Sept. 23, 1952 J. H. BRIDGES 2,611,885

FLUORESCENT TUBE LIGHTING SYSTEM AND APPARATUS

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FIG-1

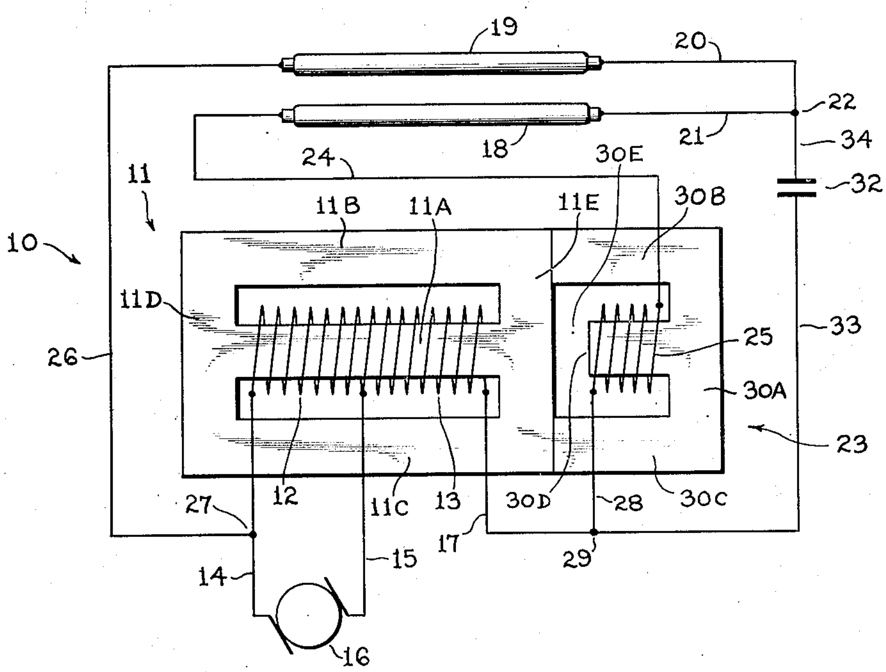
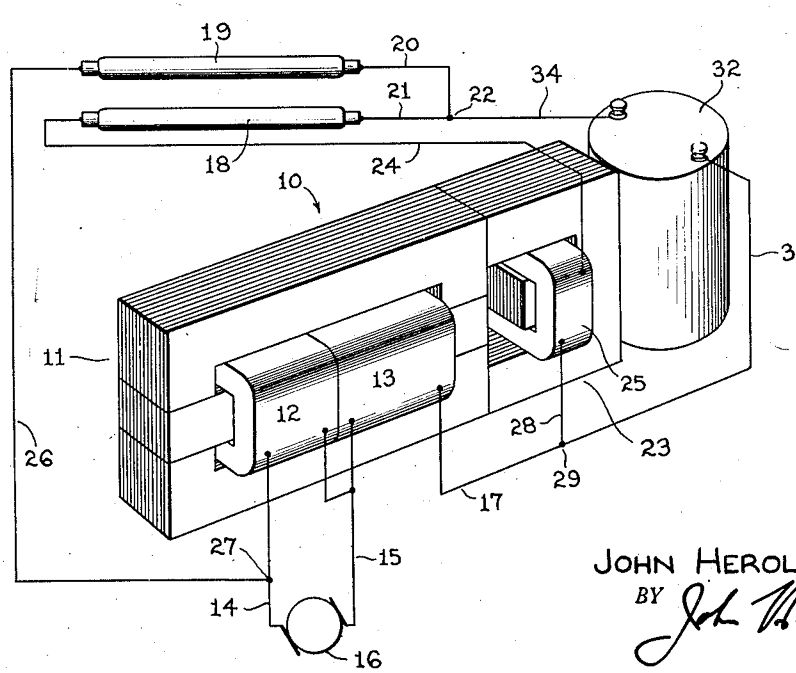


FIG-2



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FLUORESCENT TUBE LIGHTING SYSTEM AND APPARATUS

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5 Claims. (Cl. 315—255)

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My invention relates generally to electrical lighting systems and applications, and more particularly concerns a fluorescent tube lighting system and the several parts comprising the same.

An object of my invention is to provide a fluorescent tube lighting system which is simple and inexpensive of production; which is highly efficient, economical and certain in operation, at the same time insuring instant starting of the tubes, and subsequent maintenance thereof, in certain manner under even the most adverse weather conditions; and which has a high system power-factor with low stroboscopic effect, and in which the tube currents are effectively controlled.

Another object is to provide a power unit for a fluorescent tube lighting system which is unitary and compact, involving a minimum of space requirements; which is comprised of component parts which are in themselves simple and economical of production; and which is sturdy and reliable in operation, having long useful life and involving a minimum iron and copper content, at the same time giving rise to highly efficient, reliable and economical system operation.

Yet another object is to provide a transformer and associated iron core choke coil for use in a fluorescent tube lighting system where initial costs are to be at a minimum and where space requirements are at a premium, but where reliable and efficient operation is required.

Other advantages in part will be obvious and in part more fully pointed out hereinafter during the course of the following description.

Accordingly, my invention resides in the several parts, elements and features of construction, as well as in the combination of each of the same with one or more of the others, the scope of the application of all of which will be more fully set forth in the claims at the end of this specification.

Throughout the several views of the drawings, wherein I have disclosed that embodiment of my invention which I prefer at present, and in which like reference characters denote like parts:

Figure 1 is a schematic wiring diagram, disclosing the basic principles of my invention; while

Figure 2 is a view, partly in perspective and partly schematic, disclosing the power unit according to my invention as installed in a practical embodiment.

As conducive to a more thorough understanding of my invention, it may be noted at this point that wide acceptance in the arts, commerce and

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industry, has been achieved by fluorescent tube lighting systems. The growth has been so rapid that fluorescent tube lighting is closely approaching in incandescent lighting in popularity. Equipment displaying better and better operating characteristics is produced, while both production and operating costs are undergoing constant reduction.

Savings in the amount of copper and iron employed are constantly sought for. Reduction in the space requirements of the operating units is a constant objective. Efforts are continuously being made to reduce the cost of the power unit required and yet maintain satisfactory operating characteristics.

An important object of my invention, therefore, is to provide a compact, inexpensive and efficient power unit for operating a pair of fluorescent tubes with unobjectionable stroboscopic effect, satisfactory power-factor and instant starting under the varying conditions of actual use.

In accordance with the practice of my invention, I operate paired fluorescent tubes from a transformer common to both of them. Preferably, although not necessarily, this transformer has a shell-type core, and the primary and secondary windings are mounted on the central leg thereof, preferably but not necessarily side-by-side, in autotransformer connection.

Now, to insure good operating characteristics, with high system power-factor, I connect the two fluorescent tubes in series with each other and with the transformer. An iron core inductive reactance also is included in this series circuit, preferably being introduced between the secondary winding of the transformer and the fluorescent tube to which it is connected. This series has a choke to prevent excessive current while the tubes are in their conductive condition. I also connect a condenser across one tube, preferably across the reactance and the tube to which it is immediately connected. This permits initial striking of the unshunted tube followed by striking of the shunted tube. The voltage requirements of the transformer are only that of one tube.

In my novel construction, the close-coupled transformer is compact and inexpensive. Moreover, the inductance likewise is compact and inexpensive. Additionally, I am enabled to achieve the further simplification of forming the transformer secondary winding and the choke coil winding of the same size wire since a common current flows through both. A substantial saving in manufacturing costs thus is achieved.

For a more precise understanding of my lighting system and apparatus, reference is had more particularly to the schematic embodiment illustrated in Figure 1 of the accompanying drawing wherein the transformer is indicated generally by the reference number **10**. It consists of a shell-type iron core indicated generally at **11**, having a central leg **11A** and outer legs **11B**, **11C** disposed parallel with and in spaced relation to the central leg **11**, one on each side thereof. The core is completed by end pieces **11D** and **11E**. A primary winding **12** and a secondary winding **13** are disposed on the central leg **11A**. Leads **14**, **15** extend from the extremities of the primary **12** to a suitable source of alternating current power, indicated generally at **16**.

For reasons which will be developed more particularly hereinafter, the primary and secondary windings **12** and **13** are disposed side-by-side on the central leg **11A**. That is, they are not disposed in superimposed relation, one on top of the other. It will be noted that the transformer windings are close-coupled, the only flux leakage being to the air from the margins of the core. Preferably, although not necessarily, the primary and secondary windings are connected in auto-transformer connection. Such connection is entirely permissible, under the regulations of the Fre Underwriters, for potential of 600 volts or less. Illustratively, the primary may be wound for 118 volts while the secondary is wound for 332 volts, giving an output potential for the auto-transformer of 440 volts.

To achieve a high degree of economy, the winding **12** is constructed of wire of sufficient diameter to carry the higher primary current, while the winding **13** is formed of wire size just sufficient to carry continuously the prevailing secondary current. For two 40 watt fluorescent tubes, this amounts to approximately 0.9 amperes. With the current-carrying capacities of the windings **12** and **13** being accurately determined, and as well, the number of turns of both primary and secondary windings being nicely selected for inducing the proper secondary voltage, the minimum copper requirement is accurately determined, and is maintained at a very low figure.

The central leg **11A** of the transformer core is dimensioned to carry, just short of magnetic saturation, the maximum flux required for inducing the required secondary voltage, while the outer members **11B**, **11C**, **11D** and **11E** are dimensioned as to accommodate, just short of magnetic saturation, about one-half of the maximum flux coursing the central leg **11A**.

Minimum iron content is determined by maintaining the core length at the smallest possible value consistent with placing the primary and secondary windings **12** and **13** in side-by-side relation thereon, and by insuring that the spacing between outer legs **11B** and **11C**, on the one hand, from the central leg **11B** on the other hand, is maintained at the smallest possible value consistent with suppression of mutual induction between the central and outer legs. That is, the pieces **11D** and **11E** are maintained at minimum length. In this manner, and by the observance of the several precautions hereinbefore recited, the greatest possible transformer efficiency is achieved, both from an operational and practical, economical standpoint, and both the first costs and the costs of subsequent operation are brought to a theoretical minimum.

From a manufacturing standpoint, the cost is

minimized since the elements of the transformer are of the greatest possible simplicity. To facilitate simplicity in manufacture, although the following does not necessarily constitute a material part of my invention, the outer legs **11B** and **11C** may be formed with integral end pieces **11D** and **11E** giving a pair of generally C-shaped core pieces abutting the linear central leg **11A** (see Fig. 2), the several elements being tightly clamped together against chattering.

Paired fluorescent lamps **18**, **19**, in the present instance comprising conventional 40 watt lamps, although this is not an essential prerequisite, are connected in series with each other through leads **20** and **21**, joined together at junction **22**. A current-limiting choke indicated generally at **23** is likewise connected in series with the tubes **18** and **19** by means of a lead **24** between one terminal of tube **18** and a corresponding terminal of choke coil winding **25**. The ensemble consisting of the choke **23** and tubes **18** and **19** is connected to the transformer auto-connected windings **12** and **13**, in part by means of lead **26** extending from tube **19** to lead **14**, which it joins at junction **27**, and in part by lead **28** extending from choke coil winding **25** to junction **29** with lead **17** as shown in Figure 1.

Novelty resides in the construction of the iron choke **23**. The core thereof is of generally E-shaped configuration, having an end portion **30A** and outer legs **30B** and **30C**. These latter abut against one of the end pieces **11D**, **11E** of the transformer core **11**, in Figure 1 shown as comprising the end member **11E**. Thus the E-shaped choke core is disposed towards the transformer **10** and abuts snugly thereagainst. The central leg **30D** of the choke core **23** extends towards, but terminates short of, the end member **11E** of the transformer core, so as to provide an included air-gap **30E** which tends to suppress within certain calibrated limits the coursing of flux induced by the choke coil winding **25** within the core **30**. As is evident from consideration of the Figure 2, the width of the transformer and choke cores are identical so that the two elements nest snugly against each other, in neat compass.

I have provided for effective starting and for effective and efficient and subsequent operation, however, through the provision of an ingenious expedient, simple in itself. That is, I insert a condenser **32** of appreciable capacity in shunted relation across the choke **23** and its associated series-connected tube **18**, by means of leads **33** and **34** extending between junctions **29**, **22**. This condenser **32** is thus seen to be series-connected by means of lead **20** with tube **19**, the unit comprising this condenser **32** and tube **19** being in turn series-connected to the transformer by means of leads **17** and **26**. Inspection will show that upon removal of the tube **19** from its socket the entire secondary system is de-energized, while upon removal of tube **18**, it is still possible for the tube **19** to operate through the path including condenser **32**, shunting out tube **18** and choke **23**.

The function of the choke **23** is of course to serve as a current-limiting device for the series-connected tubes **18**, **19**, which possess negative resistance characteristics. That is, the characteristics of these tubes is that once the arc is struck, the internal resistance across the arc decreases tremendously. By consequence, currents of large value tend to course through the tubes. This would result in rapid destruction thereof unless current-limiting means are provided.

The effect of the introduction of the condenser 32 is that initially, with static conditions maintaining, the transformer potential in large measure is impressed across the condenser 32 and tube 19. Since at this instant the tubes are in their non-conductive conditions and no current flows substantially the entire transformer voltage is impressed across the terminals of the tube 19. This tube then ignites.

Immediately upon the striking of the arc in tube 19 the internal resistance of the tube falls off appreciably, so that the voltage necessary to maintain the arc already struck likewise lowers to a comparatively small value. Accordingly, substantially all of the secondary voltage with the exception of the small amount required to maintain the arc in tube 19, is impressed across the terminals of the tube 18. The ensemble of choke 23 and tube 18 now displays less resistance than does the condenser 32 because the impedance of condenser 32 assumes its normal value with the flow of current supplied tube 19. The arc is therefore quickly established across tube 18, once tube 19 has been ignited.

The accompanying decrease in the internal resistance of tubes 18 and 19, would result in the flow of an excessive current, since the transformer 10 is of the close-coupled type, except for the choke 23. It will be noted that this choke is provided in the main secondary circuit, and is series-connected with the secondary winding 13. Therefore, it carries the same current as the secondary 13. For efficiency, it is formed of the same wire size. Thus, an additional factor of simplicity is thereby introduced, namely, that the choke and secondary windings are wound with the same size wire. As a result thereof only two sizes of wire are required in my power unit.

The effect of the choke is of course to induce a back magnetomotive force which develops a back electromotive force tending to buck the main secondary electromotive force, and through self-induction, diminishing the current flow first through the tube 19 and then, after the tube 18 has struck, through tubes 18 and 19 together. To control in accurately predetermined manner the self-induction in the choke 23, I provide the air-gap 30E of calibrated dimensions in the leg 30D.

The stack of laminations comprising central, short arm 30D of the choke 23 is cross-sectionally dimensioned so as to carry the maximum flux which is required for proper choking action. The end-portion 30A and the outer legs 30B and 30C have cross-sectional areas sufficient to carry approximately one-half of the flux which courses the central leg 30D. The number of turns of winding 25 and the current flowing therethrough, which of course is the current flowing through the main secondary winding, determine the magnetomotive force generated in the leg 30D and hence is determinative, along with the air-gap 30E, of the choking effect of the choke 23, having given fixed cross-sectional areas of the legs 30A–30D inclusive, as well as selected material from which the choke laminations are formed.

It is preferred that the choke winding 25 be wound in the same direction or phase as the primary coil 12, so that as the primary flux courses to the right in Figure 1, along central transformer leg 11A, the secondary flux induced from the secondary winding 13, and which courses central choke leg 30D, will pass to the left in Figure 1, across included air-gap 30E, and thence will split in transformer end piece 11E and pass upwardly and downwardly to, and back across, outer legs 30B, 30C of the iron core choke 23. During the reverse half-cycle of current flow, of course, the direction of coursing of both the primary flux and the choke flux will be in directions exactly opposite that just traced, as will be more fully pointed out hereinafter.

It is now in order, for precise understanding of the operation of my new system, to trace the several circuits involved. The primary circuit for a given half-cycle will be from the left side of the source of alternating current supply 16, as seen in the drawing, through lead 14, across junction 27, to the left side of the primary winding 12. The primary current then courses across primary winding 12 to the right and thence through lead 15 back to the right side of source 16. For the succeeding half-cycle, the current flow of course will be in the opposite direction.

For the first-mentioned half-cycle of current flow in the primary winding, the resulting secondary potential is applied across lead 28, choke winding 25, and lead 24 to tube 18. Also, it is applied through lead 33 to condenser 32, lead 20 and tube 19. Tube 19 is connected by way of lead 26, junction 27 and lead 14, to the left-hand end of the primary winding portion 12 of the auto-transformer.

The voltage difference between leads 24 and 26, however, is not sufficient to obtain the initial ignition of the tubes 18 and 19 together. Thus, open-circuit conditions maintain. Since at this point there is no current flow, full potential is applied by way of condenser 32 to the tube 19.

As soon as the tube 19 is rendered conductive, the voltage demand thereacross reduces appreciably, due to the negative resistance characteristic of the tube. Only a few volts is required to maintain the arc thereacross. Moreover, as soon as the arc is struck across tube 19, a current begins to flow. Now condenser 32 interposes a substantial quadrature reactance, so that the shunt path around tube 18 and choke 23 now displays high impedance to the passage current therethrough. Substantially full transformer potential is therefore impressed across tube 18 (since in absence of current flow in choke 23 there is no voltage drop there). The comparatively large voltage which is now impressed across tube 18 quickly strikes the arc thereacross, and current flows through lead 28, through lead 21, junction 22, lead 20, choke 23, lead 24 to tube 18, thence through tube 19, across which the arc has already been struck, and back through lead 26, junction 27 and lead 14 to the left-side of the primary winding 12 of the autotransformer 12—13.

With both tubes in conductive condition, the current flow across these tubes would be excessive, up to the magnetic saturation values of the transformer core 11, unless some current-limiting means such as the choke 23 were interposed therebetween. Choke 25 admirably serves this current-limiting function, and is so calibrated as to have an impedance under load conditions somewhat less than that of the condenser 32, so as to insure that tube 18 is energized during operation. Moreover, winding 25 of choke 23 is wound in such direction as to be in phase with that of the primary winding 12. Air-gap 30E is interposed between the short, central leg 30D of the E-shaped choke core and adjacent end piece 11E of the transformer core 11, so as to limit effectively the choking action of the member until current begins to flow in tube 18.

Now, with the flow of current established, both tubes being ignited, and with the assumption that the secondary current flow is to the right in Figure 1, current flows through lead 17 away from the secondary winding 13 to junction 29. There a small quantity of current flows across lead 33, condenser 32, lead 34, junction 22, lead 20, tube 19, and back through lead 26, junction 27, and lead 14 to the left-hide of the auto-transformer winding. The larger portion of the current, however, courses from junction 29, down lead 28, across choke winding 25, lead 24, tube 18 and lead 21 to junction 22. From thence the flow is just the same as that traced with respect to the current flowing across the condenser 32. The amount of current in lamp 19 therefore somewhat exceeds that in lamp 18. This is not objectionable, however, because I find that greater current is required in tube 19 because of the irregular wave-form introduced by the condenser, in order to give balanced illumination from the two tubes.

During the reverse half-cycle of secondary potential the tubes 19 and 18 respectively are rendered conductive as more fully discussed above. With both tubes in conductive condition, the secondary current courses up from the left side of the auto-transformer through lead 14, to junction 27, across lead 26 to tube 19 and lead 20 to junction 22. There some of the secondary current courses lead 34, condenser 32, lead 33, junction 29, and lead 17 back to the right side of the auto-transformer winding. Most of the secondary current, however, courses from junction 22, down lead 21, across tube 18, up lead 24, through choke winding 25 and lead 28, back to junction 29.

The course of the magnetic flux through choke 23, for the direction of the primary current flow first traced, is to the left across short leg 30D of the choke core, across included air-gap 30E, to the right end portion 11E of the transformer core 11, where it splits into two branch streams. While one such branch stream joins one portion of the main magnetic flux in core piece 11E and courses up end-piece 11B to the right side of end portion 30B and down the web portion 30A back to the central leg 30D, the other branch stream joins the other portion of the flux in the main core and courses down end piece 11E to the right across leg 30C up web 30A and to the left across central leg 30D. During the next half-cycle of secondary current flow the direction of coursing of the induced flux is just the reverse of that just traced.

Since the choke winding 25 carries the same current as the secondary winding 13, they are wound of the same size wire. The physical dimensions of the choke core are so selected as to be at a minimum consistent with proper physical location of the choke winding 25. Thus the amount of iron employed is at a minimum.

It is my desire to provide a power unit comprising the transformer, choke and condenser of minimum compass, and to correlate the outer dimensions of these three component elements so that they nest snugly against each other in end-to-end abutting relationship, as can be more closely observed from consideration of the disclosure of Figure 2. It will be seen that the transformer, the yoke of the choke and the condenser have substantially the same transverse cross-section. The three elements are disposed in minimum compass, and provide a snug, compact and unitary construction. In overall size, my power unit, including case and compound, is somewhat more compact than the currently used "ballast."

Consequently, it readily may replace the "ballast," and its necessary starter, in a lighting fixture.

In the practice according to my new system, the transformer 10 is most compact, and is rendered highly efficient because of the direct coupling between the primary and secondary windings. In point of fact, I have found in practice that the coupling is so close that in order to limit the size and hence cost of the choke which will effectively limit the secondary current flow, it is desirable not to position the primary and secondary winding one on top of the other, but to dispose them side-by-side so as to permit a certain amount of leakage from the shell-type core. This provides an additional limiting factor or control, over and above that interposed by the choke and condenser.

Oscillographic study discloses that highly symmetrical and advantageous wave form is achieved. Without intending to be limited thereby, I attribute this to the fact that the choke core is in series-connection with both tubes. The iron content of the transformer choke is reduced to a minimum, as has already been pointed out hereinbefore. The number of different component parts is likewise reduced to a minimum, and these are of the simplest possible configuration. Only two sizes of copper wire are required, and the copper content itself is reduced to a minimum. Illustratively, the iron core transformer is approximately three by five inches in dimension, and the iron core choke is correspondingly small.

While it is true that the condenser 32 is somewhat larger than is ordinarily used, it is not prohibitively large. Illustratively, where the condenser ordinarily used for power-factor regulation in a fluorescent tube lighting system operating two 40 watt tubes might be in the neighborhood of 1.85 microfarads capacity, the condenser 32 as employed in my new assembly is of say 2.00 microfarads capacity. Good power-factor thereby is had in addition to substantial freedom from stroboscopic effect.

Since it is apparent that once the broad aspects of my invention are disclosed, many embodiments thereof will readily suggest themselves to those skilled in the art, I intend the foregoing to be construed as merely illustrative, and not in a limiting sense.

I claim:

1. A fluorescent gaseous discharge tube lighting system comprising a source of alternating current electrical energy of predetermined frequency, an auto-transformer having a shell-type core with central leg upon which primary and secondary windings are disposed in side-by-side relation and connected together in series and with the primary winding thereof connected to said source, a pair of series-connected fluorescent gaseous discharge tubes, an iron core reactor disposed in abutting relation on one end of said transformer core with the winding on said reactor connected at one end to the transformer secondary winding and at the other end connected to one end of said series-connected fluorescent tubes, and a condenser shunted across said reactor and one only of said tubes, said other end of said fluorescent tubes being connected to the primary winding, and the reactor and transformer secondary winding being formed of the same size wire.

2. A fluorescent gaseous discharge the lighting system comprising a source of alternating current electrical energy of predetermined frequency, an auto-transformer having a shell-type

core with central leg upon which primary and secondary windings are disposed in side-by-side relation and connected together in series and with the primary winding thereof connected to said source, a pair of series-connected fluorescent gaseous discharge tubes, an iron core reactor of shell-type construction disposed in abutting relation to said transformer core with central leg thereof providing an air-gap to said core and with the winding on said reactor connected at one end to one end of the transformer secondary winding and at the other end to said fluorescent tubes, and a condenser shunted across said reactor and associated tube, said other end of said fluorescent tubes being connected to said primary winding, the reactor winding and primary being wound in the same direction or phase.

3. A power unit for a fluorescent tube lighting system, comprising a transformer having primary and secondary windings mounted on an iron core and connected together in series, a choke coil having an iron core disposed at one end of said transformer core, a condenser disposed snugly against a free end of the unit comprised of the transformer and choke cores, and means connecting together one end of each of said transformer secondary, choke coil and condenser.

4. A power unit for a fluorescent tube lighting system, comprising a transformer having a shell-type core with auto-transformer-connected primary and secondary windings positioned on the central leg thereof, a choke coil having an E-shaped iron core disposed at one end of said transformer core with the outer legs of the E-core abutting against the transformer and the central

leg extending towards but terminating short of said transformer core to povide an included air-gap, and a condenser disposed snugly against a free end of the unit comprised of the transformer and choke cores, one end of each of said transformer, choke and condenser being electrically-connected together, and with the other ends of said transformer, choke and condenser adapted to be connected to fluorescent tubes.

5. In a power unit, the combination of a transformer having a shell-type core and primary and secondary windings disposed side-by-side in auto-transformer connection on the central leg thereof, and a choke coil having an E-shaped core with the outer legs directed towards and abutting against one end of said transformer core and with its central leg extending towards but terminating short of said end to provide an air-gap, said choke coil being of the same wire size as said secondary winding and connected in series therewith and wound in the same electrical direction as said primary.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,056,661	Foulke	Oct. 6, 1936
2,301,671	Abadie	Nov. 10, 1942
2,305,153	Fries	Dec. 15, 1942
2,312,867	Boucher	Mar. 2, 1943
2,418,160	Campbell	Apr. 1, 1947
2 436,399	Nathanson	Feb. 24, 1948
2,496,981	Boucher et al.	Feb. 7, 1950