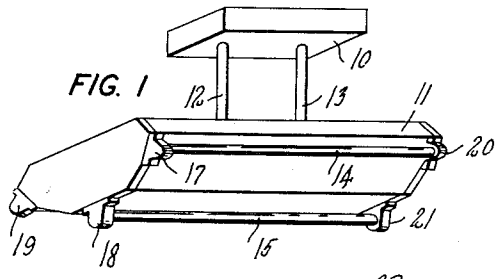
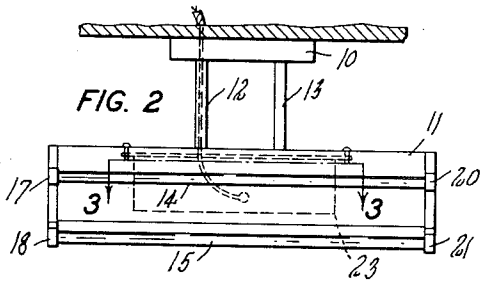
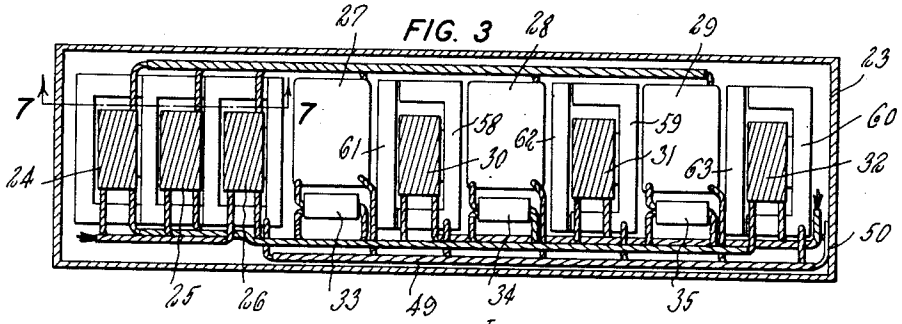
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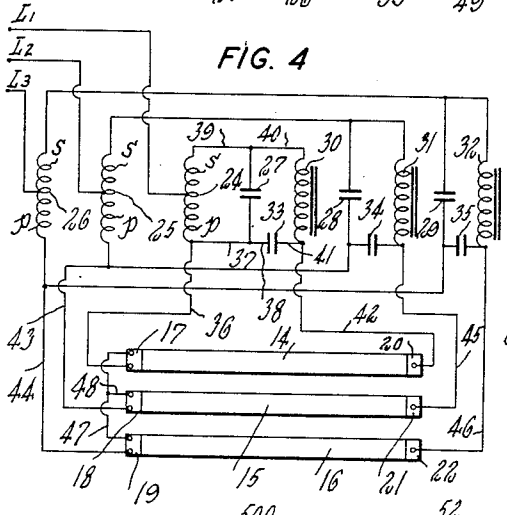
THREE-PHASE FLUORESCENT LIGHTING SYSTEM

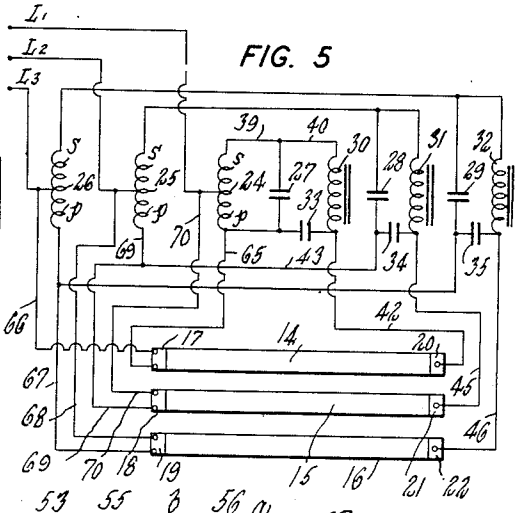
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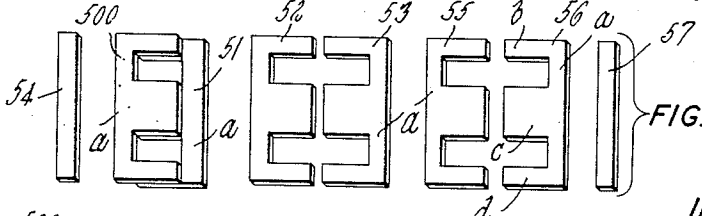


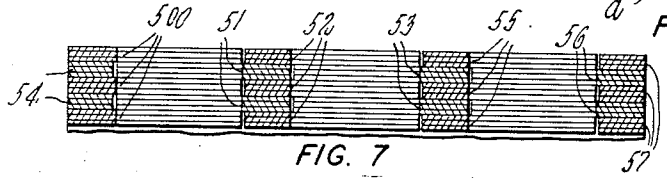












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THREE-PHASE FLUORESCENT LIGHTING SYSTEM

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11 Claims. (Cl. 240—51.11)

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This invention relates to lighting apparatus employing light sources of the electric discharge type. In the illustration disclosed in this specification it is applied to apparatus in which the light sources are fluorescent lamps; and that fact is indicated by the title. However, the invention is applicable to all situations in which electric discharge light sources of any character are connected in the several phases of a three phase alternating current, and its scope is to be construed accordingly.

The objects of the invention include that of eliminating flicker and stroboscopic effect in the operation of such light sources with greater efficiency and economy than has been possible with apparatus heretofore known; and to provide a lighting fixture for operation by three phase alternating current with a compact and economical ballast by which light of substantially uniform intensity and continuity is obtained. A related object is to provide a self contained ballast for use in the operation of gas type lamps in a three phase circuit in which the transformers for all of the lamps have a single continuous magnetic circuit and all, together with associated equipment, are contained in a single case.

A further object is to provide circuit connections between the parts of the ballast and the sockets which removably contain the lamps, so disposed as to deliver current to the lamps of sufficiently high voltage to insure starting, and at the same time to eliminate possibility of dangerous voltage being passed through a person who may carelessly handle a lamp when inserting it into its high voltage socket.

I am aware that it has been proposed heretofore to furnish a steady light by connecting three single phase gas filled lamps in the several phases of a three phase circuit; but, to the best of my knowledge and belief, no combination of such a collection of lamps with a three phase ballast in one fixture has ever been made or proposed.

My invention consists in a combination by which the objects precedently set forth are realized and, in the preferred embodiment of which, three single phase lamps are mounted on a single fixture and are connected with a ballast in the same fixture, such ballast including transformers for the several lamps having a single continuous magnetic circuit, and reactors, all compactly assembled and encased as a unit subcombination and the parts of which are connected with the sockets of the lamps in such

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manner as to eliminate danger from electric shock to persons who may carelessly handle lamps while inserting them into the high voltage lamp sockets.

A further object of this invention comprises an arrangement by which should any of the three single phase lamps be removed from the fixture or become otherwise inoperative, the other lamp or lamps will remain lighted with the same brilliance as though all three lamps were in operation.

In the accompanying drawings—

Fig. 1 is a perspective view of a lighting fixture having three tubular gas filled lamps and including an embodiment of the other features of the invention;

Fig. 2 is a side elevation of the fixture shown in Fig. 1 and representing by broken lines the casing of the ballast which is contained within the lamp fixture housing;

Fig. 3 is a plan view of the ballast on a scale larger than that of the preceding figures, showing the casing of the ballast in section on the line 3—3 of Fig. 2;

Fig. 4 is an electrical diagram showing the lamps and the parts of the ballast connected with a three phase alternating current power source and including connections by which high voltage is removed from the circuit whenever any lamp is removed from its socket;

Fig. 5 is a diagram somewhat similar to Fig. 4 but with the several transformer primaries arranged in delta.

Fig. 6 is an exploded view of the parts of a core with which the windings of all of the transformers of the ballast are assembled so as to provide a single magnetic circuit;

Fig. 7 is a longitudinal section of the assembled core taken on line 7—7 of Fig. 3 and shown on a larger scale.

Like reference characters designate the same parts wherever they occur in all the figures.

The fixture here shown comprises a canopy 10 adapted to be mounted on the under side of the ceiling of a room or any other overhead structure. A housing 11 is suspended from the canopy by tubular suspenders or stems 12 and 13, through either of which electrical conductors can be passed to the interior of the housing.

Projecting from the under part of the housing at the opposite ends are sockets in which the ends of tubular single phase lamps 14, 15 and 16 are mounted. Two of these lamps are shown in Figs. 1 and 2, and the third is shown in the diagram, Fig. 4. Those represented here are

the commonly used gas filled fluorescent tubes of the electric discharge type having electrodes sealed into both ends. The sockets for these tubes at one end of the housing are shown at 17, 18 and 19 in Fig. 1, and those for the tubes 14 and 15 at the other end of the housing are shown at 20 and 21. The third socket at this end is shown at 22 in Fig. 4.

A case for the ballast transformers and auxiliary equipment is shown by dotted lines at 23 in Fig. 2 as being contained within the housing 11 suspended from the top wall of the housing. This ballast or transformer case is shown in detail in Fig. 3 with the transformers and associated power factor condensers and reactors assembled therein as a unit combination. In the specific apparatus chosen for present illustration of the invention, there are three transformers, of which the windings are separately connected in the several phases of a three phase alternating current circuit and all the windings are combined with a single iron core structure disposed to furnish a single continuous magnetic circuit. The transformer windings are shown at 24, 25 and 26 in Fig. 3 and the core structure is shown in detail in Figs. 6 and 7. The latter has elements passing through and embracing the windings and is made of laminated parts and so designed as to permit easy assemblage with the windings and provide uninterrupted paths for magnetic flux within and around the windings. Power factor capacitors 27, 28 and 29, reactors 30, 31 and 32, and radio interference preventer condensers 33, 34 and 35 are connected in circuit with the condensers, and all are mounted compactly in the case 23.

Reference is directed to the diagram in Fig. 4 for a showing of the connections between these several electrical elements and the lamps. The three wires L^1, L^2 and L^3 from a three phase alternating current source are led through the suspender 12 into the ballast case 23 and are connected with the transformer windings 24, 25 and 26, respectively. The transformers here shown are auto-transformers, having the primary and secondary windings designated *p* and *s*, respectively. The primary winding of transformer 24 is connected by a conductor 36 with the low potential socket 17 of the lamp 14, by a conductor 37 with one terminal of power factor condenser 27, and by a conductor 38 with one terminal of the radio interference prevention condenser 33. The secondary winding of transformer 24 is connected by a wire 39 with the opposite terminal of the power factor condenser and by a wire 40 with one terminal of the reactor or choke coil 30. The opposite terminal of the reactor is connected by a wire 41 with the opposite side of the condenser 33 and by a wire 42 with the high voltage socket 20 of the lamp 14.

The other transformer primary windings are connected by conductors 43 and 44 with the low potential sockets of the lamps 15 and 16, respectively; the reactors 31 and 32 are connected by conductors 45 and 46 with the high potential sockets of these lamps; and connections essentially like those first described are made between the secondary windings of transformers 25 and 26 with the power factor condensers 28 and 29 and reactors 31 and 32, respectively, while connections essentially like those first described are made between the primary windings of transformers 25 and 26 with the condensers 28, 29, 34 and 35 and between the last named condensers and the reactors 31 and 32, respectively. All of the low potential lamp sockets have two separate

contacts arranged to bear on the metal fitting on the low potential end of the lamp tube, which is connected with the electrode at that end of the lamp, when the lamp is inserted into the socket. The several condenser primary windings are connected each with one of the contacts in the several sockets, as indicated by the diagram. In this diagram the points of connection of the conductors 36, 43 and 46 with the sockets 17, 18 and 19, respectively, represent one of the contacts in each socket. The other contacts of the sockets 17, 18 and 19 are in shunted connection with one another by a conductor 47 and branch 48.

With this mode of connection, the three transformers are connected in a three phase star circuit and the shunt 47, 48 is the center connection with the star. The metal terminal fitting of any lamp, when inserted into its socket, bridges across the separated contacts in the socket and, when all of the lamps are in place, the star circuit connection of the three transformers is completed. When any lamp is removed, the circuit between the condenser to which that lamp is related and the center connection is broken.

The core structure of the transformers, the cores of the reactors, and the metal shells in which the power factor condensers are encased are all grounded on the case 23; an insulated conductor for that purpose being shown at 49 in Fig. 3, being connected to the case at 50 and having branches connected with the several cores and transformer shells.

An important safety feature is afforded by the circuit connections of the ballast with the low voltage sockets of the lamps. The danger against which this safety feature protects is this: Burned out lamps need to be replaced from time to time, and a person making such a replacement could, by inserting one end of the new lamp into the high voltage socket while holding the other end of the lamp and being connected to ground, cause the lamp to start and be subjected to dangerous voltage if the full voltage were then applied to the socket. Such handling of a lamp in being mounted in its sockets is very liable to occur. I have removed the possibility of danger resulting from handling of a lamp in this manner by the circuit connections here shown, which cause the voltage in the circuit of any lamp to be reduced to a safe degree when the lamp is removed. Thus, assuming, for instance, that the lamp 14 has been removed, then no current passes through the primary winding of the transformer 24 which is connected to that tube. Consequently the voltage is not stepped up in the secondary winding of that transformer, but the voltage from the power line which passes through the secondary winding and through the reactor 30 is too low to energize a lamp, and the person who may place one end of a lamp in the socket 20 while handling it in the manner described is insulated against any passage of current through his body.

The core structure of the ballast is made of numerous originally separate parts constructed for easy assemblage with prewound wire coils and with each other into a unitary structure having magnetic continuity. In the illustrated embodiment, the individual pieces are cut from sheet iron .026 inch thick. Most of them have an outline similar to the letter E, consisting of a trunk portion *a* and three lateral branches *b*, *c* and *d* extending to the same side from the ends and middle of the trunk portion. A smaller proportion of these pieces are of straight bar form having the same length and width as the trunk por-

tions *a*. Groups of three pieces each are assembled in stacks with each wire coil and with their branches overlapped. Thus the group of pieces designated **50** in Fig. 6 is assembled with the group designated **51** so that their branches overlap and the middle branches of both pass through the central openings of the coils while the end branches embrace the coils. Other like groups are stacked on the two groups above described and interleaved with the coils until a core of the prescribed thickness has been built up.

Other groups **52** and **53** are similarly stacked up in assembled relation with the wire coil of a second transformer. The trunk portions of the groups in each stack are spaced apart from one another by the thickness of the overlapping branches, and the trunk portions of the stacked up groups **52** are inserted into the spaces between the trunk portions of the stacked groups **51**. Groups of bar shaped pieces **54** are inserted between the trunk portions of the groups **50**.

A third set of groups **55** and **56** of E shaped pieces are stacked in assemblage with the third transformer coil in the same way, and the trunk portions of the groups **55** are inserted in the open spaces between the trunk portions of the groups **53**. Finally, groups of bar shaped pieces **57** are inserted in the spaces between the trunk portions of the groups **56**. Then the whole assemblage makes a substantially solid laminated structure, as shown in section in Fig. 7.

In the winding of the transformer coils, the secondary coil is wound outside of the primary coil so that it is situated next to the portions of the iron core by which it is embraced. Also the coils of one of the transformers are wound oppositely to the winding of the other transformer coils. Thus the transformers **24** and **26** may be wound clockwise, as to both the primary and secondary windings, and the transformer **25** wound counterclockwise, or vice versa. This is an important factor, as it suppresses the third harmonic, preventing vibration.

The cores **58**, **59** and **60** of the several reactors are also provided with a trunk portion and three lateral branches around and between which the several coils are located. The several cores are associated with bars **61**, **62** and **63** which bridge across the branches of the cores and complete the magnetic circuits through the latter. Gaps, which may be varied in width from zero to a limited maximum value, are provided between the bars and the adjacent branches of the cores. By adjustment of the width of these gaps, the strength of the current passing through the reactor coils may be varied and adjusted. Once adjusted, the gaps are preferably filled with solid insulation and thereby made permanent.

All of the parts herein described, i. e., ballast, condensers and reactors, are compactly assembled in the case **23** and made fast therein. Although no specific fastening means are shown in the drawing, it may be understood that any mechanical fasteners or other means suitable for the purpose can be used.

By assembling the transformer windings of all three phases of the power circuit in association with what is in effect a single core, a much more compact and efficient ballast has been made, with a very large saving of cost. These factors of efficiency, economy and convenience are enhanced by the assemblage of all of the parts of the apparatus (ballast, condensers and reactors) compactly in a single case as a self-contained unit.

In this apparatus the transformers are designed

to step up the electromotive force to 600 volts when the current is turned on, which is sufficient to start the lamps. After starting, the voltage drops to a continuously operating value. The reactors cut down the current to the prescribed strength, which may be varied, as previously stated, by adjustments of the gap between the cores of these reactors and their associated armature bars. The normal operating current is 300 milliamperes, and it can be increased by this adjustment up to 500 milliamperes.

In Fig. 5 the three transformer primary windings are shown arranged in delta, the line L1 being connected to the mid-point of the auto-transformer **24** while the opposite end of the primary of the transformer is connected through lead **65** and the socket **17** with the mid-point of the transformer **26** and through leads **65** to the line L3. Similarly the opposite end of the primary of the transformer **26** is connected through the lead **67**, socket **19** and lead **68** to the line L2 and to the mid-point of the transformer **25**, while the opposite end of the primary of the transformer **25** is connected through leads **69** and **43**, socket **18** and lead **70** with the line L1 and to the mid-point of the transformer **24**. The ballast, condensers, and reactors are connected precisely as in Figure 4. With this arrangement shown in Figure 5, failure or omission of one or more of the lamps in no way interferes with the operation of any of the others, each of which has impressed on its terminals at all times the voltage differential between two of the lines L1, L2 and L3.

This application is a continuation-in-part of my application Serial No. 110,725, filed August 17, 1949, for Three Phase Fluorescent Lighting System.

While I have given specific values for some of the features of the combination herein illustrated, it is to be understood that these values are not limiting, but they may be varied widely within the limits known to be safe in this art. The principles of the described embodiment are applicable with modifications understood by those skilled in the art to fixtures designed for fluorescent lamp tubes of all the various lengths and diameters employed in practice.

I claim:

1. An electric lighting system comprising three single phase gas filled lamps of the electric discharge type, a transformer having three separate sets of primary and secondary windings assembled with a single iron core, connections for the flow of current between the separate phases of a three phase power supply source and the several primary transformer windings, individual connections from the several primary windings to the several lamps at one terminal, and individual connections between the several secondary transformer windings and the several lamps at the opposite terminal thereof, said windings of said transformer being arranged in tandem and the middle winding being in the reverse direction to the direction of the other windings.

2. An electric lighting apparatus comprising three single phase gas filled lamps of the electric discharge type, three auto-transformer units in assembled relation with a laminated iron structure disposed to provide uninterrupted paths for magnetic flux around the transformer windings, the primary winding of each transformer being connected with one of the conductors of a three phase alternating current supply line and with the low potential terminal of one of the lamps,

and the secondary windings of the same transformers being connected with the high potential terminals of the respectively same lamps; such connections of each transformer with one lamp being separate from the corresponding connections of each of the other transformers with the other lamps, the primary winding of the central unit being reversely wound to the other primary windings.

3. A three phase lighting apparatus comprising three single phase gas filled lamps of the electric discharge type, high potential and low potential sockets in which the opposite terminals of the lamps are mounted, the low potential sockets each having two separated contacts which are bridged across by the inserted lamp, three transformers connected separately with the conductors of a three phase power supply circuit, conductors leading from the primary windings of the several transformers to the low potential sockets of the several lamps, each connected to one of the contacts in the respective sockets, means connecting the other contacts of all of said low potential sockets together electrically, and connections for flow of current from the secondary windings of the respective transformers to the several high potential sockets, one of said primary windings being in the reverse direction to the other primary windings.

4. A lighting fixture comprising three single phase gas filled lamps of the electric discharge type and three single phase auto-transformers, each primary transformer element being connected in series with one contact of a two-contact lamp socket and the three primary transformer elements being connected separately to the separate phases of a three phase alternating source, the other contacts of said two contact sockets being connected separately to a different three phase alternating source from which the first said contact of the two-contact socket is connected.

5. An electric lighting starting and controlling system comprising three single phase gas filled lamps of the electric discharge type and three single phase auto-transformers having separate sets of primary and secondary windings, said primary windings being connected in star and to one terminal of a lamp and the corresponding secondary being connected through a ballast unit to the opposite lamp terminal.

6. An electric lighting apparatus comprising three single phase gas filled lamps of the electric discharge type, a three phase ballast having three transformer units provided with separate sets of primary and secondary windings assembled on a single core, each transformer winding being connected at its secondary terminals with the terminals of one only of said lamps, the intermediate terminal of each winding being connected to one of the phases of the supply and to the low voltage terminal of one of the other of said lamps.

7. An electric lighting apparatus comprising three single phase gas filled lamps of the electric discharge type, a three phase ballast having there transformer units provided with separate sets of primary and secondary windings assembled on a single core, each transformer winding being connected at its secondary terminals with the terminals of one only of said lamps, the intermediate terminal of each winding being connected to one of the phases of the supply and to the low voltage terminal of one of the other of said lamps, said coils being arranged in tandem on said core, one of said coils being wound in the reverse direction to the winding of the other two coils.

8. A lighting fixture comprising a housing, three single phase gas filled lamps of the electric discharge type mounted on said housing, and a three phase ballast including three transformer elements mounted in said housing and having a single iron core, each transformer element being connected at its terminals with terminals of one only of said lamps, and the several transformer elements each having terminals connected separately to the separate phases of a three phase alternating current source.

9. An electric lighting system comprising three single phase gas filled lamps of the electric discharge type, a transformer element having three separate sets of primary and secondary windings assembled with a single iron core, connections for the flow of current between the separate phases of a three phase power supply source and one terminal of the several primary transformer windings, individual connections from the other terminal of the several primary windings to the several lamps at one terminal of such lamp, and individual connections between the several secondary transformer windings and the several lamps at the opposite terminal of such lamp.

10. An electric lighting apparatus comprising three single phase gas filled lamps of the electric discharge type, a ballast having three transformer units in assemblage with a unitary laminated iron core, one terminal of one of the primary windings of the several transformer units being separately connected with the several conductors of a three phase alternating supply line, the opposite terminals of the primary windings of the several transformer units and one terminal of the secondary of the said transformer units being individually connected with one terminal of the several lamps, and the other terminal of the secondary windings of the several transformer units being individually connected with the opposite terminals of the respective lamps.

11. In combination, means for supporting three gas filled lamps of the electric discharge type and a controlling circuit for said lamps including a ballast comprising three transformer coils, a laminated iron structure supporting said coils and disposed to provide a continuous magnetic circuit around each and all of said coils, each transformer coil being connected to one terminal of one of said lamps and with one conductor of a three phase alternating current supply circuit separate from the others, said coils being arranged in tandem on said laminated iron structure and the middle coil being wound in the reverse direction to the windings of the other two coils.

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