouts, the paired transformers are of the "step-up" type. Since the paired transformer cores are magnetically separate from each other, the windings of the individual cores do not have any appreciable effect magnetically on the windings of the other core.

The primary windings P1 and P2 are connected either in series or in parallel, as desired, across a source 16 of alternating current potential. In the embodiment under discussion, the windings are connected in parallel, so that each primary winding has impressed thereacross the full potential of the source 16. Were the primary windings connected together in series, they would each take one-half of the impressed voltage. For a given number of turns in the secondary winding, the parallel-connected primary windings must contain twice the number of turns as the number of turns in series-connected primaries, so that the volts-per-turn will remain the same.

A primary winding energizing circuit is readily traced for a given half-cycle of current flow, as follows: From the right side of source 16 in Figure 1, thence through lead 18 to junction 19. Thence part of the energizing current flows to the right through lead 21, to junction 22, lead 23, junction 24 and lead 25 back to the left side of source 16. From junction 19 the other part of the energizing current flows to the left along lead 26 to the right end of winding P2, through the winding P2 and lead 27 to junction 28, and through lead 23, junction 24 and lead 25 to source 16.

Of course, during the opposite half-cycle, the direction of energizing current flow is just the reverse, whereupon energizing circuits may be traced from the left of source 16 in Figure 1, up lead 25 to junction 24. There the energizing current branches, and part courses to the left along lead 23 to junction 28, thence through

lead 27, across primary winding P2, through lead 26, junction 19 and lead 18 back to the opposite side of source 16. The other part of the charging current simultaneously courses to the right along lead 23 to junction 22, over lead 21, through winding P1 to the left, lead 20, junction 19, and lead 18 back to source 16.

Directing attention first to the core 10a, secondary winding S2 and primary winding P2 are connected in autotransformer circuit with a fluorescent gas discharge tube T2 and a power-factor correcting condenser 17. Circuit may be traced from the left side of secondary winding S2, through lead 29, condenser 17, tube T2, lead 30, junction 31, lead 18, junction 19, lead 26, to the left across primary winding P2, lead 27, junction 28, lead 23, and to the right across secondary winding S2. Of course, during the next half-cycle of primary current flow, the direction of secondary current flow is just the reverse of that traced.

Flux generated in core 10a by primary winding P2 serves to generate a secondary voltage in the secondary winding S2 sufficient to energize the load consisting of condenser 17 and tube T2. For a given half-cycle, flux may be assumed to course to the left in Figure 1, from primary coil P2, along leg 11a, interlinking the turns of secondary coil S2 and developing a high potential therein.

During the next half-cycle, of course, the direction of flux is just the reverse of that traced in the foregoing. Flux courses to the right of primary winding P2, and splitting at end piece 15a, courses in part up the end piece, to the left along leg 13a, and shown down end piece 15a, to the left along leg 12a, and up end piece 14a to leg 11a. The flux reunites at the left end of leg 11a and courses to the right along leg 11a, back to primary winding P2.

At first, the secondary winding, its load being deenergized, interposes but little reluctance to the coursing of magnetic flux therethrough. Voltage builds up in coil S2 during each half-cycle of current flow, and because of the high value of this induced voltage, the arc across the tube load is struck. The flux splits at leg 14a, and courses in part up leg 14a, to the right along outer leg 13a and down leg 15a to central leg 11a and back to the primary winding P2; and in part courses down leg 14a, to the right along leg 12a, up end piece 15a, and back to primary winding P2. Immediately, the secondary winding develops a back electromotive force in a direction opposite to the primary electromotive force, thereby tending to decrease the developed secondary voltage.

While it is true that a counter-magnetomotive force is built up in winding S2 when current flows through tube T2, and it may be said that to a certain extent at least, the winding S2 serves to oppose the flow of the primary flux through central leg 11a, the condenser 17 is relied upon mainly to provide sufficient reactance to control the secondary output. Without the condenser, the negative characteristics of tube T2 would impose a heavy burden upon the line. With the current-limiting condenser 17 in the secondary circuit of tube T2, the magnetic core 10a requires no shunts. The condenser additionally provides a leading current in its side of the transformer system sufficient to restore system power-factor to approximately unity. By the same token, the condenser serves to de-

phase the tubes T1, T2, and stroboscopic effect thus is substantially eliminated.

Because no shunt leakage paths are required, windings P2 and S2 are readily mounted on the core in superimposed relationship, where desired, particularly for economy in space and of iron content. Better voltage regulation, however, is obtained with larger iron content.

Turning now to core 10b, it will be observed that quite like core 10a, two windings P1 and S1 are provided. The secondary winding S1 is connected in autotransformer relationship with primary winding P1 and a fluorescent tube load T1. A secondary circuit is traced from the right of secondary coil S1, over lead 45, through tube T1 across lead 44 to junction 31, lead 18 to junction 19, lead 20 across primary winding P1, lead 21 to junction 22, to the right along lead 23 and across secondary winding S1. Of course, during the next half-cycle of primary current, the direction of secondary current is just the reverse of that traced.

Unlike the transformer section just described, however, the load T1 for this section does not interpose sufficient impedance when in operation, to limit the admittance of the main magnetic circuits within safe limits. Accordingly, the magnetic shunts Sh1 and Sh2 and associated air-gaps G1 and G2, already described, must be provided.

In core 10b, the primary flux generated by primary winding P1 courses, during a given half-cycle, to the left in Figure 1 along leg 11b, splits at the end piece 14b and follows two main magnetic paths of low reluctance. One of the paths sequentially includes the upper end of piece 14b, leg 13b, and during the de-energized moments of secondary tube load T2, end piece 15b down to leg 11b; and the other path sequentially includes the lower end of piece 14b, leg 12b, and during the de-energized moments of secondary load T2, end piece 15b up to leg 11b. The flux reunites at the right end of leg 11b and courses along the leg back to primary coil P1, interlinking as it goes, the secondary winding S1 and developing a high potential therein.

As this secondary potential builds up, it reaches the energizing potential of tube T1, and quickly energizes the tubes. Immediately, a back flux is developed by coil S1, interposing a high reluctance to the flow or coursing of the primary flux. The primary flux then in large measure courses the shunt paths, just sufficient flux interlinking the secondary winding to maintain a voltage and current necessary to energize the tube.

The path of the flux now may be traced from primary winding P1 as follows: to the left in Figure 1 along 11b to end piece 14b, thence splitting up and to the right along leg 13b, and down and to the right along 12b. The greater part of the flux, always seeking the path of least reluctance, courses down shunt path Sh1, across air-gap G1, to leg 11b and up through shunt Sh2, across air-gap G2, to leg 11b and directly back to the primary winding P1, thus effectively bypassing the secondary winding S1. Flux just sufficient to maintain the secondary winding energized within desired values, continues past shunts Sh1, Sh2 to end piece 15b, then to the left across leg 11b to the primary winding. When the primary flux wave subsides, the generated secondary voltage falls (during each current half-cycle) to such value that the arc across the tube extinguishes. Immediately, the reluctance

of the principal magnetic circuit falls off to its normal value, and the coursing of the primary flux therethrough is re-established.

During the next succeeding half-cycle of primary current flow, the direction of coursing of flux is, of course, just the opposite of that described. Flux circuits may be traced as follows:

At the first part of each half-cycle, before the arc is struck across tube T1, the flux follows the secondary winding S1 and inducing the rated high voltage therein. The flux splitting at end piece 15b courses in part up and to the left along 13b and down end piece 14b to leg 11b; and in part down and to the left along leg 12b, up end piece 14b, to leg 11b. There reuniting, the flux courses to the right along leg 11b, to primary winding P1.

As soon as the arc across tube T1 strikes, the reluctance of the principal magnetic circuit builds up enormously, due to the back electromotive force induced in the secondary winding S1. Accordingly, the principal passage of flux is across the shunt leakage paths. At such times, the flux courses to the right along leg 11b, to the air-gaps G1, G2. Only sufficient flux continues along leg 11b, interlinking secondary winding S1, to ensure energization of this winding to the required extent. This small stream splits at end piece 15b, part flowing up and to the left along leg 13b, down end piece 14b, to the leg 11b; the other coursing down end piece 15b, to the left along leg 12b, up end piece 14b to leg 11b, and thence back to the primary winding.

By far, the greater part of the flux splits adjacent air-gaps G1 and G2, and courses across air-gaps G1, G2, through shunts Sh1, Sh2 and to the left along legs 12b, 13b, through end piece 14b, to leg 11, and then to the right across leg 11b to primary winding P1.

This cycle of magnetic flux flow is repeated for each half-cycle of primary current flow, and ensures that the energy across the secondary winding is at all times maintained within safe limits.

There is substantially no magnetic reaction between the several secondary circuits of our transformer system. Surges of flux arising in one transformer section are not transmitted to the other transformer section. Improved wave form, accordingly, is achieved; there being a substantial absence of transient harmonics on the fundamental waves; as more particularly pointed out hereinafter.

While the primary and secondary windings of each substantially magnetically separate core are illustratively described as being connected in autotransformer relationship, it must be understood that good wave form is achieved where the primary and secondary windings of each core are electrically separate, and are linked only by the related magnetic core. In such instances, we prefer to connect individual secondary windings of the cores with individual fluorescent tube loads.

Tubes T1 and T2 employed in our system may be of generally conventional design, having spaced and opposed electrodes for maintaining an arc discharge therebetween, and having a filling such as mercury in small amount and some starting gas such as argon or the like. As is conventional with such tubes, the general design is such that the greatest emission from the mer-

cury is around the 2537A line. The argon serves to support discharge until the mercury is vaporized and comes into operation. A lining of a suitable fluorescent salt is provided on the interior of the tube wall, the combination of which salts is selected in accordance with the color of the radiation which is desired. Since the general construction of such tubes is in large measure conventional, no further discussion thereof will be made at this time. Should hot-cathode tubes of the tube conventionally on the market be employed, the terminals of the hot-cathode electrodes will simply be short-circuited, in order to ensure that all parts of each electrode will be at the same potential. Alternatively, cold-cathode tubes, with a single terminal for each electrode, can readily be designed, but since such tubes would now have to be made up on special order, we prefer at this time to employ the tube equipment already available on the market.

As illustrative of the excellent wave form achieved through the practice of our invention, Figure 4 is a facsimile of a recorded oscillograph study of the condensive or leading power-factor side of our autotransformer unit. Similarly, Fig. 5 represents a wave form study of the inductive or lagging power-factor side of our autotransformer unit. In both figures, the substantial absence of transient waves will be noted.

Wave forms, even more improved than those illustrated, are achieved by shunting the tube loads with radio frequency condensers. They serve in large measure to suppress what very slight disturbance from transient phenomena there is, corresponding to alternating energization and de-energization of the tubes. Such condensers are shown at 35, 36 in Fig. 1, directly shunting or by-passing corresponding tubes T1, T2. The condensers, illustratively, are of 0.006 m. f. capacity.

It becomes apparent from the foregoing that the improved wave form we obtain in accordance with the new practice set forth herein, is conducive to an improved life of the tube load, there being practically uniform intensity and quality of emission throughout the useful life of the tubes. Additionally, current distribution, in the lighting system provided, is good, and because of the improved wave form maintaining, sputtering of electrode material is reduced to a minimum. Improved life of the power-factor correcting condenser is achieved. Insulation requirements are reduced, with consequent reduction of first cost, and puncturing of insulation becomes an infrequent phenomenon.

The compactness of the new power unit, its simplicity and small space requirements, are illustrated in Fig. 3 of the drawing. Therein, a case or holder 39 of magnetic material and interiorly insulated, or of non-magnetic material, provides a support for the separate magnetic cores. The cores are encased closely adjacent each other, with the power-factor correcting condenser likewise disposed in the casing and separated by partition 46 from the cores. At each end, casing 39 terminates in a clip 40, 41, for connecting the casing and its associated parts, as a compact power unit, to a tube-lighting unit or the like, such as a reflector, not shown. The windings of the magnetic cores, as well as the condenser, are connected as prescribed hereinbefore. Leads 29, 25, 18, and 45 extend from the transformer windings on the magnetic cores, as described hereinbefore, and end in terminals 75 mounted exteriorly of the casing, to facilitate

connecting the power unit to the load for which it is intended.

Compactness, sturdiness, and reliability under all reasonable operating conditions, characterize our new power unit, and the many savings which are made possible in system insulation, in tube replacements, elimination of costly and bulky auxiliaries, all contribute to a unit cost which is most attractive from the standpoint of the operator.

As many possible embodiments may be made of our 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.

We claim:

1. An electric lighting system, comprising, in combination, transformer means having two main magnetic cores disposed in substantially separate magnetic relationship, primary and secondary windings mounted on each main magnetic core magnetically independent of the other core, said secondary winding being connected in individual circuits with individual electric discharge lamp loads, shunt means extending magnetically between the primary and secondary windings of one of said main magnetic cores, and a current-limiting condenser in the lamp circuit of said secondary winding of the other main magnetic core.

2. An electric lighting system, comprising, in combination, a first transformer core, including, an inner core portion and an outer core portion forming magnetic flux paths therewith on opposite sides thereof, primary and secondary windings mounted on said inner core portion; magnetic by-pass means of high reluctance shunting said core magnetically between the primary and secondary windings; a second transformer core disposed in substantially separate magnetic relationship with said first transformer core and having primary and secondary windings mounted thereon; individual electric discharge lamp loads connected in individual circuits with the individual secondary windings of said transformer cores; and a current-limiting condenser in the circuit of the secondary winding of said second transformer core.

3. An electric lighting system, comprising, in combination, transformer means having two main magnetic cores disposed in substantially separate magnetic relationship, primary and secondary windings mounted on each main magnetic core magnetically independent of the other core and connected in autotransformer circuit with individual electric discharge lamp loads, shunt means extending magnetically between the primary and secondary windings of one of said main magnetic cores, and a current-limiting condenser in the circuit of said primary and secondary windings of the other main magnetic core.

4. An electric lighting system, comprising, in combination, transformer means having two main magnetic cores disposed in substantially separate magnetic relationship, primary and secondary windings mounted on each main magnetic core magnetically independent of the other core and connected in autotransformer circuit with individual electric discharge lamp loads, radio-frequency condensers shunting said electric discharge lamp loads, by-pass means extending magnetically between the primary and secondary windings of one of said main magnetic

cores, and a current-limiting condenser in the circuit of said primary and secondary windings of the other main magnetic core.

5. An electric lighting system, comprising, in combination, transformer means having two main magnetic cores disposed in substantially separate magnetic relationship; primary and secondary windings mounted on each main magnetic core magnetically independent of the other core and connected in auto-transformer circuit with individual electric discharge lamp loads, said primary windings being additionally connected in parallel across a source of electric power; shunt means extending magnetically between the primary and secondary windings of one of said main magnetic cores, and a current-limiting condenser in the circuit of said primary and secondary windings of the other main magnetic core.

6. An electric lighting system, comprising, in combination, a first transformer core, including, an inner core portion and an outer core portion forming magnetic flux paths therewith on opposite sides thereof; autotransformer connected primary and secondary windings mounted on said inner core portion and connected in energizing relationship with an electric discharge lamp load; magnetic by-pass means of high reluctance shunting said core magnetically between the primary and secondary windings; a second transformer core disposed in substantially separate magnetic relationship with said first transformer core and having autotransformer connected primary and secondary windings mounted thereon and connected in energizing relationship with a second electric discharge lamp load, the primary windings of both said cores being additionally connected in parallel across a source of electric power; and a current-limiting condenser in the circuit of the autotransformer windings of said second transformer core.

7. An electric lighting system, comprising, in combination, first and second transformer cores disposed in substantially separate magnetic relationship, each said core having an inner core portion, and an outer core portion forming main magnetic flux paths therewith on opposite sides thereof; said first core additionally having shunt pieces forming high reluctance shunt paths therewith intermediate said inner and outer core portions; a primary and a secondary winding mounted on the inner core portion of each transformer core, with the windings of the first transformer core placed one on each side of said magnetic shunts, and each secondary winding series-connected in autotransformer circuit with an electric discharge lamp load and its related primary winding; and a current-limiting condenser additionally included in the winding and lamp load circuit of said second transformer core.

8. A power unit for electric discharge tubes, comprising in combination, a casing, two main magnetic cores disposed in substantially separate magnetic relationship within said casing, primary and secondary windings mounted on each main magnetic core magnetically independent of the other core, by-pass means of high reluctance shunting one of said main magnetic cores magnetically between the related primary and secondary windings, and a current-limiting condenser included in said casing and connected with the secondary winding of said other main magnetic cores.

9. A power transformer unit comprising, in combination, two main magnetic cores disposed

in substantially separate magnetic relationship, primary and secondary windings mounted on each main magnetic core magnetically independent of the other core, by-pass means of high reluctance shunting one of said main magnetic cores magnetically between the related primary and secondary windings, and a current-limiting condenser connected in series with the secondary winding of the other of said main magnetic cores.

10. A power transformer unit, comprising, in combination, two main magnetic cores disposed in substantially separate magnetic relationship; primary and secondary windings mounted on

each main magnetic core magnetically independent of the other core, each secondary winding being series-connected in autotransformer connection with its related primary winding and the primary windings being connected together in parallel; by-pass means of high reluctance shunting one of said main magnetic cores magnetically between the related primary and secondary windings; and a condenser connected in series with the secondary winding of the other of said main magnetic cores.

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