Feb. 14, 1967 A. E. FEINBERG 3,304,464

FLUORESCENT LAMP BALLAST AND CIRCUIT

Filed Nov. 8, 1963 3 Sheets-Sheet 1

Fig. 1

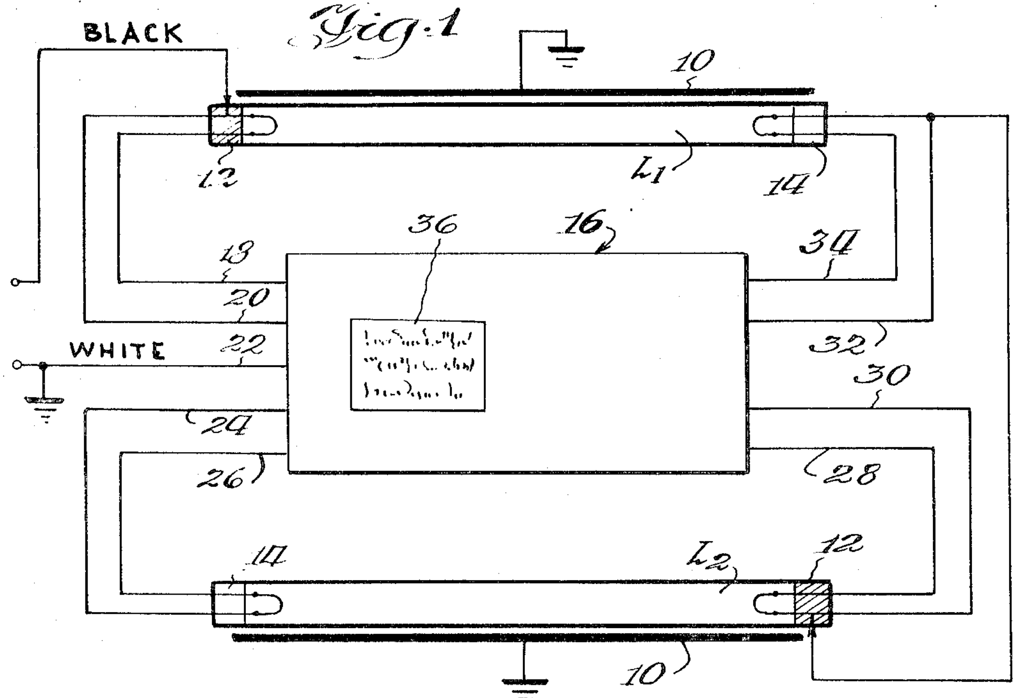

Fig. 2

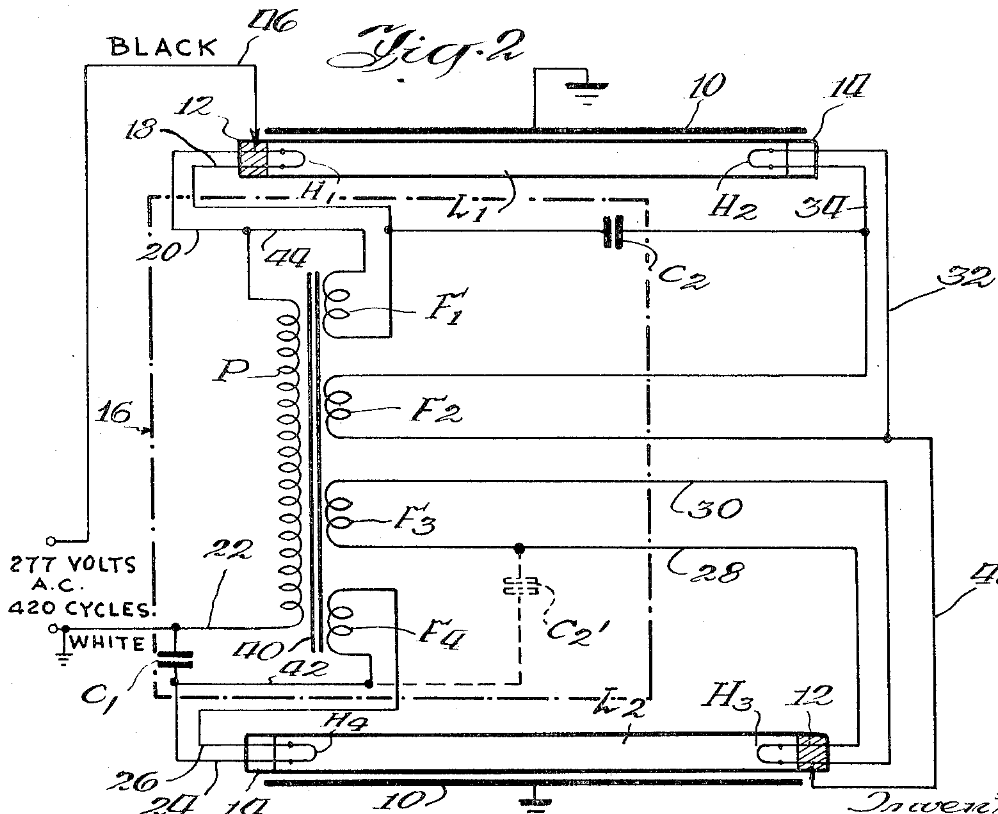

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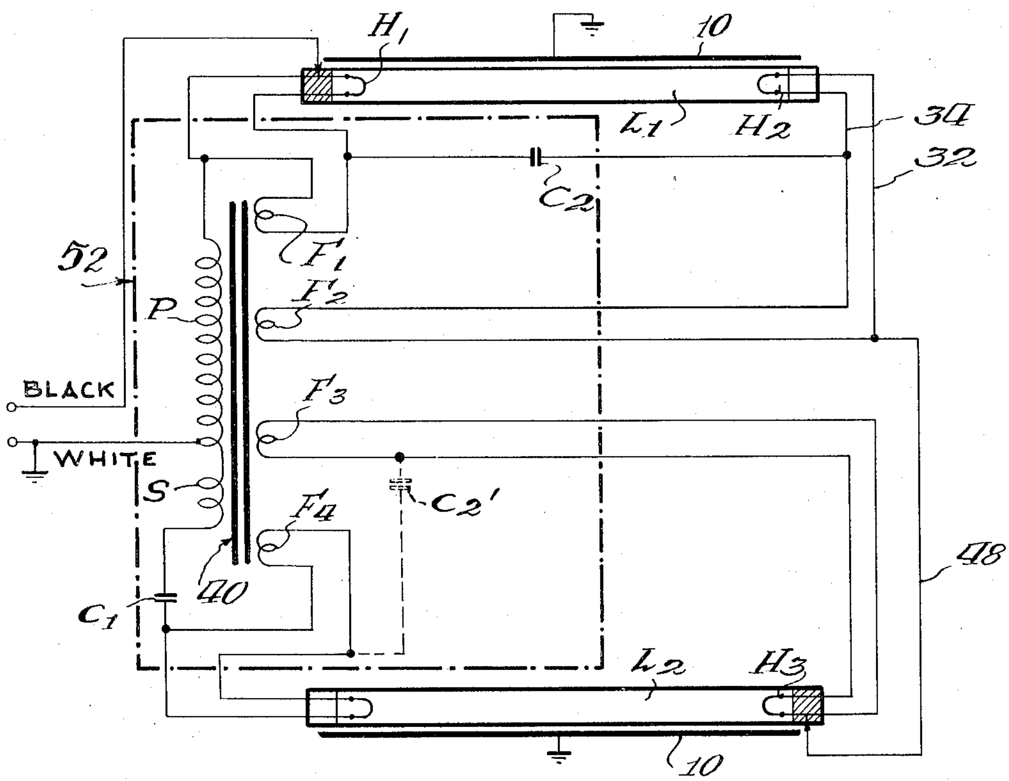
Fig. 3



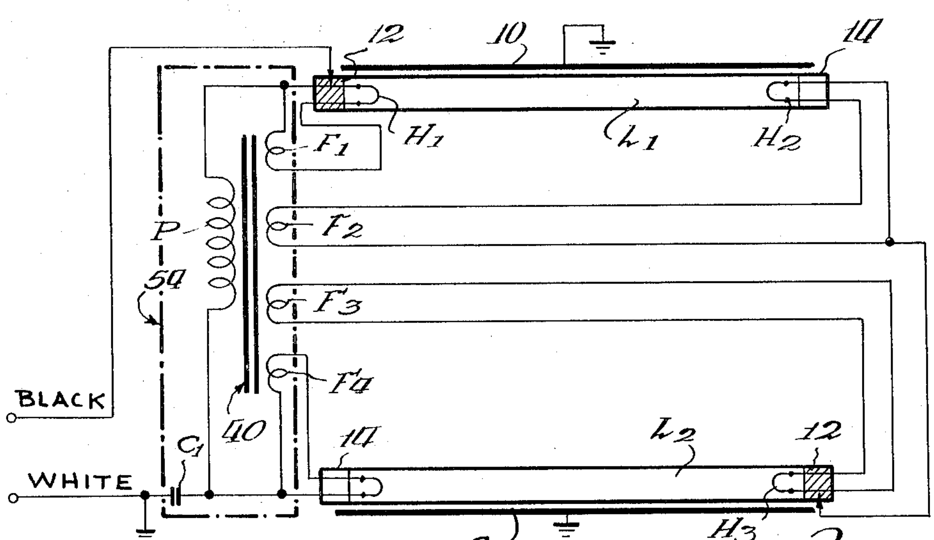


Fig. 4

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Fig. 5

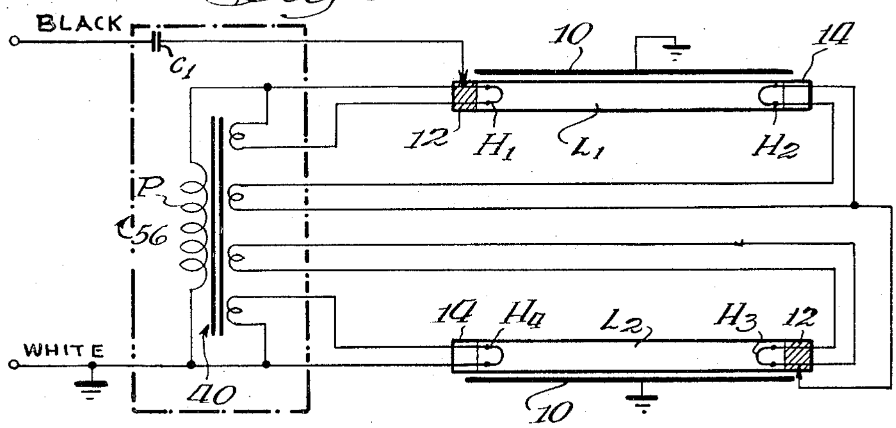


Fig. 6

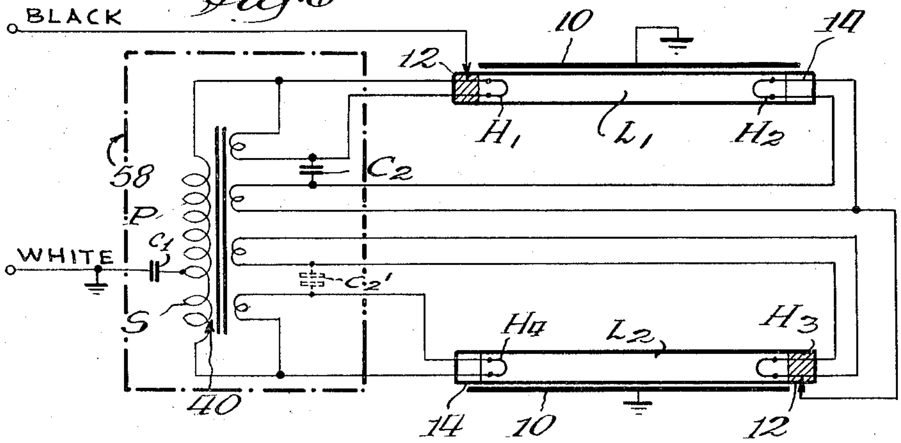
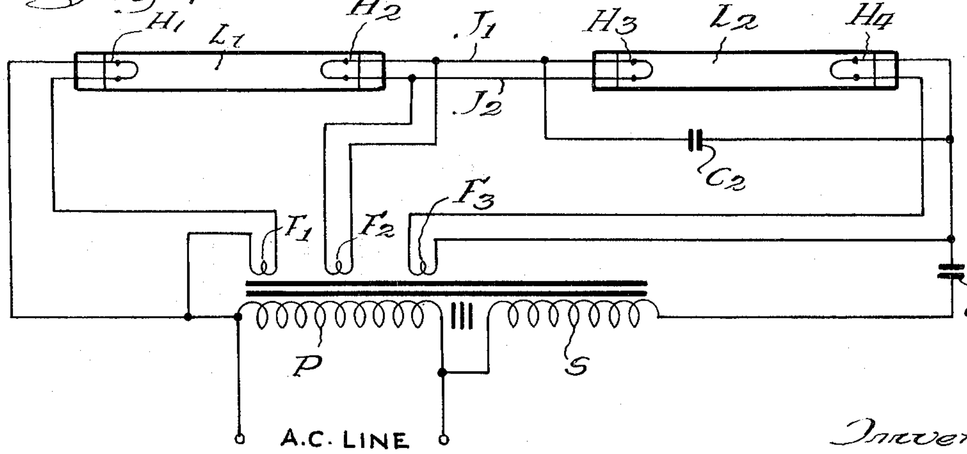


Fig. 7



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FLUORESCENT LAMP BALLAST AND CIRCUIT

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13 Claims. (Cl. 315—97)

This invention relates generally to fluorescent lamp ballasts and circuits and more particularly is concerned with a ballast and circuit which will provide a safeguard against the hazards of electrical shock.

The advantages of the invention are particularly valuable in circuits which include heated-filament fluorescent lamps since this type of lamp may fire or ignite if one filament is heated and a person is holding the other end and touching the terminals while himself being grounded. Even "instant-starting" of such lamps is not unusual, especially in the case that the line voltage is quite high.

The fluorescent lamp is a type of arc discharge device which consists of an elongate tube having an inert gas at low pressure therein, along with a small quantity of mercury. A sufficiently high voltage applied across the end terminals of the fluorescent lamp will cause ionization of the gas in the tube, and the resulting arc discharge or gaseous discharge, as it may be called, produces radiation which activates the phosphors with which the interior of the tube is coated. This provides the well-known fluorescent illumination which has become so familiar.

It is well-known to decrease the voltage required to cause the break-down or ionization of the gas within the fluorescent lamp by using heated filaments at the tube ends to provide initial free electrons as a cloud at each end of the tube. A popular fluorescent lamp which operates on this principle is the so-called rapid start lamp which has filaments in its ends that are heated continuously during starting and as well during operation, as opposed to the so-called pre-heat lamps which have filament current only during starting. One of the most common of the rapid start lamps is rated at 40 watts and it ignites at a voltage of 205 volts, A.C. Two of such lamps in series ignite at a voltage of about 280. Both of these values are R.M.S.

In ballasts and associated circuits intended to use this type of lamp, the hazard referred to above is present unless some steps are taken to avoid the application of open circuit voltage of more than 180 volts across the lamp under conditions that one filament is heated, if a person should be touching the terminal opposite that one which is at 180 volts and the person be grounded. Ground is normally established through a part of the fixture, through water and gas pipes or through damp masonry. Some of the expedients used in the past have been the isolation of the primary winding and the provision of means to limit the flow of current to ground in any event to an accepted safe value, the maximum of which at this time is 5 milliamperes, set by Underwriters' Laboratories.

The invention herein will be described in connection with a circuit intended to be energized from a source of A.C. voltage of 277 volts at a frequency of 420 cycles per second. At this high source voltage, no step up transformation is normally needed to ignite a 40 watt rapid start lamp, and as soon as the filaments are heated, the full voltage of the primary will be available to ignite the lamp. The hazard of such a circuit should be obvious.

The invention is not limited to this specific application, since, as will be seen, circuits are provided in which an additional voltage is required to ignite the lamps. Ballasts and circuits operating at lower frequencies advantageously may use the teachings of the invention. The invention also will be described in connection with two lamp ballasts, but is applicable as well to ballasts using more than two lamps.

The primary object of the invention is to provide a ballast and fluorescent lamp system for use with filament-heated lamps in which the hazard of shock is substantially decreased, if not fully eliminated, notwithstanding the fact that the ballast connects the lamps substantially directly to the line without isolation of the primary or employing complex circuitry.

A commonly used circuit for a pair of rapid start lamps employs a pair of lamps in series, a series connected primary and a step-up auto-transformer secondary winding connected across the lamps, one lamp being shunted by a capacitor, a power factor correcting capacitor in series with the lamps, and three filament windings closely coupled with the primary winding are provided for serving the filaments of the lamps. The common filaments use one filament winding. This circuit is hazardous for use with a high line voltage, especially where the secondary winding is eliminated. Even the use of disconnect sockets, as commonly connected, will not relieve the hazard, because, with one lamp in the circuit and the circuit energized, it is still possible to cause the ignition of the other lamp holding on to one terminal, since the opposite end is at a high potential.

Accordingly, it is another object of the invention to provide a ballast and circuit for two lamps connected as described above, but in which the shock hazard is substantially eliminated by a novel improvement to the said circuit which improvement does not alter the manner in which the lamps are ignited and operated. In this case, the capacitor which is in series with the lamps acts as a current limiting device.

Still a further object of the invention is to provide a novel circuit of the character described in which a capacitor is provided that serves the multiple purposes of providing a current limiting device for safety purposes and of decreasing the current flowing in the filament windings once the lamps have ignited.

Many other objects of the invention will become apparent to those skilled in this art from a study of the specification which follows, taken in connection with the drawings, in which preferred embodiments of the invention are illustrated and described in considerable detail to permit a full understanding thereof.

The same reference numerals and letters are used throughout the several figures of the drawings to designate the same or similar elements, so far as practical, but such use in FIG. 7 is not to be considered a presumption or inference that the function or operation of the invention is disclosed in said FIG. 7.

FIG. 1 is a schematic or block diagram of the ballast and circuit of the invention, applied to one system.

FIG. 2 is a circuit diagram showing the details of a ballast constructed in accordance with the invention connected into a circuit with heated filament lamps.

FIG. 3 is a circuit diagram similar to that of FIG. 2 but of a modified form of the invention using an auto-transformer connected secondary winding.

FIG. 4 is a circuit diagram similar to that of FIG. 2, but showing still another modified form of the invention.

FIGS. 5 and 6 are likewise circuit diagrams of further modified forms of the invention.

FIG. 7 is a circuit diagram of conventional prior art apparatus used with heated filament fluorescent lamps in which the lamps are ignited in sequence and operated in series.

The invention is characterized by the provision of a ballast for igniting and operating at least two fluorescent lamps, and by the provision of a lighting circuit using such ballast and lamps in which the lamps are connected in series and have heated filaments; in which means are provided for independently energizing the filaments which heretofore have been connected together in other circuits; and by the provision of a three terminal disconnect socket for the terminal pins of one of the lamps at an end of said lamp which would in prior art circuits be electrically connected to the other of the series pair of lamps.

Means are provided in some of the forms taken by the invention to achieve sequence ignition and series operation of the lamps, and means are provided in all of the circuits embodying the invention for limiting the current flow through the ballast by a series reactive device in the line circuit or in the lamp circuit. This normally takes the form of a condenser. In the case of the reactive device in the line circuit, an additional advantage obtains in the decrease of current flow in the primary winding after ignition of the lamps, which will cause a decrease in the current flow of the filament circuits and result in a consequent decrease in watt loss in the ballast.

In order best to discuss and understand the nature of the invention, a conventional prior art circuit of the same type as the invention is illustrated in FIG. 7 and discussed hereinafter. This apparatus is a typical sequence start, series operating circuit using a ballast connected to an ordinary A.C. line for igniting and operating a pair of heated filament lamps of the so-called rapid start variety, say —40 watt rapid start lamps. The primary winding P is connected across a source of A.C. voltage such as for example the conventional 120 volt, 60 cycle line. The voltage being insufficient to ignite even a single one of the lamps L1 and L2, there is provided on the transformer core mounting the primary winding P a secondary winding S which may be loosely coupled with the primary winding. Following the connections around the periphery of the diagram, it will be seen that the left hand terminal of the primary winding P is connected in series with the lamps L1 and L2 and the condenser C1 to the right hand terminal of the secondary winding S, in that order. The condenser C1 is variously called the series, operating or running condenser.

Filament winding F1 closely coupled to the primary winding P energizes the filament H1; filament winding F2 closely coupled with the primary winding P energizes the both filaments H2 and H3; and the filament winding F3 energizes the filament H4. The filament winding F1 is sometimes a few turns of the end of the primary winding. A condenser C2 is shunted across the lamp L2. The secondary winding S is connected in additive autotransformer relation with the primary in the series circuit.

When the primary winding is energized from the source, practically the entire voltage of the primary winding P added to the induced voltage of the secondary winding S appears across the lamp L1, between the filaments H1 and H2. This is because practically no current is flowing in the circuit, and the condensers have no voltage drops across them. This voltage is sufficient to ignite the first lamp L1 and current will now flow through the circuit, but by-passing the lamp L2 through the shunt condenser C2. When current flows through C2, a voltage drop appears across it, and the capacitance of the condenser in view of such current flow is chosen to produce a voltage drop sufficient to ignite the lamp L2. Now, with both lamps ignited and operating, current will prefer the lower impedance of the lamp L2 to the impedance of the condenser C2 so that most of the current will flow through said lamp L2.

The series condenser C1 will provide power factor correction if desired, or may be chosen to provide ballasting for the lamps.

It will be noted from the description above of the prior art circuit of FIG. 7 that the filament winding F2 is connected to provide the current for both of the heaters H2 and H3 which are connected together. It may be said that these heaters are common in the series circuit, and indeed they are connected to common jumpers J1 and J2, but for the purposes of the description which will

follow, the filaments H2 and H3 will be designated contiguous to one another with reference to a series circuit including both lamps, meaning that they face one another but do not necessarily connect. The filament windings H1 and H4 in this circuit are not contiguous, but are separated by other elements of the apparatus, and are what may be termed the outer filaments of the pair of series connected lamps.

While the departure of the invention from the prior art will become apparent in what follows, it is pointed out preliminarily that in the structures of the invention, each filament of the lamps has an independent filament winding so that the contiguous filaments are not connected together. Likewise it is pointed out that disconnect sockets are used for mounting the lamps, but in an unusual manner.

In the circuits to be described herein, those of FIGS. 2, 4 and 5 have the lamps connected directly across the line, and hence the so-called operating or running condenser in each case must be current limiting, and the current drawn from the line will be leading. Other reactive components may be used in such cases, such as chokes, but these are usually expensive compared to capacitors.

In the case of the circuits of FIGS. 3 and 6, there is an auto-transformer connected secondary winding in series with the lamps, and there may be sufficient reactance provided by this winding to ballast the lamps, so that the capacitor may be either power-factor correcting or current limiting, in the event it is desired that the circuit be leading.

Also, in the circuits of FIGS. 4 and 5, it will be seen that there is no shunting condenser across one lamp, this being intended to illustrate a set of conditions wherein the primary voltage is sufficiently high to ignite the lamps together so that no starting aid is required. For rapid start lamps of 40 watts and more, a sequence start circuit is preferred.

Referring now to FIG. 1, it should be appreciated that the fluorescent lighting industry in this country has developed along lines in which the fixture manufacturer, as a rule, assembles the components which include the metal fixture identified symbollically at **10**, the sockets indicated at **12** and **14**, the lamps L1 and L2 and the ballast **16**. The fixture manufacturer purchases this ballast **16** as a completely enclosed and potted canister from the ballast manufacturer who encloses within the canister those components which will provide the desired igniting and operating characteristics for the lamps. The ballast **16** will have the transformer, capacitor, inductors, and similar components all suitably arranged and connected, and the article which is furnished to the fixture manufacturer is a canister which has a plurality of electrical leads protruding therefrom, as indicated at **18**, **20**, **22**, **24**, **26**, **28**, **30**, **32** and **34**. These electrical leads are permanently connected into the canister of the ballast **16**, and are coded color-wise in accordance with standards established by the Underwriters' Laboratories and by organizations whose aim is to establish such standards. For example, the lead **22** is designated "white," this being the color standardized as the line lead to ground. The exact specifications of the ballast, including the type of lamps with which it will operate, the voltages, currents, frequencies, etc., are all described upon the label of the ballast, and, in addition, it is mandatory and essential that there be a circuit diagram upon the ballast, as indicated at **36**, which gives the exact manner in which the ballast leads must be connected to give safe and proper operation thereof within a circuit.

The ballast **16** of FIG. 1 may be illustrated in the circuit diagram of FIG. 2. Such ballast **16** would include all of the condensers and windings illustrated in FIG. 2.

The circuit of FIG. 2 is a sequence-start circuit using a shunting condenser. The circuit requires the use of a three terminal disconnect socket, of the type described in U.S. Patent 2,767,349, in which there are two contacts or sockets for receiving the pins of the end of a fluorescent lamp, and a third terminal to be connected to another electrical conductor which makes electrical engagement with a movable one of the pin contacts or sockets only after the lamp has been engaged and twisted to its final seated position. This latter motion spreads the movable pin contact toward the third terminal. This type of socket is quite acceptable as a safe device because both ends of the lamp must be in their respective sockets to enable the lamp to be twisted. It is appreciated, however, that if one lamp end is placed in a conventional socket which has its contacts at a high potential, and the pins of the other end of the lamp are engaged by the user, who may be coupled to ground, there will be a shock hazard, even if it is expected that said other end is going to be put into a disconnect socket of some kind.

In FIG. 2 the disconnect sockets are shaded and designated **12** while the conventional sockets are designated **14**. It will be seen that there are provided a pair of lamps L1 and L2 connected in series across a primary winding P and that each lamp has a filament or heater at each end, there being four filaments H1, H2, H3 and H4 served by transformer secondary filament windings F1, F2, F3 and F4, respectively. This provision of a completely independent filament winding for each filament is a departure from the known arrangements where filament-heated lamps are connected in series, since the contiguous filaments, that is, H2 and H3, would be connected together in the conventional circuit of FIG. 7 and served by the single filament winding.

All of the filament windings are secondaries of a transformer **40** which mounts the primary winding P and said filament windings are closely coupled with said primary winding. The primary winding P is connected on the interior of the ballast **16** with the series condenser C1 which is a current limiting capacitor, the latter being connected between the leads **22** and **24**. The lead **22** is the white lead which is directed to be connected to the grounded side of the power source which in this case is designated 277 volts A.C. at 420 cycles. The lead **24** extends to one terminal of the lower, left hand outer socket **14** which is of conventional construction and a connection **42** on the interior of the ballast extends to the filament winding F4 along with the lead **26**. Filament winding F3 has leads **28** and **30** extending out of the ballast **16** to the contiguous socket **12** at the lower right which is a disconnect socket. The filament winding F2 has its leads **32** and **34** extending to the upper right contiguous socket **14** which is a conventional two-pin socket, while the filament winding F1 has its leads **18** and **20** extending to the upper left outer socket **12** which is a disconnect socket. The filament winding F1 and the upper terminal of the primary P are internally connected by the lead **44** and a shunting condenser C2 is internally connected between the leads **18** and **34** so that the portion of the lead **34** which is shown extending from the right hand terminal of the condenser C2 and the filament winding F2 is within the ballast canister **16**.

There are two external electrical leads, one being the lead **46** which is the black lead to the so-called "hot" side of the line, and extends to the third terminal of the outer disconnect socket **12** of the filament H1; the other being the electrical lead **48** which extends from the lead **32** to the third terminal of the lower right contiguous disconnect socket **12**. Leads **46**, **20** and **22** with the primary winding P define the input circuit.

When the leads **22** and **46** are connected to the line, so long as neither lamp L1 or L2 is in place, no current flows through the primary winding P. Now, leaving the lamp L1 out of the circuit, if a person inserts lamp L2 nothing could happen if the pins are touched because the circuit is open at **46**. Holding the left hand pins of the lamp L1 and inserting it in the contiguous socket **14** will not be of any consequence, because there is no potential at either lead **32** or **34** at this time.

Now, if lamp L2 is out of the circuit and lamp L1 inserted, the circuit through the primary winding P is completed and the filament windings energized. Lamp L1 has its left hand or outer filament H1 and its right hand or contiguous filament H2 both heated, but the voltage across the lamp L1 is practically zero, so that lamp cannot ignite. Now, if the ordinary series circuit of FIG. 7 were being used, the contiguous filament H3 of lamp L2 would be directly connected to the contiguous filament H2 of the lamp L1. As soon as a user placed a lamp L2 in a conventional socket of an ordinary series circuit and touched the opposite pins, while being grounded he would complete the entire circuit from the black lead **46** through the condenser C2 and the lamp in his hand to ground, and he could be seriously shocked.

As opposed to this, in the circuit of FIG. 2 if the user touched the left hand pins of lamp L2 and inserted the other end in the contiguous socket **12** at H3 nothing would happen, because even though he may have caused the contiguous filament H3 to heat up, there is no connection to high potential until he twists the lamp in its socket, and he cannot do this without properly seating the opposite outer end on its socket **14**. Even inserting the left hand end of lamp L2 in outer socket **14** and touching the pins at the right hand end of the lamp L2 will produce no shock because the left hand end of the lamp L2 is at ground potential anyway.

A variation in the circuit of FIG. 2 is indicated by the dotted line connection with condenser C2′. In this case this is an alternate connection for the condenser C2. The first lamp to light with the condenser C2 in place and the condenser C2′ out is the lamp L2. The first lamp to light with the condenser C2′ in place and the condenser C2 out is the lamp L1.

The condenser C1 is a current limiting reactive component because, during operation, the lamps L1 and L2 are in series directly across the line **22**, **46** and there must be some ballasting to prevent the lamps from destroying themselves. With the primary winding P always connected across the line, there is constant current flowing in the filament windings to keep the filaments energized. It will be appreciated that the primary winding P with the leads extending to the lamps and the lamps comprise the output circuit. Here the condenser C1 is in the output circuit.

The circuit of FIG. 3 uses a ballast **52** which is substantially the same as the ballast **16** of FIG. 2 except in the respect that the line voltage in this instance is assumed to be insufficient either to ignite or operate the lamps. An autotransformer secondary winding S is mounted on the transformer **40** either closely coupled or loosely coupled with the primary winding P. In the latter case, a lagging reactive component is available for ballasting the lamps during operation, and the effect upon the series condenser C1 may be to change its value since it is not required for current limiting to the same extent as before. The secondary winding is in auto-transformer connection with the primary winding for added ignition and operation voltage. In all other respects, the circuits of FIGS. 2 and 3 are the same. The output circuit here comprises the lead from the top end of the primary to the lamps, the lamps, the lead from the bottom end of the secondary winding and the condenser C1.

For high frequencies, tight coupling of S is sufficient, since C1 will supply sufficient current limiting reactance. In the case of situations where S is loosely coupled, the wave shape of the lamp current will be improved, since it is known that a fully leading current ballasted apparatus has peaked waves which give lesser lighting efficiency than where there is inductive reactance ballasting the apparatus.

The ballasts **54**, **56** and **58** of FIGS. 4, 5 and 6, respectively, may all be discussed together. These vary from the circuits and apparatus previously described in certain facts which may readily be pointed out. In the first place, the condenser C1 in each case is directly in the line, that is, in the input circuit. In FIGS. 4 and 6 it is in the white lead **22**, and in FIG. 5 it is in the black lead **46**. This means that before the lamps are ignited, there is very little reactive drop in the condenser C1 and all of the voltage is available for ignition. This represents maximum current flowing in the filaments but practically no current being drawin from the line.

In the case of FIGS. 4 and 5, if there is no shunting condenser, the lamps are expected to ignite simultaneously, and the moment that they do, maximum rated current will be drawn from the line, and the reactive drop in the condenser C1 will become quite high. Since, in effect, the condenser C1 is in series with the primary winding P, the voltage in the primary will drop, and the filament voltages will drop, and the current losses due to the filaments will decrease. This is a very important feature of these circuits of FIGS. 4, 5 and 6 since the ballasts are cooler, more efficient and have less losses than do those in which the filament current remains at its maximum value at all times.

In the case of FIG. 6, or in FIGS. 4 and 5 if they had shunting condensers, where the lamps ignite seriatim, the filament windings do not lose sufficient voltage between the igniting of the lamps to affect the ignition of the second lamp. The same advantage of reduced filament voltage and losses is achieved, as in FIGS. 4 and 5.

In the second place, where the condenser C1 is in series with the primary winding, failure of the transformer section of the ballast will not create a hazard because of a direct connection to a high voltage line, since the condenser will be available to limit the flow of current which might otherwise be a dead short circuit.

The placement of the condenser C1 in the black lead **46** as in FIG. 5 requires an additional lead to be extended from the ballast canister, but an added safety feature provided because the limiting condenser is in the high voltage lead should justify the added expense. A grounded transformer would be best protected against by FIG. 5.

FIG. 6 is of the same variety as FIG. 3 in that there is a secondary winding S in autotransformer relation with the primary winding to aid in starting and operation. Again, it may be tightly or loosely coupled, depending upon frequency, voltage of the line, the type of lamp, etc.

The circuits of FIGS. 4, 5 and 6 if used with shunting capacitors are especially suitable for use with rapid start lamps, because these lamps do not require heating of the filaments after ignition, and there will be no deleterious effect upon lamp life as a result of these decreased filament currents. These circuits are also advantageous where high power source frequencies are used, that is, frequencies of the order of several hundred cycles per second, because the filaments do not cool down as rapidly between half cycles as they might in the case of 60 cycle current, the hot spots being fairly well maintained between half cycles.

What it is desired to secure by Letters Patent of the United States is:

1. A fluorescent lighting system for a pair of gaseous arc discharge lamps energized from an A.C. source having a high potential side and a grounded side and in which each lamp has a filament in each end thereof with two external contacts at each end connected with a respective filament, which comprises: a transformer having a primary winding, a first pair of filament windings closely coupled to the primary winding with one end of each being the terminal of an output circuit including all of the primary winding therein, a second pair of filament windings closely coupled to the primary winding, a pair of three-terminal disconnect lamp sockets having two lamp-receiving terminals and a disconnect terminal which makes electrical engagement with one of the other two terminals but only when a lamp is inserted into the socket with its external contacts engaging the lamp terminals and is turned to a detent position in said last-mentioned socket, a pair of two-terminal lamp sockets, the first pair of filament windings being connected respectively to the lamp-receiving terminals of the first disconnect socket and first two-terminal socket, the second pair of filament windings being connected respectively to the lamp receiving terminals of the second disconnect socket and the second two-terminal socket, so that each filament winding is connected to the lamp-receiving terminals of a single socket, the primary winding being connected in an input circuit across the source with at least the high side of the source connected through the disconnect terminal of the first disconnect socket so that said primary cannot be energized unless said last-mentioned disconnect terminal is in electrical engagement with one of the other terminals of said first disconnect socket, one lamp being engaged in the first disconnect socket and the second two-terminal socket, the other lamp being engaged in the first two-terminal socket and the second disconnect socket, an electrical lead from one terminal of the second two-terminal socket to the disconnect terminal of the second disconnect socket, and current limiting impedance means in circuit with said lamps during operation thereof.

2. A system as claimed in claim **1** in which said primary winding has one end thereof connected directly to the grounded side of said line.

3. A system as claimed in claim **1** in which said current limiting impedance means comprise a capacitor connected in series with said lamps.

4. A system as claimed in claim **1** in which said current limiting impedance means are in series with said lamps in their operating circuit.

5. A system as claimed in claim **1** in which said current limiting impedance means are in the output circuit but not in the input circuit.

6. A system as claimed in claim **1** in which said current limiting impedance means are in the input circuit but not the output circuit.

7. A system as claimed in claim **5** in which said current-limiting impedance means comprise a capacitor.

8. A system as claimed in claim **5** in which said current-limiting impedance means comprise a capacitor connected between one end of the primary winding and one end of one of said first pair of filament windings.

9. A system as claimed in claim **5** in which said current-limiting impedance means include a secondary winding in additive auto-transformer relationship with said primary winding and a series capacitor.

10. A system as claimed in claim **6** in which said current limiting impedance means comprise a capacitor in series with the high side of the source.

11. A system as claimed in claim **6** in which said current limiting impedance means comprise a capacitor in series with the grounded side of the source.

12. A system as claimed in claim **6** in which the output circuit includes a secondary winding mounted on said transformer in additive auto-transformer relationship with said primary winding and in series with said lamps in their operating circuit.

13. A system as claimed in claim **1** in which there is a condenser shunting one of the lamps whereby to cause the lamps to ignite in sequence and operate in series.

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